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Space Governance for the 21st Century: Balancing Space Development with Sustainability

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**Space Governance for the 21st Century:
Balancing Space Development with Sustainability**

Adam Routh

November 2023

**Thesis Submitted in Fulfilment of the
Requirements for the Degree of
Doctor of Philosophy
in the
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Faculty of Social Science and Public Policy
King's College London**

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ABSTRACT**Space Governance for the 21st Century:
Balancing Space Development with Sustainability****Adam Routh**

The development of space is occurring in new ways and at an accelerated pace compared to even just a decade ago. As new and greater volumes of space activities, like large constellations of small satellites, space traffic management, and on orbit rendezvous, proximity, servicing, and assembly operations become routine, new international governance will be necessary to balance the development of space with space sustainability. While some international space governance does exist, it is poorly suited to govern new space activities and the environmental threats posed by space development. The need for new governance is well documented, yet the international community, and specifically the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), has been unable to organize around space governance and produce effective international governance measures.

This research will compare governance regimes of the air, maritime, and internet domains to understand how stakeholders and international organisations approach governance of a global commons. Through the examination of the International Maritime Organization, International Civil Aviation Organization, and the multistakeholder group responsible for internet governance this research will draw insight into the organisational structures, processes, tools, and techniques that aid in the creation of international governance to inform new governance for space.

Findings offer insight into the organisational qualities, governance tools, and necessary change needed to govern space more effectively. First, despite differences across case studies, there are key features of effective international governance present in each. Each system of governance is designed based on unique features and qualities of that domain and its stakeholders. Still, decision-making processes, membership participation, enforcement, and keeping pace with new technology all play central roles in effective international governance.

Proper consensus decision-making can play an outsized role in whether a forum can advance governance or not. The case studies make clear that to properly use consensus as a decision-making approach requires thoughtful consideration of the increased transaction costs weighed against necessary agreement compliance. For example, not all governance outputs require a high degree of compliance to be effective and therefore do not justify higher transaction costs associated with strict consensus processes. Similarly, thoughtful use of consensus also requires evaluating where in the diplomatic process consensus is required. Not every diplomatic decision requires full consensus. Yet, COPUOS currently does not adjust its decision-making approach based on output or where in the diplomatic process it requires consensus, which has allowed the forum's use of consensus to hinder the development of new governance.

Another finding is that strong governance leverages a multitude of governance tools. Treaties are an important governance measure, but so too are standards and recommended practices, guidelines, codes, performance-based measures, audit schemes, scoping exercises, and educational resources, among other tools. Many of the emerging space activities will continue to evolve quickly, which requires producing governance in a timely manner and continuous evolution of agreements. In each case study, evolving activities were governed by a spectrum of measures that allowed the IO to affect member behaviour quickly and overtime through complementary outputs.

Each case study made clear that effective governance requires constant work across multiple workstreams, yet COPUOS is a small three body organisation with too few resources to increase work cadence or volume. A larger secretariat and the capacity to create new subcommittees or working groups is likely to aid space governance. COPUOS will require major changes to accommodate space governance needs. Finally, this research offers recommendations for future research capable of exploring additional possible solutions to existing space governance problems.

TABLE OF CONTENTS

List of Abbreviations	vi
1. THE SUSTAINABLE DEVELOPMENT OF SPACE	1
Space Sustainability	4
Development of Space.....	8
Politics and Power of Space Development.....	9
Conclusion.....	14
2. RESEARCH QUESTION & METHODOLOGY	16
What is Effective Governance?	16
Methodology	19
Research Outline	25
3. INTERNATIONAL SPACE GOVERNANCE	27
Global Governance.....	27
Space Governance and its Gaps	31
Conclusion.....	59
4. IMO, ICAO, AND INTERNET GOVERNANCE ORGANISATIONS.....	61
The International Maritime Organization.....	61
International Civil Aviation Organization.....	74
Internet Governance	86
Conclusion.....	103
5. SMALL SATELLITES AND CONSTELLATIONS FOR SUSTAINABLE DEVELOPMENT	106
Small Satellites and Space Development	107
Maritime Case Study	115
Civil Aviation Case Study	131
Internet Case Study	143
Analysis and Conclusion	158
6. SPACE TRAFFIC MANAGEMENT	170
Understanding Space Traffic Management.....	171
Maritime Case Study	180
Civil Aviation Case Study	190
Internet Case Study	198
Analysis and Conclusion	208
7. ON-ORBIT RENDEVOUS, PROXIMITY, SERVICING, & ASSEMBLY OPERATIONS.....	219
Understanding ORPSAO.....	220
Maritime Case Study	229
Civil Aviation Case Study	236
Internet Case Study	245
Analysis and Conclusion	255
8. ANALYSIS AND CONCLUSION	267
Summary of Research Approach.....	270
Research Contributions to Space Governance	271
Options for Future Research.....	291
Bibliography	293

LIST OF ABBREVIATIONS

ADS-B	Automatic dependent surveillance broadcast
AFS	Convention on the Control of Harmful Anti-fouling Systems on Ships
AI	Artificial intelligence
AIAA	American Institute of Aeronautics and Astronautics
AIS	Automatic identification system
ANC	Air Navigation Commission
ANP	Air Navigation Plans
ATM	Air traffic management
BUNKER	Convention on Civil Liability for Bunker Oil Pollution Damage
BWM	Convention for the control and Management of Ships' Ballast Water and Sediments
CAEP	Committee on Aviation Environmental Protection
CD	Conference on Disarmament
CIR	Critical internet resources
CLC	Convention on Civil Liability for Oil Pollution Damage
CONFERS	Consortium for Execution of Rendezvous and Servicing Operations
COPUOS	Committee on the Peaceful Uses of Outer Space
CORISA	Carbon Offsetting and Reduction Scheme for International Aviation
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CSC	Convention for Safe Containers
DNS	Domain Name System
ESA	European Space Agency
ETM	Environmental Technical Manual
FAL	Convention on Facilitation of International Maritime Traffic
FAL-C	Facilitation committee
FIR	Flight information region
GA	General Assembly
GAC	Government Advisory Committee
GATMOC	Global Air Traffic Management Operational Concept
GEO	Geosynchronous orbit
GNAP	Global Air Navigation Plan
GNSO	Generic Names Supporting Organization
GNSS	Global navigation satellite system
HNS	Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substance by Sea
IAA	International Academy of Astronautic
IADC	Inter-Agency Debris Coordination Committee
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IANA	Internet Assigned Numbers Authority
ICANN	Internet Corporation for Assigned Names and Numbers
ICAO	International Civil Aviation Organization
ICJ	International Court of Justice
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFR	Instrument flight rules
IGF	Internet Governance Forum
IMO	International Maritime Organization
IMSAS	IMO's Member State Audit Scheme
IO	International organisation
IoT	Internet of things
IP	Internet protocol
IPng	Internet Protocol Next Generation
IPv4	Internet protocol version 4
IPv6	Internet Protocol version 6

ISO	International Organization for Standards
ISO	International Standards Organizations
ISOC	Internet Society
ISP	Internet service provider
ISPS	International Ship and Port Facility Security
ISS	International space station
ITLOS	International Tribunal for the Law of the Sea
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union Radiocommunications sector
IXP	Internet exchange points
LEG	Legal Committee
LEO	Low earth orbit
LL 1966	Load Lines Convention
LLMC	Convention on Limitation of Liability for Maritime Claims
LOSC	Convention on the Law of the Sea
LRIT	Long-range identification and tracking system
MARPOL	Convention for the Prevention of Pollution from Ships
MASS	Maritime autonomous surface ships
MBM	Market based measure
MEPC	Maritime Environmental Protection Committee
MONALISA	Motorways and Electronic Navigation by Intelligence at Sea
MPEC	Marine Environment Protection Committee
MSC	Maritime Safety Committee
MUNIN	Maritime unmanned navigation through intelligence in networks
NAT	Network address translation
NCSR	Sub-Committee on Navigation, Communications and Search and Rescue
NGO	Non-governmental organisation
NSA	Non-state actors
NUCLEAR	Convention relating to the Civil Liability in the Field of Maritime Carriage of Nuclear Material
OOS	On-orbit servicing
OPRC	Convention on Oil Pollution Preparedness, Response, and Co-operation
ORPSAO	On-orbit rendezvous, proximity, servicing, and assembly operations
OST	Outer Space Treaty
PAL	Convention relating to the Carriage of Passengers and their Luggage by sea
PAN	Procedures for Air Navigation
PAROS	Prevention of Arms Race in Outer Space
PBN	Performance based navigation
PIRG	Planning and Implementation Regional Groups
PTI	Public Technical Identifiers
RIR	Regional internet registry
RO	Recognized Organization
RPASP	Remotely Piloted Aircraft Systems Panel
RPO	Remote proximity operations
SALVAGE 1989	Convention on Salvage
SARP	Standards and Recommended Practices
SFV	Convention for the Safety of Fishing Vessels
SOLAS	International Convention for Safety of Life at Sea
SSA	Space situational awareness
STCW	Convention for Standards of Training, Certification, and Watchkeeping for Seafarers
STCW-F	Convention for Standards of Training, Certification, and Watchkeeping for Seafarers for Fishing vessels and personnel
STM	Space traffic management
SUPP	Regional Supplementary Procedures
TCP/IP	Transmission Control Protocol and the Internet Protocol
UAS	Unmanned aircraft system

UAS-AG	Unmanned Aircraft Systems Advisory Group (UAS-SG)
UASSG	Unmanned Aircraft Systems Studies Group
UAV	Unmanned arial vehicles
UN	United Nations
USC	University of Southern California
USOAP	Universal Safety and Oversight Audit Program
UTM	Unmanned traffic management
VHF	Very high frequency
VTs	Vessel traffic services
WC3	World Wide Web Consortium
WRC	World Radio Conference
WSIS	World Summit on the Information Society
	World Summit on the Information Society

1. THE SUSTAINABLE DEVELOPMENT OF SPACE

Today, states, as well as private companies, are debating how new space activities, like small satellite constellations, space traffic management, space debris mitigation and removal, or on-orbit servicing and assembly do or do not fit within existing space law and governance. As space is developed further, governing the domain will be essential for balancing the exploration and exploitation of space with the domain's sustainability. Indeed, without necessary governance, environmental issues like, space debris or orbital congestion, could threaten the very use of certain Earth orbits and the future of space development. Governments and industry must work together to develop new space governance at a time when space development is accelerating.

Satellites orbiting the earth beam down information providing communications, earth imagery, advanced military warning, location data, and other information essential for modern, global commerce and advanced militaries. As a result, near-Earth space has become critical to humanity's modern way of life irrespective of whether a country is spacefaring or not. An already critical domain, the space domain is poised to see more exploration and exploitation in the coming years. Enabled by novel technology and pursued by governments and commercial actors alike, the space domain is rapidly evolving to include fleets of thousands of small satellites, tourism, on-orbit servicing and assembly, and in-space manufacturing. With these advancements comes the promise of even greater economic and scientific value for spacefaring and non-spacefaring nations alike.

Suggesting the space domain is experiencing rapid change is not an exaggeration. A commercial space company, SpaceX, launched approximately 2706 small satellites between November 2019 and July 2022, an unprecedented amount that more than doubled the number of satellites in orbit.¹ In 2019, space start-ups attracted nearly \$5.7 billion in financing, nearly \$2.2

¹ Jonathan McDowell, "Starlink Statistics," *Jonathan's Space Page*, 2022, accessed July 2022, <https://planet4589.org/space/stats/star/starstats.html>.

billion more than the previous year record.² More broadly, the global space economy grew to over \$415 billion, or 8%, in 2019.³ 2019 also saw a 46% increase in global launches from 2018.⁴ This growth has led Goldman Sachs, Morgan Stanley, and Bank of America Merrill Lynch to suggest the space economy could reach \$1-2.7 trillion by the 2040s, putting it on par with today's civil aviation sector.⁵

In a near self-perpetuating manner, growth in the space sector is generating additional attention around the world. India, Luxemburg, the United Arab Emirates, Russia, China, the U.S., European countries, among others, are all paying closer attention to the space sector than in recent years. Through commercial and government projects and national policies which are meant to enable space sector growth, countries are signalling their new—or renewed—interest in space.⁶ Though often too expensive for many developing countries, space development holds value for non-spacefaring nations alike, motivating many to increase involvement in international forums, like the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS).⁷ Even throughout the COVID-19 pandemic, space exploration and development continued to occur at a rigorous pace. In May of 2020, during a spike in the pandemic, China launched its newest crew capsule for the first time and the U.S. returned human spaceflight back to the continental United States – and on a commercial rocket no less.⁸

² “Startup Space Report: update on investment in commercial space ventures,” Bryce Space and Technology, 2020, iii, accessed June 2021, https://brycetek.com/reports/report-documents/Bryce_Start_Up_Space_2020.pdf.

³ Space Foundation Editor Team, “The Space Report Reveals 2018 Global Space Economy Exceeded \$400 Billion for the First Time,” Space Foundation, Last Modified July 15, 2020, Accessed June 2020, <https://www.spacefoundation.org/2019/07/15/the-space-report-reveals-2018-global-space-economy-exceeded-400-billion-for-the-first-time/>.

⁴ Space Foundation Editor Team, “The space report reveals 2018 global space economy exceeded \$400 billion for the first time,” The Space Foundation, 2019, accessed April 2020, <https://www.spacefoundation.org/2019/07/15/the-space-report-reveals-2018-global-space-economy-exceeded-400-billion-for-the-first-time/>.

⁵ Economic comparisons to the civil aviation industry reflect 2019 figures, see: Industry High Level Group, “Aviation Benefits Report,” International Air Transportation Association, 2019, 5, <https://www.icao.int/sustainability/Documents/AVIATION-BENEFITS-2019-web.pdf>; and, for space economy figures, see: Space Frontier Foundation, “New Space 2018: Space, a Trillion Dollar Market?” YouTube video, posted July 19, 2018, <https://www.youtube.com/watch?v=VxOsjeMx64Y>.

⁶ For a more detailed analysis of these long-term pursuits see: Ram S. Jakhu & Joseph N. Pelton eds., *Global Space Governance: An International Study*, (Cham, Switzerland: Springer 2017), 205, 379, 479; and, Namrata Goswami, “China in Space: Ambition and Possible Conflict,” *Strategic Studies Quarterly* 12, no 1 (Spring 2018), 74-77.

⁷ Kenneth Hodgkins, interview by author, Washington, D.C., March 17, 2020.

⁸ Stephen Clark, “China’s First Long March 5B Rocket Launches on Crew Capsule Test Flight,” *Spaceflightnow*, May 2020, <https://spaceflightnow.com/2020/05/05/chinas-first-long-march-5b-rocket-launches-on-crew-capsule->

Despite the eagerness to accelerate the pace of space development, governance to ensure space is explored and exploited sustainably has not been pursued with equal fervor. Many critical space governance gaps exist, including governance of new activities, capacity of existing international space governance fora to account for changing governance needs, and ensuring the space domain continues to offer humanity great benefits without becoming another “tragedy of the commons” example to list only a few.

Not unlike other domains over time, space activities have simply outgrown the existing space governance regime. The process of formulating new rules and laws in response to emerging activities is not new to international governance, either. Indeed, governance is, and arguably should be, a continuous process wherein laws, regulations, norms, and other governance measures evolve and adapt overtime based on how technology, actors, and activities change. Space governance is simply in need of its next evolutionary step.

This thesis will explore new forms of space governance to promote the sustainable development of space. The central research question is: *How can other governance regimes inform the development of contemporary space governance for the space activities expected to be most essential to the sustainable development of space?*

Because many of the space technologies and services necessary to sustainably develop space are still very early in the development process or in the earliest stages of use, this research will examine similar technologies and services through civil aviation, maritime, and internet domain case studies to learn how space activities might be more effectively governed. Before examining the case studies this research will first discuss what the sustainable development of space entails and provide a brief discussion of how power and politics influences space governance. Both provide necessary context for improving space governance for critical space activities.

test-flight/; and, Launch America, “NASA, SpaceX to Launch First Astronauts to Space Station from U.S. Since 2011,” National Aeronautics and Space Administration, accessed April 2020, <https://www.nasa.gov/specials/dm2/>.

Space Sustainability

As essential as space services are, they are being threatened by an increasingly vulnerable space environment. Space debris, and specifically human made debris, is polluting critical Earth orbits and threatening the destruction of satellites that provide these essential services. Even simply having enough ‘real-estate’ in important Earth orbits, like GEO, to accommodate satellites is also becoming a serious issue. As debris and orbital congestion threaten the ability to use space for essential commercial, military, and civil activities, economic growth and further development of space is likely to slow or may even halt. It is not an exaggeration to say humanity’s continued use of space is not guaranteed. Sustainability practices must be adopted to further develop space.

UN COPUOS defines long-term sustainability of outer space activities as “the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations.”⁹ For the purposes of this research, the definition provided by COPUOS will be used because it applies acutely to the research topic and reflects international agreement through the rigorous consensus processes followed by COPUOS members.

It should be noted, however, that there is some debate with certain elements of the COPUOS definition. There is a long history of disagreement over what exactly “peaceful purposes” entails.¹⁰ For example, Sputnik did not serve purely peaceful purposes and militaries have been operating in and through space since the dawn of the space age. Moreover, “equitable access to the benefits” is also subjective given there are high technical and financial barriers to accessing and reaping the benefits of space, creating disparities between spacefaring and non-spacefaring

⁹ United Nations General Assembly, *Guidelines for the Long-term Sustainability of Outer Space Activities*, (Vienna: 20-29 June 2018, Committee on the Peaceful Uses of Outer Space), 2/20.

¹⁰ The first U.S. space policy, NSC Memo 5520, was designed to permit access to space for military reconnaissance satellites; More recently, the economic value of space through commercial activities has intensified competition over the domain, again suggesting human activities in space have never been completely peaceful.

nations. While there is some disagreement over terms, the complete definition was agreed upon by COPUOS members representing a shared vision for sustainable space activities.

The most pressing space sustainability issue is space debris. Space debris is defined by the UN Office of Outer Space Affairs as “as all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional.”¹¹ Debris is generated primarily from intentional or accidental break-ups or released during normal operation of launch vehicles or spacecraft.¹² Earth’s gravity will eventually pull some debris back to Earth where it will likely burn up in Earth’s atmosphere, but the timeline for re-entry can vary; debris below 600km can take a few years to fall back to Earth while debris above 1000km can take several centuries.¹³ There have been an estimated 500 fragmentation collisions or explosions in the last 60 years, with roughly 62% of the effects still on orbit.¹⁴ These events and other routine activities have left some 20 thousand debris objects larger than 10cm and millions of objects smaller than 10cm in Earth orbits.¹⁵ Traveling at speeds up to 17,500 miles per hour, even the smallest debris can pose a threat to spacecraft.

Debris threatens the ability to use space from low earth orbit (LEO) through medium earth orbit (MEO) and geosynchronous orbit (GEO), potentially disrupting earth observation, communication, navigation, and many other essential satellite services for all actors. If unchecked, debris will greatly hinder our ability to further develop space. For example, LEO is expected to host thousands of small satellites, if debris becomes so dense, our ability to access MEO and GEO will be impacted and our ability to communicate between MEO and GEO and Earth may also be impacted. With future LEO satellite services, like internet, expected to be a key driver of space revenues in coming years, losing LEO to debris could have numerous

¹¹ United Nations General Assembly, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*, (Vienna: 2010, Committee on the Peaceful Uses of Outer Space), 1.

¹² Ibid.

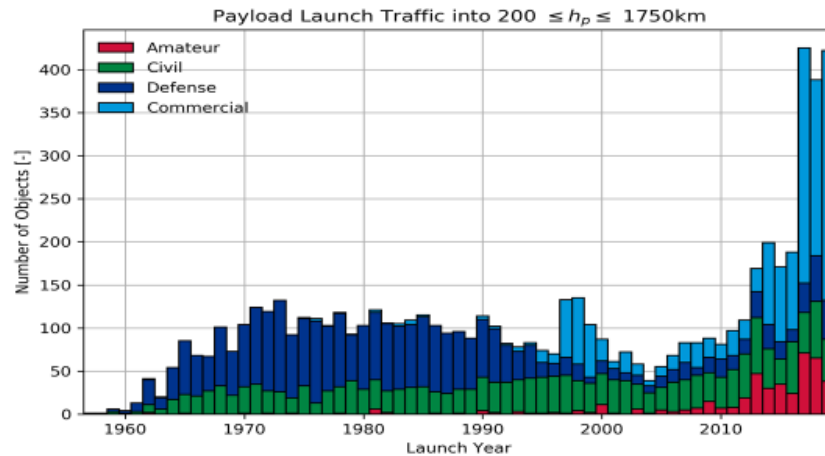
¹³ Marit Undseth, Claire Jolly, and Mattia Olivari, “Space Sustainability: The Economics of Space Debris in Perspective,” OECD Directorate for Science, Technology and Innovation, OECD Space Forum Secretariat, 2020, accessed June 2021, <https://www.oecd-ilibrary.org/docserver/a339de43-en.pdf?expires=1658254516&id=id&accname=guest&checksum=054EE32FBE046F285005811E264E9913>.

¹⁴ Undseth, Jolly, and Olivari, “Space Sustainability: The economics of space debris in perspective,” 19.

¹⁵ “Distribution of space debris around Earth,” European Space Agency, October 2019, accessed April 2020, https://www.esa.int/Safety_Security/Space_Debris.

downstream economic effects for space development. Moreover, debris does not have to reach critical levels to negatively affect space development. Should the risk to satellites from debris increase, investors could see the risk as too high and decide not to support development of satellites and services.¹⁶

Figure 1 – Missions to LEO and GEO



Source: European Space Agency, "Space Environment Statistics," European Space Agency, <https://sdup.esoc.esa.int/discosweb/statistics>.

Debris has become a more pressing issues in recent years as the rate of satellite deployment increases at unprecedented rates with plans to launch tens-of-thousands of new satellites (see figure 1).¹⁷ As space is further congested, the probability of collision between active satellites and space junk increases. While different models produce varying rates of collision between satellites and debris, all models predict the rate of collision will increase in coming years, and some by as much as 50%.¹⁸ It is also predicted that as debris levels increase at faster rates than it is removed, a self-cascading effect of collisions will occur (known as Kessler Syndrome), wherein debris causes new collisions which produce more debris which cause more collisions.¹⁹ Should the Kessler Syndrome occur, it is expected to be most disruptive for LEO from 650-

¹⁶ Undseth, Jolly, and Olivari, *Space Sustainability: The economics of space debris in perspective*, 28.

¹⁷ Michael Sheetz and Magdalena Petrova, "Why in the next decade companies will launch thousands more satellites than all of history," *CNBC*, December 2019, accessed April 2020, <https://www.cnbc.com/2019/12/14/spacex-oneweb-and-amazon-to-launch-thousands-more-satellites-in-2020s.html>.

¹⁸ Undseth, Jolly, and Olivari, "Space Sustainability: The economics of space debris in perspective," 26.

¹⁹ "The Kessler Effect and How to Stop it," European Space Agency, accessed April 2020, https://www.esa.int/Enabling_Support/Space_Engineering_Technology/The_Kessler_Effect_and_how_to_stop_it.

1000km and 1400km where most satellites currently orbit.²⁰ Kessler Syndrome would threaten to foreclose critical earth orbits from use. One study concluded that a major debris causing event may be required before the issue is taken more seriously.²¹

Debris in space is increasing but there is currently no means of removing it. Some spacefaring actors, like the United States, European Space Agency, and Russia, have adopted debris mitigation measures that reduce the chance of creating new debris.²² Governments and commercial companies are also investing in the development of active debris removal systems, which would be able to intentionally deorbit existing debris, but none are operational.²³ There is no international legal requirement to limit or remove space debris, either. Though some space actors are implementing debris mitigation measures and investing in active debris removal systems, not all are, and a few actors alone cannot solve the space debris issue. Preventing Kessler Syndrome will require international cooperation from all space actors. In all, debris poses a grave threat to the development of space. If there is any disagreement over this issue, it is not whether debris will cause harm to Earth orbits, but when.

Human development of space has reached somewhat of a juxtaposition: on the one hand, technology is allowing space to be developed in new ways and for greater economic and scientific return. On the other hand, to develop space further, space sustainability must be prioritized. Fortunately, some of the technologies necessary to develop space, like active debris removal, space traffic management, and novel satellite services, are also useful in sustaining the

²⁰ Undseth, Jolly, and Olivari, "Space Sustainability: The economics of space debris in perspective," 26; and, Thomas G. Roberts, "Popular Orbits 101," Center for Strategic and International Studies, last updated March 2020, accessed April 2020, <https://aerospace.csis.org/aerospace101/popular-orbits-101/#:~:text=The%20majority%20of%20satellites%20orbiting,full%20orbit%20around%20the%20Earth.>

²¹ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, "Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)," Institute for Defense Analysis, April 2018, 6-5, accessed April 2020, <https://www.ida.org/-/media/feature/publications/g/gl/global-trends-in-space-situational-awareness-ssa-and-space-traffic-management-stm/d-9074.ashx>.

²² "Debris Mitigation," NASA Orbital Debris Program Office, 2019, accessed April 2020, <https://orbitaldebris.jsc.nasa.gov/mitigation/#:~:text=Two%20years%20later%2C%20the%20U.S.,own%20orbital%20debris%20mitigation%20guidelines.>

²³ "ESA Commissions World's First Space Debris Removal," European Space Agency, August 2019, accessed April 2020, https://www.esa.int/Safety_Security/Clean_Space/ESA_commissions_world_s_first_space_debris_removal; and, "Active Debris Removal," Astroscale, 2020, accessed April 2020, <https://astroscale.com/services/active-debris-removal-adr/#:~:text=Working%20with%20national%20space%20agencies,that%20are%20already%20in%20orbit>

environment. But this symbiotic relationship between technology can only be fully realized if supplemented with international cooperation via contemporary space governance. Rules must be established to help regulate how actors develop space so the domain can be preserved. To continue developing space in the ad hoc manner as humanity has for the last sixty-years would likely render the space domain too insecure for long-term development.

Development of Space

The development of space for civil, commercial, and military ends is nothing new. Indeed, states and private actors have been developing space for one reason or another since Sputnik. What has changed in recent years, however, is the speed and scale at which space development is occurring. Due to lower financial costs associated with space technologies and services more actors can explore and exploit space than ever before. Indeed, the use of space for government or commercial purposes is taking new form and ushering in the next phase of space development with even greater potential for economic and scientific returns.

The term ‘development’ can invoke different meanings and definitions, but generally details a process that creates growth or positive, lasting change.²⁴ Development of space in this research describes the process of creating growth, or positive lasting change through commercial and civil space exploration and exploitation. Inherent in this definition is the need for sustainable practices; it would be difficult to create positive, lasting change if the space domain is overburdened with debris. This definition is also not prescriptive, therefore does not limit the ways in which space may be developed but does imply the right type of development will be generally positive.

Undoubtedly, the number of new technologies and services used to develop space will be immense. From new satellites constellations, to software, AI algorithms, robotics, and novel communications, there are simply too many individual pieces of technology or activities to discuss them all in this research. And not all technology needs to be discussed to understand how space development is likely to occur in the near-term or where governance discussions should

²⁴ Owen Barder, “What Is Development,” Center for Global Development, August 2012, accessed April 2020, <https://www.cgdev.org/blog/what-development>.

focus. Like the train in the development of the American West, or the internet in the development of the modern global economy, there are a few central space technologies and services that will enable the next wave of space development.

These technologies and services include constellations of small satellites, on-orbit rendezvous, proximity, servicing, and assembly operations (ORPSAO), and space traffic management (STM) (which for this research includes SSA). These are the technologies and services that are going to be central for the next wave of development in space and will therefore be the focus of this discussion. These technologies enable greater development of novel space systems, which produce new economic incentives to invest in and use space technologies and services and facilitate the orderly operation of space activities and services. Together they represent key space innovation and the means to sustain space more effectively.

While many of these emerging technologies and services are poised to generate new space development opportunities, many also require international cooperation. For example, an effective STM system, like air traffic management in civil aviation, requires international cooperation to be effective. Indeed, international cooperation in some of these key areas is in part what powers their ability to offer so much potential for sustainable space development. This core group of technologies and services are each in varying stages of development or initial use but are expected to become common place in the near-term. Each will be discussed in detail in subsequent chapters.

Politics and Power of Space Development

Developing space, like developing the high seas or civil aviation, must contend with inter-state politics and state power. That is because space, like the high seas, civil aviation, and even the internet provides states with economic, scientific, and military value that inherently makes space development political. Understanding the use of state power—the use of social relations to develop the means to influence other actors and their ability to determine their own circumstance

or fate²⁵—to create or influence space governance is important because it has and will continue to illuminate the character and means by which space governance evolves. For the purposes of this research, the discussion of politics and state power will be limited to its effects on space governance historically and in the near-term.

The creation of space governance, and COPUOS, was influenced by the politics and state power of the Cold War. Because of the Cold War, initial space governance was largely the means to balance power between the United States and the Soviet Union.²⁶ Institutional power, defined as the ability to “exercise indirect control over others, such as when states design international institutions in ways that work to their long-term advantage” most aptly describes the role of power in space governance during the Cold War.²⁷ This is evidenced by the US and Soviet Union’s choice to govern space activities through the UN while exercising considerable influence over the UN, the creation of COPUOS, and the multilateral treaties COPUOS produced during that period.²⁸

The transition from Cold War politics to the post-cold war politics of globalization and liberalism also influenced space governance, though through a diffusion of power. During the post-Cold War period rather than producing treaties, space governance began to struggle as state power (e.g., influence at COPUOS) waned.²⁹ During this period space governance did not stall completely, but multilateral efforts began to reflect political impasse while national policies received more attention. The shift is due, in part, because there was not a need to use space governance to balance power; the US had a clear power advantage. Instead, economic and scientific returns became the focus for space development during this period and neither required the US or other developed nations to focus political influence and state power on space governance.

²⁵ Michael Barnett and Raymond Duvall, “Power in Global Governance,” in *Power in Global Governance*, eds Michael Barnett and Raymond Duvall (Cambridge: Cambridge University Press, 2005), 5.

²⁶ Ibid., and Kenneth Hodgkins and Adam Routh, “Emergence of and perspectives for a new paradigm in space diplomacy,” in *A Research Agenda for Space Policy*, eds Kai-Uwe Schrogl, Christina Ginnopapa, and Ntorina Antoni (Northampton, Massachusetts: Elgar Publishing Limited, 2021), 40.

²⁷ Michael Barnett and Raymond Duvall, “Power in Global Governance,” 3.

²⁸ Kenneth Hodgkins and Adam Routh, “Emergence of and perspectives for a new paradigm in space diplomacy,” 40.

²⁹ Ibid., 46.

Today, space governance is once again defined by a bipolar international order split between the United States and some democracies, like Europe, on one end and China and other authoritarian states, like Russia, on the other. Related to space governance, state power in this new era still reflects institutional power, but unlike the Cold War where the US and Soviet Union cooperated through institutions to wield (or balance) power collectively, today there is a struggle between the US and democracies and China and authoritarians to wrestle total influence from the other. This can be seen in China's attempts to undermine or reshape western institutions in its image, and through the inability of either sphere to agree on even shared perspectives, like the prohibition of destructive ASATs.³⁰

Other expression of power, including coercive, structural, and productive power are less applicable for a few reasons. Coercive power is poorly equipped to develop effective international governance because it would require one or a few states to compel other states to comply with a system of rules that are not self-executing.³¹ In other words, international governance is only as effective as the domestic laws and enforcement that each state chooses to adopt to meet international obligations. While the system remains bipolar, it is unlikely that one or even a few countries could coercively force many other countries to adopt domestic legislation necessary to enforce international governance at a scale sufficient for international governance to shape the development of space. Indeed, even during the Cold War where US and Soviet influence covered large portions of the international community, the superpowers chose to create COPUOS with only a relatively small number of loyal countries, a decision made based on their desire to wield influence over the forum.³²

Similarly, structural and productive expressions of power rely on social and discursive features that are poorly suited to affect international governance of space in the near term. Structural power exists based on the creations and preservation of social positions that give

³⁰ "China's Approach to Global Governance," Council on Foreign Relations, accessed September 24 2023, <https://www.cfr.org/china-global-governance/>; and, Theresa Hitchens, "Russia Spikes UN Effort on Norms to Reduce Space Threats," *Breaking Defense*, September 1, 2023, accessed September 24, 2023, <https://breakingdefense.com/2023/09/russia-spikes-un-effort-on-norms-to-reduce-space-threats/>.

³¹ Michael Barnett and Raymond Duvall, "Power in Global Governance," 3.

³² Kenneth Hodgkins and Adam Routh, "Emergence of and perspectives for a new paradigm in space diplomacy," 40

power to one over another, like slave and master.³³ Structural power does have some influence over international governance but because it requires normalizing dominate and subordinate positions, structural power takes time to develop. The democratization of space power via commercial advancements and industry growth combined with competition between the United States and China provides little opportunity for structural power to develop and shape new space governance in the near-term. Though one could argue some structural power exists based on the size of the US space industry and the historical influence of the US in space governance, the US has had little ability to force outcomes in larger diplomatic space fora, like the UN, for several decades. Finally, productive power relies on discursive and social identities, which can also take time to influence international governance in ways less suited to affect international governance of specific domains, like space, for similar reasons to that of structural power.³⁴

Given that the interests of powerful states are imbedded in the design of institutions, which influences regime development over time,³⁵ combined with two similarly powerful countries, the US and China, it seems unlikely that either will be able to wield institutional power to develop new space governance unless the forum can accommodate competing state power via its decision-making style and processes such that influence is more equitable and governance outputs are not dependent on complete member support. If the forum cannot accommodate competing state interests and influence, then space governance is likely to be influenced by bilateral and/or multilateral agreements constructed outside of international fora. The Artemis Accords are one example of institutional power shaping new space governance outside of a multilateral fora.

More on organisational processes and decision-making style will be discussed in subsequent chapters, but when an IO is able to advance new measures despite some objections though tacit acceptance, multiple active workstreams, a spectrum of output types, among other features, power in those forums can be more dispersed or dissimilar to the power dynamics outside of the

³³ Michael Barnett and Raymond Duvall, "Power in Global Governance," 3.

³⁴ Ibid., 20-21.

³⁵ Thomas G. Weiss and Rorden Wilkinson eds., *International Organization and Global Governance*, 2nd ed. (New York: Routledge, 2018), 9.

forum, providing greater opportunity for the IO to deflect state power unless a state chooses to really focus its efforts on a given IO or topic. For example, in the IMO, states with the largest registries have considerable influence rather than the states with the biggest economies or militaries. Similarly, the use of tacit acceptance offers fewer opportunities for states to hold proceeding hostage for reasons unrelated to the forum.³⁶ While simply producing governance measures does not mean they will be effective, a forum that can produce measures can continue to advance and adapt governance as the international system and technology change, which is important for creating effective governance of a global commons (more on effective governance will be discussed in the next chapter).

When governance is effective it produces benefits, like new economic opportunity or environmental preservation. When governance produces benefits, more states are likely to adopt and adhere to it. Indeed, benefits can be a persuasive factor despite power and politics. The importance of governance benefits is present in all three case studies. While each will be discussed in greater detail in later chapters, the IMO, ICAO, and internet governance regimes have each seen growth and state support because of the benefits the governance has provided. For example, while the USSR did not initially attend the Chicago Convention nor was an inaugural member of ICAO, it did eventually join and has benefited from the rules, norms, and agreements ICAO develops. Perhaps the more obvious example of the importance of benefits is the internet. Early in the internet's development as its value became clear governments began to organize around a shared system of governance that would emphasize the internet's value. Benefits are not stagnant, however. As technology and state interests change, so too do possible benefits from governance. Therefore, to ensure a governance regime provides benefits, it much routinely adapt.

³⁶ An example of strict decision-making styles permitting unrelated political concerns to influence governance creation can be found in COPUOS. On several occasions Cuba, which has no space program or active space assets, has leverage the strict consensus processes to kill outputs only to concede after other countries agree to unrelated concessions. Hodgkins, interview; James Higgins, interview by author, Washington, D.C. January 28, 2020; and, Niklas Hedman, interview by author, Washington, D.C., July 17, 2020.

Power and politics will continue to be important in the development of new space governance. How each shapes the development of space governance will depend on the issues and the capacity of space governance fora to manage power and political dynamics. To be sure, states must choose to participate in an IO and adhere to international governance of any kind. Which means there is no organisational design capable of compelling states. That said, if an IO can advance governance that provides benefits, benefits can encourage states to participate in the IO and adhere to the governance.

Conclusion

The sustainable development of space is a complex task with many facets. Technology is quickly emerging that offers new possibilities for scientific and economic return through the exploration and exploitation of space. In a catch-22, these technologies pose both additional risk to space sustainability and offer solutions to some of these same sustainability challenges. Standing in the way of these technologies encouraging sustainable practices is international cooperation and a space governance regime that accounts for them. Yet, international cooperation and space governance must be developed against the politics and power infused into the international system. Not all space actors are equally concerned with space sustainability and even where there is general agreement about the importance or need for new space governance, political motivations have discouraged cooperation. Still, politics and state power are not new to international governance generally, and new space governance is needed all the same. The right system of international space governance will need to account for the realities of the current and future international system.

The intent of this analysis is to contribute to an underdeveloped area of literature to inform governments, the private sector, and academia as they attempt to advance more contemporary space governance. Thus far, studies are often narrow in scope using only a single domain or attempt to apply comparative methods broadly across a swath of international law and activities, rather than the more focused approach presented here. Even fewer comparisons have been made between space governance and the internet, which given the novel nature of internet governance compared to other domains, is long overdue. Additionally, small satellites, STM, and ORPSAO and their influence on space development and sustainability are rarely considered together for the

purpose of understanding space governance, yet in many ways they create a symbiotic relationship capable of influencing space development and sustainability. Given the existing threat to space sustainability and the increasing pace of space development, more research is desperately needed to better understand how these space technologies and services may collectively impact space development with sustainability and what governance is necessary to create balance.

While not policy prescriptive in a strict sense, the insights from this study will help its audience further develop and understanding of the issues and obstacles of space governance. Even though effective governance is subjective, this study hopes to provide thoughtful analysis which enables policymakers across government and non-governmental sectors to make more informed decisions about the practices, laws, regulations, organisations, and other tools intended to govern humanity's near-term development of space.

2. RESEARCH QUESTION & METHODOLOGY

There are two key elements for examining new space governance for the sustainable development of space. First, the space activities under discussion—small satellites and constellations, ORPSAO, and STM—are still in their infancy, so understanding how to create governance to support them requires working with the limited knowledge available and anticipating how the technologies and services will evolve overtime. The second element requires understanding what allows a governance entity to positively affect international governance over time.

Using existing literature on small satellites and constellations, STM, and ORPSAO and case studies of international governance organisations, this research will explore how new space governance could be developed to advance space development sustainably. The central research question is:

How can other governance regimes inform the development of contemporary space governance for the space activities expected to be most essential to the sustainable development of space?

The goal of answering the research question is to identify governance needs for the space activities in question and the international organisational features that will enable space governance entities to address those needs.

What is Effective Governance?

A key part of the methodology for evaluating current space governance, is understanding what could be considered effective international governance generally. The first component that helps to inform the topic of effective international governance is theory. Indeed, international relations discussions of governance are influenced by the theoretical lens through which one examines the topic. Through theory it becomes easier to understand and assess governance because it provides a foundation for understanding of events and outcomes. Realist and functionalist theories are two theories that offer useful insight. While there are many other

theories that offer explanations of events and outcomes, together realism and functionalism offer a pragmatic theoretical spectrum for assessing international governance. Indeed, they offer comprehensive theoretical contrast for understanding why and how states pursue international governance, which is necessary to understand what can constitute effective governance.

According to realist theories, international governance is a product of self-interested states, often the most powerful states, working together because it is in their self-interest to do so.³⁷ To this end, the creation of international organizations and their influence depends on the interests of powerful states. Realism also tends to hold a more pessimistic view of the value available to states from cooperation via institutions (and subsequently IOs) because, according to realism, states are concerned about relative gains, which can undermine cooperation.³⁸ Conversely, functionalist theories suggest international governance, more specifically institutions, exists because it is simply the most effective way to cooperate; the cost and benefit of more ad hoc cooperation would be less beneficial than through more formal arrangements.³⁹ Consequently, according to functionalism, states chose to cooperate through governance because it is in their interest to do so. While important differences are present, both theories suggest a governance regime exists because it provides states with benefits, though each theory does offer different perspectives as to how or why a governance regime provides benefits.

As it relates to global commons, a common benefit for states is the economic, military, environmental, and other value—some of which is irreplaceable—that global commons often provide. For example, ocean fisheries cannot be replaced by inland fisheries, therefore many states find it beneficial to sustain ocean fisheries. Space is one global commons with growing economic, scientific, environmental, and military value, but to harness the value of space, the critical earth orbits must be sustained. Understanding what makes for effective governance, thus, must provide the means to sustain space despite development. Concepts like the ‘tragedy of the commons’ describe the challenges of governing global commons.

³⁷ Jason Charrette and Jennifer Sterling-Folker, “Realism,” in *International Organization and Global Governance 2nd edition*, eds. Thomas G. Weiss and Rorden Wilkinson (New York: Routledge, 2018), 97.

³⁸ Robert O. Keohane and Lisa L. Martin, “The Promise of Institutional Theory,” *International Security* 20, no. 1 (Summer 1995): 39-51, accessed October 2023, <https://www.jstor.org/stable/2539214>.

³⁹ Robert O. Keohane, “Realism, Institutionalism, and Cooperation,” 4.

Tragedy of the commons describes a situation in which an environment is degraded following over-consumption, by many actors, of the resources found in that environment. Though the concept dates back to Aristotle, the concept gained contemporary popularity after Garret Hardin wrote in *Science* (1968) reflecting on the ‘tragedy’ of a system wherein states are locked into a system that compels each to use resources as if the resources are unlimited when they are not.⁴⁰ As discussed in the previous chapter, space development is on verge of creating a tragedy of the commons for Earth orbits. Elinore Ostrom’s framework for governing common pool resources provides important insight into how governance can help to avoid a tragedy of the commons situation. Ostrom’s work identifies that successful management of large, global commons is adaptive governance because technology and rules evaders will always challenge stagnant governance.⁴¹ Adaptation has also been found to be a key characteristic for IO survival in the face of larger system shocks or changes.⁴² Indeed, a lack of adaptation can be an indication of an ineffective governance regime because it will fail to produce outputs or adequately implement agreements which leave the regime unable to address problems affecting the domain and its actors.⁴³ In other words, without adaptation, governance is not likely to produce benefits.

In sum, effective governance requires that states benefit from it, which for space requires balancing sustainability and development. Adding in the work of Ostrom and others, to create a system of governance that can balance sustainability with development, that system must be able to adapt. For this reason, assessing space governance and the case study governance regimes will require evaluating their ability to adapt or evolve in an effort to provide states with benefits. Evolution in governance is identifiable by the rate at which new measures are produced or amended and the ways the organisation changes over time (e.g., modifies processes, create new committees, etc.). For example, the fact that COPUOS has only seen changes to its membership

⁴⁰ Garret Hardin, “Tragedy of the Commons,” *The Garret Hardin Society*, March 13, 2005, accessed September 24, 2023, https://www.garretthardinsociety.org/articles/art_tragedy_of_the_commons.html.

⁴¹ Thomas Dietz, et al., “The Struggle to Govern the Commons,” *Science* 203, no. 5652 (2003): 1908, accessed September 24, 2023, <https://doi.org/10.7717/peerj.14906>.

⁴² Mette Eilstrup-Sangiovanni, “What Kills International Organisations? When and Why International Organisations terminate,” *European Journal of International Relations* 27, no. 1 (2021): 9, accessed September 24, 2023, <https://doi.org/10.1177/1354066120932976>.

⁴³ Organization for Economic Cooperation and Development, “International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation,” 101.

but not its processes, structure, remit, or other features is a key reason why the organisation has been unable to produce new or amended existing governance. As a result, answering the research question will require paying close attention to how the case studies adapt to keep pace with their respective governance needs.

Methodology

Examining the governance gaps of emerging or near-term space technologies and services is a difficult task. Knowing how these new space systems or activities will affect the economy, science, or individual users is often informed speculation. For example, only after the U.S. commercial space firm, SpaceX, began launching hundreds of small satellites as part of its emerging broadband service did astronomers realize the extent to which satellite constellations would obstruct their view of the sky and hinder their work.⁴⁴ This means outlining methods of governing these emerging activities can be difficult: how does one create regulations for nascent technologies and services that do not hinder their development but also provides enough governance to protect space sustainability for all? While difficult, waiting until these technologies or services are fully developed and active could render new governance too little too late.

Other challenges for developing international governance are more common or timeless in nature. Including, issues of political or diplomatic concerns between states, like those related to sovereign authority or state freedom; international organisational capacity to effect new governance, which speaks to the predominant need of member states to cooperate in the development of international agreements; and, the nature of governance as a tool for shaping state behaviour due to the fact that states choose not to follow agreed upon governance tools, like international law.⁴⁵ These issues can all speak to why international governance is hard. But hard does not mean unnecessary or without value, nor do hard issues warrant being ignored. In fact, they should warrant more attention with the intention of making them easier to solve. Indeed,

⁴⁴ For more on this topic see: Jonathan McDowell, "The Low Earth Orbit Satellite Population and Impacts of the SpaceX Starlink Constellation," *ArXiv.org* (March 2020), doi:<http://dx.doi.org/10.3847/2041-8213/ab8016>.

⁴⁵ For governance adherence see: Heather Pickering, "Why Do States Mostly Obey International Law," *E-International Relations* (February 2014), <https://www.e-ir.info/2014/02/04/why-do-states-mostly-obey-international-law/>.

developing governance is hard but can still add value, though the value governance adds is often tied to the organisation's ability to adapt overtime, including changes to its structure, membership, agreements, processes, among other critical areas.

New research examining space governance gaps and how best to close them can inform actors in useful ways as they develop many of the new technologies necessary to further space development but sustainably. Understanding how to develop new governance despite the nascent nature of many new space activities and technologies can best be informed by comparison to other domains which have implemented similar technologies or overcome similar governance challenges. Indeed, comparisons are a fundamental method for learning in social science.⁴⁶

The inductive approach used in this research is borrowed from Yin (2018) and aims to explore global commons governance behaviour and events (or lack of them) that enable governance to adapt over time to provide state members with benefits. An inductive approach was selected because, as Yin notes qualitative data addressing the behaviour and events of case studies is helpful for describing or explaining events and outcomes at a higher level and illuminating important and innovative concepts⁴⁷ Indeed, the problem is that the behaviour and events associated with existing space governance is leading to inadequate governance that threatens the sustainability of the space environment. Explaining the space governance behaviour and events requires comparing space governance to governance regimes that, while imperfect, are more capable of governing their respective domains. In this way it becomes possible to show contrast between a failing space governance regime and more successful governance regimes at a pragmatic level. A deductive approach would centre on theory, which while important to an inductive approach as well, is not the focus of this research. By highlighting contrasting approaches to governance this research can inform how to improve space governance.

This research will leverage three case studies to discover how new space governance for small satellites and constellations, STM, ORPSAO can be developed. The first case study is

⁴⁶ B. Guy Peters, "Approaches in Comparative Politics," in *Comparative Politics*, 2nd ed, ed. Daniele Caramani (Oxford: Oxford University Press, 2011), 38.

⁴⁷ Robert K. Yin, *Case Study Research and Applications Design and Methods 6th ed.*, (Los Angeles: Sage Publishing, 2018), 169-170.

maritime, or shipping, governance. As one of the oldest and most developed areas of international law and governance pertaining to global commons, maritime governance was used to inform the development of existing space governance and so, it can be used to inform the development of new space governance.⁴⁸ The International Maritime Organization (IMO) is currently governing shipping via laws, norms, and other governance tools that cover sustainability, shipping traffic management, and governance of emerging technologies and services, like maritime autonomous surface ships. Each of these areas is relevant to the space activities in focus in this research and capable of informing a contemporary system of space governance.

Comparative value can also be gleaned from civil aviation governance. The air domain shares some similar qualities to space, such as being a global common or needing to traverse through airspace to access space. Indeed, some research has already been conducted on the similarities between airspace governance and space governance.⁴⁹ ICAO, and its processes, procedures, outputs, limitations, and strengths can inform the development of new governance for space because like the IMO, civil aviation governance has had to address sustainability, air traffic management, and governing of emerging technologies, like unmanned aircraft systems (UAS).

The final case study is internet governance. Internet governance possesses unique organisational structures compared to other governance regimes that permit internet governance to keep pace with rapid technology developed. For example, non-governmental organisations, like ICANN are staffed by predominantly non-governmental professionals and have considerable influence over the use of internet protocols and internet resources, and ultimately shape internet governance. Indeed, important aspects of internet governance are largely influenced by private actors rather than governments.⁵⁰ The alternative governance structure can offer alternative

⁴⁸ For a thorough discussion of the sources of international law that informed the development of existing space treaties see: M.J. Peterson, *International Regimes for the Final Frontier*, 2005.

⁴⁹ See: Ram Jakhu, Tommaso Sgobba, and Paul Stephen Dempsey, eds., *The Need for an Integrated Regulatory Regime for Aviation and Space: ICAO for Space?* (Noordijk: Springer-Verlag/Wien, 2011).

⁵⁰ For more on internet governance, see: Laura DeNardis, *The Global War for Internet Governance*; Laura DeNardis, *Protocol Politics* (London, England: MIT Press, 2009); and, Milton Mueller, *Networks and States* (London, England: MIT Press, 2010).

perspectives to explore new space governance. While there are some unique features of internet governance, the regime must still address sustainability and traffic management like maritime, civil aviation, and space governance. Maritime, civil aviation, and internet governance offer more comparative utility for developing space governance than the few examples previously listed, but those examples should demonstrate their comparative value.

It is important to note that space is unique in some important ways to each of the previous case studies. Perhaps the most important difference is the lack of clear demarcations of sovereignty that help illuminate clear lines of state responsibility in aviation, shipping, and the internet. While States are responsible for launching or landing items from their territory, orbits and celestial bodies are not subject to territorial claim according to existing international law. Without sovereignty, adjudicating responsibility can be tricky, creating important and unique governance challenges. Another unique quality of space is its harsh and remote environment. These features make it challenging to understand what is happening in space and take action quickly while increasing dependence on technical means to understand and operate within the space domain. Such a dependence can challenge space domain inclusivity through high development costs and knowledge requirements. They can also complicate solving problems. For example, we are unable to remove space debris. Finally, the origins of space development were military in nature, which have, in some instances, created a culture of secrecy around space activities that makes improving transparency difficult; transparency is necessary for space governance. Military origins and the difficulty of understanding what is happening in space due to its remoteness also tend to create sensitivity around relative space development gains among countries. Such tension can complicate space governance discussions by increasing political significance of some space activities and by blurring the line between peaceful or commercial and malicious or military activities. The case studies do share some of the qualities mentioned, though space development is influenced by them to a much greater extent.

Broadly, the case studies represent three existing areas of governance with many similarities and useful differences to space governance. Each of which can help inform how new space governance may be developed to encourage the development of space without sacrificing the domain's security.

Each case study will examine how associated international organisations were developed, their specific qualities (i.e., membership, participation, processes and procedures, remit, outputs, shortcomings, etc.), the ways the regime is adapting to meet governance needs. Though each of these comparative interest areas are general, each case study will provide unique and different findings based on individual qualities of the governance regime and the domain it governs. For example, while all three have somewhat similar supporting organisations, like the IMO or ICAO, the specific qualities of each organisation, to include membership structures, outputs, voting procedures, etc., are different. These differences, along with other unique factors associated with the different domains, will provide useful perspective for developing new space governance.

Examining the case studies to inform the development of new space governance requires evaluating a complex set of variables and factors that all influence the utility of a specific governance regime. While the exact composition of a governance regime often varies in character (e.g., different membership, processes, technology, politics, etc.), as discussed previously, each must adapt to remain effective. Each domain and forum must find the right composition of processes, outputs, among other factors based on the unique qualities of governance needs. For example, the pace of technology change affecting civil aviation warrants more use of standards and recommend practices than what international shipping requires. Yet, standards and recommend practices are still useful in certain situations for shipping. Finding what works requires an organisation to be agile; a willingness and ability to change as governance needs change.

Organisational agility does not mean the organisation undergoes radical change frequently. Rather, agility is evident in the frequency and volume of various measures adopted to govern. New outputs, the variety of outputs, amending existing measures, reforming processes, inclusivity of members, creating new working groups or committees, among other examples can all show how agile an organisation is. Conversely, stagnant processes, few outputs, and little change over time can reflect a stalled or ineffective governance organisation—as is evident by COPUOS. To this end, much of the data collected from the case studies will reflect how each organisation manages to remain agile to accommodate governance needs. Case studies will detail

how often agreements are produce or amended, the variety and volume of governance measures, how the organisation has changed over time, and other examples to show how the IMO, ICAO, and internet governance community remain agile to govern.

Other case studies, like the Antarctic Treaty, could be used to help inform space governance, but few other case studies offer such complementary comparative value as the air, maritime, and the internet domains offer. These three case studies provide a deep history of international governance detailing its evolution over time. From Hugo Grotius' postulation of the sea as international territory in 1609, to international recognition that state sovereignty extends into the airspace above a state's territory in 1944, and the development of the internet as a military project, each case study provides a different, but necessary historical context shaping the development of international governance. Each case study represents critical global commons requiring international cooperation for effective governance. And each case study requires international fora to help govern.

Each case study also faces similar requirements to balance development with sustainability in a world driven by ever faster technology innovation. Though sustainability challenges across the domains may be somewhat unique given the characteristics of the domains, the underlying governance structures which influence actor behaviour is often domain agnostic. For example, avoiding oil pollution in the maritime domain is different than avoiding debris in space, but whether these issues are effectively governed depends more on the organisation responsible for governing the domain than the characteristics of the domain or individual sustainability needs.

To be sure, comparative assessments are imperfect, and at times, prospective. However, the comparative method can be a very useful way of learning about new, but similar issues in a social science research field. Civil aviation, maritime, and internet governance are three areas of international governance that represent the best comparative studies to inform the development of new space governance given the similarities in governance challenges between each. Through the case studies, this project will shed light on how new governance for space activities expected to be most essential to the sustainable development of space may be developed.

This research will contribute to the growing body of space governance literature by offering comparative assessments of similar domains facing similar governance challenges to that of space; assessing governance lessons for specific space technologies and services necessary to sustainably develop space (small satellites and constellations, STM, and ORPSAO); and, useful insights to reform existing space governance organisations to better account for the changing character and increasing environmental instability of the space domain. This research will also contribute broadly to the study of international governance by offering analysis of contemporary governance challenges affecting four global commons. In all, this research will offer pragmatic insights into the development of new space governance necessary to sustainably develop space at a time when space development is both increasingly necessary and hazardous to the space environment.

This research can also contribute to existing knowledge by providing evidence of the relationship between governance adaptation and governance benefits to states. More than simply drawing correlations between the evolution of case study organisations and benefits, this research aims to provide more detailed insights about how adaptation takes place in governance fora by examining the characteristic of each organisation against changing governance challenges. Specifically, how each organisations keeps pace with changing environmental, technological, and development considerations depends on how the organisation is able to leverage processes and various governance tools to overcome the often-conflicting interests present between environmental sustainability and the benefits of domain development. In all, this research intends to provide both pragmatic recommendations for developing new space governance and offer insights into the nuances of how international organisations manage adaption.

Research Outline

The report will proceed as follows:

Chapter four will discuss the IMO, ICAO, and internet governance organisations, including actors, organisation structures, outputs, compliance, decision making, and the organisation's impact on its domain. The purpose of chapter four is to provide working knowledge of each

organisation so that proceeding chapters can focus on specific governance challenges with proper insight into each organisation.

Chapter five, six, and seven are the case study chapters. Chapter five explore small satellites and constellations and sustainability challenges. Chapter six explores STM management and traffic management in the case study domains. And Chapter seven explore ORPSAO and the governance of emerging technologies. Each chapter will conclude with relevant insights from the case studies as it applies to developing new space governance. Finally, chapter eight will offer final analysis and conclude the research. Chapter eight will briefly restate the problem, summarize the research, highlight what new contributions this research has offered, and suggest where future research could add additional value.

3. INTERNATIONAL SPACE GOVERNANCE

Space Governance should be thoughtfully considered given the current global reliance on space assets and the services they provide. The difference between long-term development of space for important economic and scientific returns and space becoming another tragedy of the commons is proper space governance. For the purposes of this research a “governance regime” is considered the full scope of rules, norms, institutions, and activities designed to influence state behaviour, decision-making, and interactions. A space governance regime would, therefore, include national and international activities, laws, and norms that influence how states and private actors explore, exploit, and sustain outer space.⁵¹ It is through these mechanisms that new governance can encourage space development while protecting the space environment.

Global Governance

Global governance “refers to the totality of the ways, formal and informal, the world is governed.”⁵² Global governance includes several complementary elements, including formal laws (domestic and international), soft law, principles, norms, organisations, and decision-making procedures, and which often reflect state’s interests and influence state’s behaviour.⁵³ The purpose of global governance is primarily a means of facilitating international relations between states.⁵⁴ Intended to help organize actions between actors in an anarchic system of sovereign states, agreeing on rules, cooperating through organisations, and establishing practices and methods to cohere actors and their activities often enables mutually beneficial outcomes that would otherwise be more difficult to achieve in the Westphalia system.⁵⁵ Since the treaty of

⁵¹ This definition was informed by Robert O. Keohane, “Realism, Institutionalism, and Cooperation,” *After Hegemony: Cooperation and Discord in the World Political Economy*, (Princeton University Press, 1984) 5-17.

⁵² Weiss and Wilkinson, *International Organization and Global Governance*, 9.

⁵³ For a thorough discussion of global governance see: *Ibid.*, 8.

⁵⁴ *Ibid.*, 7; Craig Murphy, “The Last Two Centuries of Global Governance,” *Global Governance* 21, no. 2 (2015), 189-196; Global Development Research Center, “Our Global Neighbourhood: Report of the Commission on Global Governance,” *Global Governance*, Chapter 1, 1995, accessed July 2020, <http://www.gdrc.org/u-gov/global-neighbourhood/>; Thomas G. Weiss, *Global Governance: Why? What? Whither?* (Cambridge: Polity Press, 2013), 90-127; Ramesh Thakur, “The United Nations in Global Governance: Rebalancing Organized Multilateralism for Current and Future Challenges,” *The United Nations*, 2011, 19-28, accessed April 2020, <https://www.un.org/en/ga/president/65/pdf/calendar/20110628-globalgov.pdf>.

⁵⁵ “Treaty of Westphalia,” Yale Law School, Lillian Goldman Law Library, accessed April 2020, https://avalon.law.yale.edu/17th_century/westphal.asp.

Westphalia in 1648 states have been the principal actor responsible for influencing global governance, but other mechanisms, like financial markets, also play a highly influential role in global governance.⁵⁶

Within the last few decades discourse on global governance as also begun to include the role of private and non-state actors due to their increasing influence in international relations. For example, non-governmental organisations (NGOs), like the Internet Corporation for the Assigned Names and Numbers (ICANN), has considerable influence over internet governance through its ability to regulate key aspects of how the internet functions.⁵⁷ Other examples include even less formalized entities built around emerging technologies, like social media or the Internet of Things (IoT), that provides non-state actors (NSA) and individuals considerable influence to affect governance.⁵⁸ Through this range of actors and entities, global governance is produced, adapted, and evolved over time to address challenges and issues that cannot be adequately addressed by a single or few actors.

Within global governance resides international governance. International (meaning interstate) refers more specifically to the formal choice of states to create governance (vs the informal mechanisms of governance mention previously, like financial markets or social movements). These formal mechanisms often occur through legal frameworks, international organisations, or coalitions of the willing.⁵⁹ International governance comes in many forms but its most prominent form is legal frameworks, like treaties, soft law, customary international law, and standards.⁶⁰

⁵⁶ Weiss and Wilkinson, *International Organization and Global Governance*, 11.

⁵⁷ For more on the role of ICANN in internet governance see: Laura DeNardis, *The Global War for Internet Governance*, (New Haven: Yale University Press, 2014), 22.

⁵⁸ The Arab Spring is a good example of how the internet enabled NSAs to change governance. For more see: Taylor Dewey, Julianne Kaden, et. al., "The Impact of Social Media on Social Unrest in the Arab Spring," Sandford University, March 2012, accessed April 2020, <https://publicpolicy.stanford.edu/publications/impact-social-media-social-unrest-arab-spring>.

⁵⁹ Weiss and Wilkinson, *International Organization and Global Governance*, 10.

⁶⁰ Ibid., 10.

Though states are the principal actor in international governance, like global governance, NSA and NGOs are increasingly able to influence how states choose to develop international governance.

NSA and NGO influence is, in large part, due to technology. Governments simply cannot effectively govern new and unfamiliar technology quickly enough without the help of the private sector that develops it. Digital technologies are a prominent example here: new methods of conducting business transactions, new digital currencies, and even scarcity of virtual resources, like internet domain names and numbers, developed or managed by the private sector requires that these private organisations be involved when creating international governance. The private sector's involvement in international governance is often channelled through states, though there are examples where NSA and NGOs participate alongside states; the International Telecommunications Union (ITU) through the World Radio Conference (WRC) is one example. Even though there is increasing involvement from NGOs and NSA, because international governance is predominately executed through international and national law, states continue to be the most important and influential actors.

In international law, states are the subjects of law, while the objects of international law can be anything.⁶¹ In other words, according to international law, only states are accountable to international legal requirements, not individuals or other private actors. Similarly, while states are the subjects, anything, be it a private company, individual, or activity can be the focus of international law. We see this in international law formation (in international law there is no centralized law-making powers, so states must actively work to create international law), legal content (international laws are expressions of a state's will), and law enforcement (the International Court of Justice (ICJ) will only recognize states as claimants and states much enact

⁶¹ Christopher D. Johnson, interview by author, Washington, D.C., February 10, 2020. Of note, some international organizations, like the EU can also be subjects of international law.

international law through national measures⁶²).⁶³ This democratic process of creation and consent by states is often at the foundation of international law's legitimacy.⁶⁴

As states use law to create governance they do so in two main forms, general international law, which speaks to the broad overarching legal themes detailed in foundational international legal documents like the Vienna Convention on the Law of Treaties and UN Charter, and specialized international law focused on specific subject areas, like space, maritime, or human rights law.⁶⁵ While specialized law will conform to the overarching legal principles detailed in general international law, specialized rules often prevail over more general rules.⁶⁶ This is because specialized rules cater to the particular needs of a given topic whereas general legal principles speak more broadly to nature and purpose of international law.⁶⁷

International law also employs classifications to categorize types of activities vs location of activities. While types of activities would reflect what an actor is doing (e.g., sailing a ship), the locational categorization reflects where an actor is doing them (e.g., the high seas vs territorial waters). This distinction is important because what an actor is doing has different legal implications depending on where that actor is doing it. Such categorization is important when discussing space governance because many of the issues discussed early in the development of space governance (and some issues being discussed today) reflect confusion or disagreement over how these categorizations can and should be applied to space or other governance regimes.⁶⁸ While some forms of international law, like treaties, are by-in-large considered legally binding, other forms, like soft-law or customary international law, are not necessarily binding and often elicit greater debate concerning adherence and enforcement.⁶⁹

⁶² The ICJ is the principle judicial organ of the United Nations.

⁶³ Cassandra Steer, "Sources and Law-Making Processes Relating to Space Activities," in *Handbook on Space Law*, edited by Ram S. Jakhu and Paul S. Dempsey (New York: Routledge, 2017), 3.

⁶⁴ *Ibid.*, 3.

⁶⁵ Johnson, interview.

⁶⁶ Cassandra Steer, "Sources and Law-Making Processes Relating to Space Activities," 18.

⁶⁷ For a detailed discussion on general principles and space law, see: *Ibid.*, 9.

⁶⁸ For examples, there is no international agreed upon rule for where airspace stops and outer space begins, which has ramifications for civil aviation and space development and governance.

⁶⁹ Dinah L. Shelton, "Soft Law," in *Handbook of International Law*, edited by David Armstrong (New York: Routledge, 2009), 68-69; and, Cassandra Steer, "Sources and Law-Making Processes Relating to Space Activities," 8.

In addition to international law, national law also plays a major role in governance. Because most treaties are non-self-executing, meaning they require national legislation to be applied by national courts, a state must often enact local measures to ensure coherence to international law.⁷⁰ National legislation can also govern activities in ways that international regimes do not. For example, there are no binding international agreements related to space debris, yet the United States and other countries have national laws enabling regulations to address space debris. Though national laws are often a necessary component of global governance, national laws cannot govern activities of other states.

In sum, global governance reflects a variety of active measures (e.g., laws) and passive measures (e.g., financial markets) that influence actor's behaviour. States are the primary actors responsible for global governance, though NSA and NGOs can influence it as well. Within global governance falls international governance which reflect a more curated system of rules developed by states. International governance is often a reflection of state's interests, and as a result, developing new international governance is often necessary but difficult because states seek solutions best suited to their needs. Navigating divergent state interests is a leading barrier to necessary space governance.

Space Governance and its Gaps

International space governance includes a special regime⁷¹ of international and domestic law, norms, and organisations specific to the topic of space, though some legal principles are shared with other legal regimes. Space law consists primarily of treaties, national laws, and customary or soft law.⁷² Aside from customary international law, which is established as states routinize behaviour over time, space law treaties and soft law are primarily developed through the UN General Assembly (GA), Conference on Disarmament (CD), COPUOS, other specialized UN agencies, like the ITU, or bilaterally between individual states themselves.⁷³ Often, the international organisations that may produce space treaties or other governance tools adhere to

⁷⁰ Carlos Vasques, "The Distinction Between Self-Executing and Non-Self-executing Treaties in International Law," (Lecture, Georgetown University, 10 May 2018).

⁷¹ For definition of governance regime see note 9.

⁷² Steer, "Sources and Law-Making Processes Relating to Space Activities," 20-22.

⁷³ Ibid., 8.

their own procedures, have different membership, voting processes, and underlying principles (e.g., their mission) which can affect the forum's ability to address certain space governance topics and develop new laws or norms. Space governance tools developed nationally are produced through domestic legislators or regulatory processes as states see fit, are often necessary to enforce international space governance, and can reflect unique or divergent interpretations of international governance measures, like those within the United States and Luxemburg which authorize mining space resources.

Though international space governance was first developed in the 1960s and continues to be developed today, there are many issues with the current space governance regime that limit its ability to effectively govern contemporary space activities. This inability is due to a number of issues, including: the dated nature of current space governance agreements and the failure of international organisations to develop new ones; disagreements between states over how space can or should be used and developed; divergent state interests in space technology and development; space knowledge and technology disparity between major and minor spacefaring nations; and the speed at which new space technology is being developed. In all, technology and opportunities to develop space have progressed while the space domain's governance regime has not. A lack of effective governance permits unregulated development, which is currently threatening the domain's security, and consequently, the prospect of further development of space.

International Space Treaties

Developed through COPUOS during the 1960s and 1970s, there are currently five existing treaties focused on space activities that represent the core of international space governance. COPUOS, like other specialized committees within the UN was tasked with addressing space governance by the UNGA in 1959. While the topic has only grown in importance over the years, COPUOS and other multilateral fora have since failed to develop new binding agreements. An inability to develop new space treaties in recent years has required COPUOS to shift its focus away from treaties and toward developing voluntary guidelines, which lack the binding nature of

formal treaties.⁷⁴ Moreover, because COPUOS was founded on principles which recognize the “importance of international cooperation in the exploration and exploitation of outer space for peaceful purposes” the forum is often described as ill-suited to address issues that may be viewed by its members as falling outside the scope of its founding principles, like those related to military use of space or some economic topics.⁷⁵

1967 Outer Space Treaty

The treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, also known as the Outer Space Treaty (OST), was the first treaty produced. It was considered by the COPUOS Legal Subcommittee in 1966 and opened for signature on January 27, 1967, in Washington, London, and Moscow. The OST entered into force on October 10th of the same year. Though preceded and influenced by the 1962 Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, the OST was the first formal space governance treaty and outlines many of the most important ideas associated with space governance to be developed thus far; like that the exploration and use of outer space shall be the province of all [human]kind; that outer space shall be free for exploration and use by all; and the non-appropriation of celestial bodies.⁷⁶ As of January 2019, 109 states have ratified the OST.⁷⁷

The OST contains 17 articles covering a range of topics some of which reflect broader international law principles, like liability and sovereignty, while others, like article 4 which prohibits the placement of weapons of mass destruction in outer space, reflect more specific ideas and the inter-state politics at the time the OST was created.⁷⁸ Its articles broadly reflect the need to keep space peaceful and that space is a domain for international cooperation rather than appropriation. More specifically, some of the more significant articles state that: space

⁷⁴ Hodgkins, interview.

⁷⁵ Higgins, interview.

⁷⁶ Outer Space Treaty, p. 205.

⁷⁷ United Nations, *Status of International Agreements Relating to Activities in Outer Space as at 1 January 2020*, (Vienna: Office for Outer Space Affairs, 2020).

⁷⁸ The OST was developed reflected the Cold War standoff between the U.S. and the Soviet Union. See: Walter A. McDougall, *The Heavens and the Earth: A Political History of the Space Age*, (Baltimore, MD: Johns Hopkins University Press. 1997), 194, 294-297.

exploration should be for peaceful purposes for all humankind (Article 1); that the moon and celestial bodies is not subject to national appropriation (Article 2); space activities should adhere to international law (Article 3); space should remain free of weapons of mass destruction (Article 4); and, state parties to the OST are responsible for national activities, including those by the private sector (Article 6).⁷⁹ Though the OST covers a number of overarching legal themes and relevant topics, it does not discuss them in depth.

In many ways the OST serves as a defining space treaty wherein states recognize the need to govern space activities, provide foundational principles for how space will be governed, and enables supplemental treaties to address more specific elements of space governance.⁸⁰ Its 17 articles created, at the time, a useful foundation for space law and governance, but are not comprehensive and have been increasingly described as too generic to effectively govern many new space activities, services, and challenges, like space debris and ORPSAO activities.⁸¹

For example, while Article 3 of the OST requires State Parties to conduct space activities “in accordance with international law...in the interests of maintaining international peace and security and promoting international cooperation...” article 3 does not provide enough detail to ensure clarity of what this looks like in application. What does being in “accordance” or the “interests of maintaining...peace and security” look like in application? Does temporarily interfering with another state’s satellite through GPS jamming or laser dazzling represent a breach of international peace? Does a single state’s occupation of many critical Earth orbital slots by satellites represent in effect a sovereign claim over those orbits? Many other questions related to the application of the OST also exist. Given the ambiguity, it has also been argued that the OST is only prescriptive in obligations of conduct but not in outcome of conduct.⁸² But even this argument is regularly challenged by states conducting activities clearly counter to the treaty,

⁷⁹ Outer Space Treaty, p. 205.

⁸⁰ United Nations, *United Nations Treaties and Principles on Outer Space and Related General Assembly Resolutions*, (New York: Office for Outer Space Affairs, 2008), VI.

⁸¹ Jakhu and Pelton, *Global Space Governance an International Study*, 5.

⁸² *Ibid.*, 23.

like the routine use of space for non-peaceful military purposes.⁸³ Ultimately, the OST's vagueness creates opportunity for differing interpretations.

The treaty's age is also a problem. Produced more than 53 years ago, it fails almost entirely to account for issues impacting space security today. Issues like space debris are almost entirely unaccounted for in the OST. Article 9 requires state parties to conduct space activities with due regard to the corresponding interests of all state parties and addresses the harmful contamination of space from human activities.⁸⁴ The OST otherwise does not specifically require states to consider space security to any meaningful extent aside from consultations between parties when one feels another's actions may cause harmful interference with the activities of another.⁸⁵ It may be possible to suggest article 9 supports the establishment of rules to improve space security, but aside from new agreements being formed based on the tenants within the OST, the treaty does not provide any prescriptive guidance to ensure space is developed sustainably. There has been enough emphasis on space sustainability by parties to the OST to suggest the OST does advocate for space sustainability.⁸⁶ But the committee has only been able to produce non-binding guidelines on the issue, suggesting states have different ideas of what space sustainability requires.

Many legal questions like those previously mentioned exist because the OST lacks enough detail to outline clearly what falls within its remit and because the treaty is simply too old to address many contemporary space topics. New commercial, military, and civil pursuits in space have pressed the legal boundaries of the OST. Applying the OST to a growing set of space activities and challenges will likely only become more complicated as new space activities expected in the near- and medium-term continue to sit outside the treaty's scope.

⁸³ Ibid., 23. For discussion of the legal grey area around armed conflict in space, see: Dale Stephens, "Military Space Operations and International Law: The Woomera Manual Project – Part 1," *Just Security*, March 2002, accessed April 2020, <https://www.justsecurity.org/68815/military-space-operations-and-international-law/>, and Hitoshi Nasu, "NATO Recognizes Space as an "Operational Domain": One Small Step Toward a Rules-Based International Order in Outer Space: The Woomera Manual Project – Part 2," *Just Security*, March 2020, accessed April 2020, <https://www.justsecurity.org/68898/nato-recognizes-space-as-an-operational-domain-one-small-step-toward-a-rules-based-international-order-in-outer-space/>.

⁸⁴ Outer Space Treaty, Article 9.

⁸⁵ Ibid., Article 11.

⁸⁶ The production of the Long-Term Sustainability Guidelines could have only been developed if COPUOS members felt space sustainability was condoned by the terms imposed by existing treaties.

1968 Rescue Agreement

The next treaty produced by COPUOS was the 1968 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into outer space, also known as the Rescue Agreements. Negotiated by the Legal Subcommittee of COPUOS between 1962 and 1967 and entered into force in December of 1968, the agreement generally elaborates on articles 5 and 8 of the OST. Drawing on article 5 of the OST, which describes astronauts as “envoys of mankind”, the agreement reinforces international cooperation in the exploration and use of outer space for the benefit of all countries while recognizing the difficulty and risk of space exploration. The rescue agreement does not specifically define “astronaut” and uses “personnel of a spacecraft” when discussing people in spacecraft within the agreement’s ten articles.⁸⁷ The agreement does define “launching authority” as the “state responsible for launching.”⁸⁸ As of January 2019, there are 98 parties to Rescue Agreement.

The Rescue Agreement’s 10 articles address the obligation of contracting states to assist in the rescue and return of astronauts and space objects that return to Earth outside of the launching authority’s territory for reasons “owing to accident, distress, emergency, or unintended landing.”⁸⁹ Article 2 of the Rescue Agreement states “contracting parties...shall immediately take possible steps to rescue [personnel of a spacecraft] and render them all necessary assistance.”⁹⁰ Article 2 also states that the Contracting Party with jurisdiction over where the personnel or space object has landed has the “direction and control” over rescue or return operations, though the launching authority may support if agreed to by the Contracting Party.⁹¹ Article 5 imposes cost on the launching authority for rescue or return costs, but does not provide any detail about how to arrive at those costs or how payment must be made.⁹² Further, article 5 states that rescue or return operations may be conducted when the launching state requests them or when a Contracting Party “receives information or discovers that a space object or its

⁸⁷ Rescue Agreement, Article 1.

⁸⁸ Ibid., Article 6.

⁸⁹ Ibid., Article 10.

⁹⁰ Ibid., Article 2.

⁹¹ Ibid., Article 2.

⁹² Ibid., Article 2.

component parts...in its jurisdiction...or any other place not under the jurisdiction of any state.”⁹³ Collectively, articles 2-5 detail the agreement’s processes and thresholds for action. The relatively concise nature of the Rescue Agreement leaves some ambiguity around when, how, and at what cost should people or space objects be rescued or returned and suggests the agreement may not cover some new space activities and actors coming into operation, like commercial actors or space tourists.⁹⁴

Rescue and return of people is unlikely to produce much controversy outside of minor costs and cooperation disagreements between the contracting party and launching authority; there is ample precedent in search and rescue operations in civil aviation and maritime shipping to suggest states are generally cooperative during search and rescue operations. The Rescue Agreement’s language discussing space objects may prove more controversy, however. As detailed above, the agreement may be invoked upon request from the launching state or when the Contracting Party receives information about items relevant to the agreement. The Agreement’s language in articles 2-5 require clearly identifying the launching authority to establish ownership of the space object and financial liability for recover and return costs. But because space objects can break up for many reasons and be damaged in the process, identifying ownership of space objects can be difficult.

Moreover, multiple actors (states and private) routinely embark on space activities together through cooperative agreements or through commercial space services. Such cooperation can muddle the liability of the “launching authority.” For example, the U.S.-based Iridium Satellite, LLC has operated satellites built by another U.S.-based satellite manufacture and launched them on a Russian rocket out of Kazakhstan. While the Rescue Agreement states the launching authority is the state that conducted the launch, it could be argued that Russia, Kazakhstan, and Iridium could each be responsible for the launch. *Iridium owned* the satellite, so the US is responsible based on the OST, but it was *launched from Kazakhstan* on a *Russian rocket* operated by Russians. Thus, identifying who the launching state is can be tricky and legally

⁹³ Ibid., Article 3.

⁹⁴ Stephen Grove, “Legal Problems of the Rescue and Return of Astronauts,” *The International Lawyer* 3 no. 4 (July 1969), 898, accessed April 2020, www.jstor.org/stable/40704588.

amorphous. Without the legal footing to establish responsibility, it is unclear how costs for rescue or return operations would be determined. Afterall, there is no dispute settlement mechanism for space law.⁹⁵

Though not without some ambiguity, the Rescue Agreement is perhaps the least controversial of the current space treaties. Its specific focus and scope suggest states invoking it are interested in cooperation, though its vagueness around rescue and return procedures and associated costs could cause disagreement. Legitimate disagreements could also be made as new and emerging space activities and services, like space tourism, introduce new considerations. With space activities rapidly advancing, the agreements utility will ultimately be determined by how parties to the treaty choose to leverage it for the support it lends to space activities.

1972 Liability Convention

The Convention on International Liability for Damage Caused by Space Objects (Liability Convention) was the third agreement produced through COPUOS. Debated by the Legal Subcommittee from 1963-1972 before entering into force in 1972, the Liability Convention “provides that a launching State shall be absolutely liable to pay compensation for damage caused by its space objects on the surface of the Earth or to aircraft, and liable for damage due to its faults in space.”⁹⁶ Given that the OST requires that space activities adhere to general international law and that states are responsible for the activities of their nongovernmental actors, the Liability Convention was a logical outgrowth. There are 98 parties to the Convention as of January 2019.⁹⁷

Offering more detail on liability than the OST, article 1 of the Liability Convention provides definitions for: “damage,” which means ‘loss of life, personal injury or other impairment of health or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organisations; “launching,” which includes attempted launches;

⁹⁵ Hanneke Van Traa-Engelman, "Settlement of Space Law Disputes," *Leiden Journal of International Law* 3, no. 3 (1990): 139-155, accessed April 2020, <https://doi.org/10.1017/S0922156500002235>.

⁹⁶ Convention on International Liability for Damage Caused by Space Objects, United Nations office for Outer Space Affairs, 29 March 1972, UNTS 961, p. 187, article 2.

⁹⁷ United Nations, *Status of International Agreements Relating to Activities in Outer Space as at 1 January 2020*.

“launching state,” which includes “a state which launches or procures the launching of a space object, or a state whose territory or facility a space object is launched; and, “space object”, which “includes component parts of a space object as well as its launch vehicle and parts thereof.”⁹⁸ With 28 articles, the Liability Convention is the most comprehensive of the five existing space treaties, but as will be discussed, it is not without its ambiguities which can hinder its effectiveness.

Article 2 plainly states that “a launching State shall be absolutely liable to pay compensation for damages caused by its space object on the surface of the earth or to aircraft in flight.”⁹⁹ Article 3 addresses damage caused “elsewhere than on the surface of the earth” and suggests the launching State is liable “only if damage is due to its fault or the fault of persons for whom it is responsible.”¹⁰⁰ The Liability Convention is unique in international law because it is the only fault-based liability regime.¹⁰¹

The wording in article 3 has important implications for the practicality of the Liability Convention because the Convention does not provide a definition of ‘fault’. Given how little information is available for activities in space—due to a lack of SSA capabilities—proving fault can be difficult if not impossible. A good example of this is the 2009 Russian and Iridium satellite collision, which destroyed both satellites and created thousands of pieces of debris.¹⁰² The collision occurred when the known defunct Cosmos 2251 collided with the active Iridium satellite. Due to inadequate SSA data, there was simply no way to conclusively determine which actor was at fault, so both actors were able to rid themselves of liability.¹⁰³ Moreover, because there are no STM norms, Iridium was not obligated to move its satellites to avoid the collision nor was Russia obligated to deorbit its satellite prior to the end of its service life. It has been

⁹⁸ Liability Convention, Article 1.

⁹⁹ Ibid., Article 2.

¹⁰⁰ Ibid., Article 3.

¹⁰¹ Joel A Dennerley, “State Liability for Space Object Collisions: The Proper Interpretation of ‘Fault’ for the Purposes of International Space Law,” *European Journal of International Law* 29, no. 1, (February 2018), 281-301, <https://doi.org/10.1093/ejil/chy003>.

¹⁰² For a detailed analysis of this collision see: T.S. Kelso, “Analysis of the Iridium 33-Cosmos 2251,” (paper presented at the 19th AIAA/AAS Astrodynamics Specialist Conference, Pittsburgh, PA, 11 August 2009).

¹⁰³ Frans G. von der Dunk, “Too-Close Encounters of the Third Party Kind: Will the Liability Convention Stand the Test of the Cosmos 2251-Iridium 33 Collision?” *Proceedings of the International Institute of Space Law* 28, (2009), 202-205.

argued that the idea of due regard outlined in Article 9 of the OST would require both Russia and Iridium to take steps to avoid collisions, but the lack of standards for collision avoidance or debris mitigation at the time of the collision suggest article 9 reflects more of an obligation of conduct rather than outcome.¹⁰⁴

It may be argued that because liability as a legal concept is covered in numerous other international legal regimes that actors have other legal avenues to pursue liability claims for space activities outside of the Liability Convention.¹⁰⁵ Regardless of the legal avenue chosen, the need to prove fault for incidents in space will likely remain necessary, meaning liability claims broadly, and the Liability Convention specifically, is dependent on honest reporting from space operators and technology that provides detailed SSA information about activities in orbit.

As tens of thousands of satellites are launched in the coming years and decades, the Liability Convention would seem to be a necessary legal tool, however as the 2009 Iridium-Cosmos example shows, significant legal gaps within the convention may render it less useful. The Iridium-Cosmos example demonstrates how the treaty's vague use of fault can be a challenge to the treaty's effectiveness. It also shows that the convention requires complementary norms and services, like those associated with STM, to truly be effective.

1976 Registration Convention

Like civil aviation or maritime governance, there were early calls for states to register space objects with the UN.¹⁰⁶ Built on GA res. 1721B, which calls for states to register objects launched into space, and working through the Legal Subcommittee, COPUOS developed the Convention on Registration of Objects Launched into Outer Space (Registration Convention) between 1962-1974 before entering into force in 1976.¹⁰⁷ A registry of space objects was

¹⁰⁴ Ram Jakhu, "Iridium-Cosmos Collision and Its Implications for Space Operations," in *Yearbook on Space Policy 2008/2009*, eds Kai-Uwe Schrogl, Wolfgang Rathgeber, Blandina Baranes, Christophe Venet (Germany: Springer, 2010), 259.

¹⁰⁵ Jakhu and Pelton, *Global Space Governance an International Study*, 25.

¹⁰⁶ "Resolution Adopted by the General Assembly: 1721 (XVI). International co-operation in the peaceful uses of outer space," United Nations Office for Outer Space Affairs, December 1961, accessed April 2020, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/resolutions/res_16_1721.html.

¹⁰⁷ Convention on Registration of Objects Launched into Outer Space, 15 September 1976, UNTS 1023, p.15.

considered necessary by member states to address issues of state responsibility associated with the Rescue Agreement and tenants of the Liability Convention.¹⁰⁸ As of January 2019, there are 69 parties to the Registration Convention.¹⁰⁹

Article 1 of the Registration Convention borrows definitions of “launching state”, and “space object” from the Liability Convention and adds a definition for “state of registry,” which means “a launching State on whose registry a space object is carried in accordance with article 2 [of the Registration Convention].”¹¹⁰ Article 3 mandates the creation of a registry managed by the Secretary-General of the UN and in accordance with article 4.¹¹¹ Article 4 requires states to provide information about space objects carried on their national registry “as soon as practicable” including, launching state(s), designator of the space object, date and location of launch, orbital parameters, and the function of the space object.¹¹² While designed to provide transparency and ample information to effectively utilize the Rescue Agreement and Liability Convention, the details (or lack thereof) of the Registration Convention, and specifically articles 1, 2, and 4, allow States to provide false, insufficient, or no information on space objects.¹¹³

Article 4 of the Registration Convention requires states to provide information about the space object’s “general function” and “basic orbital parameters.”¹¹⁴ Reporting on a satellite’s ‘general function’ is often viewed as vague language or a security risk for military and intelligence satellites, so it is not uncommon that imprecise, false, or no information on the space object’s general function is provided.¹¹⁵ Similarly, despite the Registration Convention’s requirement to provide orbital parameters of a space object—information necessary to help verify a space object’s purpose and avoid collisions—this information is also often not provided

¹⁰⁸ Registration Convention, preamble

¹⁰⁹ United Nations, *Status of International Agreements Relating to Activities in Outer Space as at 1 January 2020*, (Vienna: Office for Outer Space Affairs, 2020).

¹¹⁰ Registration Convention, Article 1.

¹¹¹ Ibid., Article 3.

¹¹² Ibid., Article 4.

¹¹³ For a detailed analysis of the Registration Convention and its limitations, see: Ram S. Jakhu, Bhupendra Jasani, and Jonathan C. McDowell, “Critical issues related to registration of space objects and transparency of space activities,” *Acta Astronautica* 143 (2018), 406-420.

¹¹⁴ Registration Convention, Article 4.

¹¹⁵ Jakhu, Jasani, and McDowell, “Critical issues related to registration of space objects and transparency of space activities,” 411; and, Jakhu and Pelton, *Global Space Governance an International Study*, 27.

to the UN.¹¹⁶ The Convention's requirement to provide information "as soon as practicable" does not provide a precise timeframe for reporting, allowing states to report when they choose, sometimes years or decades after launch.¹¹⁷ The Registration Convention (and Liability Convention) also consistently links "launching state" with "space object", suggesting a relationship. A causal relationship between launching state and space object allows some to suggest that to be a 'space object' it must be launched from Earth, which implies a spacecraft produced in space may not require registration.¹¹⁸ Collectively, these loopholes or the vagueness of the language in the Registration Convention has generally resulted in the treaty providing less utility than intended.

It would not be inaccurate to argue states have generally chosen to adhere to the Registration Convention when and how it suits them. On one hand, the language within the Registration Convention makes it permissible for states to provide only the information states deem necessary when and if doing so is convenient. On the other hand, failing to comply does not render consequences from the UN, nor does the UN have the power to police its members generally. The Convention also lacks the means to verify what information is provided.

In all, the lack of compliance with the Registration Convention and the progress being made around SSA systems suggest the agreement is quickly becoming less useful.¹¹⁹ It also suggests that a more comprehensive system for cataloguing and tracking space objects will be necessary to sustainably develop space.

1979 Moon Agreement

The final space treaty to be produced through COPUOS is the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, also known as the Moon Agreement. Considered by the Legal Subcommittee between 1972-1979 before being adopted in

¹¹⁶ Jakhu, Jasani, and McDowell, "Critical issues related to registration of space objects and transparency of space activities," 411.

¹¹⁷ Ibid., 409.

¹¹⁸ Thomas Cheney, interview by *Filling Space*, July 5, 2020, accessed May 2020, <https://filling-space.com/2019/07/05/who-defines-laws-in-outer-space/>.

¹¹⁹ While current networks are imperfect, they often offer more data than is provided via the Registration Convention and SSA networks are expected to provide more accurate and timely data in the future.

1979, the Moon Agreement goes further than the OST in discussing the use of space-based resources and celestial bodies while also giving the UN greater oversight of such activities. Of the Moon Agreement's additional emphasis, its inclusion of the idea that the moon and its natural resources are the "common heritage of mankind" (CHM), is perhaps the most significant addition. Though adopted by the GA in 1979, it was not until 1984 that enough states (five) ratified the Agreement enabling it to enter into force. Of the 18 parties to the treaty (as of January 2020), none are advanced spacefaring nations; France and India did sign the treaty but have not ratified it.¹²⁰

Articles 1 of the Moon Agreement provides that the treaty covers the moon and its orbits or "other trajectories to or around it" and other celestial bodies within the solar system (except the Earth).¹²¹ Articles 2 and 3 provide the moon and other celestial bodies are to be used exclusively for peaceful purposes in accordance with international law and that military activities of any kind are prohibited with the exception of military personnel who conduct scientific research.¹²² The first 10 articles of the Moon Agreement generally elaborate on the OST concerning the peaceful uses of the moon.

Article 11, however, does add considerable specificity to the idea of non-appropriation and CHM by stating:

"The moon and its natural resources are the common heritage of mankind...the moon is not subject to national appropriation by any claim of sovereignty, by means of use or occupation or by any other means...neither the surface nor the subsurface of the moon, nor any part thereof or natural resources in place, shall become property of any State, international intergovernmental or non-governmental organisation, national organisation or non-governmental entity or any natural person."¹²³

¹²⁰ United Nations, *Status of International Agreements Relating to Activities in Outer Space as at 1 January 2020*.

¹²¹ Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 11 July 1984, UNTS 1363, p. 3, article 1.

¹²² Ibid., Articles 2, 3.

¹²³ Ibid., Article 11.

CHM is an important concept in legal literature implying every state has equal right to the benefits of a given resource considered to fall under the CHM concept and that the use of those resources should be governed by an international regime.¹²⁴ First proposed in 1970 during negotiations to develop UN Convention on the Law of the Sea III, CHM was included in the Moon Agreement to bolster the “common province of mankind” principle found within the OST.¹²⁵ “Province” is argued to suggest *responsibility* while “heritage” is said to suggest *ownership*.

The extent to which Article 11, as well as article 15 which effectively requires all spacecraft, installations, or equipment on the moon to be accessible to other state parties upon request, requires equitable sharing of lunar resources and access to lunar facilities is a prominent reason the treaty has so few parties.¹²⁶ These provisions are also a central reason the treaty is often invoked in current discussions of space-based resource utilization.

While the Moon Agreement does constitute international law as a formal treaty between states, with so few signatories it holds little sway over state behaviour. In fact, states are beginning to draft national legislation that legalizes and legitimizes commercial and government exploitation of space-based resources.¹²⁷

Other International Agreements

In addition to the five core treaties several principles and non-binding guidelines have been produced to support existing treaties and provide best practices for space activities and

¹²⁴ Carol Buxton, “Property in Outer Space: The Common Heritage of Mankind Principle vs. the First in Time, First in Right, Rule of Property,” *Journal of Air Law and Commerce* 69, no. 4 (2004), 68-69, accessed May 2020, <https://scholar.smu.edu/jalc>.

¹²⁵ *Ibid.*, 69.

¹²⁶ M.J. Peterson, *International Regimes for the Final Frontier*, 160-161.

¹²⁷ For example, the U.S. and Luxembourg have formalized national legislation legalizing lunar and celestial mining. While other major spacefaring nations have made formal statements about their intent to also pursue space-based resource utilization for national, rather than international, ends. See: *U.S. Commercial Space Launch Competitiveness Act of 2015*, H.R.2262, 116th Congress, <https://www.congress.gov/bill/114th-congress/house-bill/2262/text>; “Legal Framework,” Luxembourg Space Agency, updated November 2019, accessed May 2020, <https://space-agency.public.lu/en/agency/legal-framework.html>; Vladimir Soldatkin, “Russia wants to join Luxembourg in space mining,” *Reuters*, 6 March 2019, accessed May 2020, <https://www.reuters.com/article/us-luxembourg-ussiaspace/russia-wants-to-join-luxembourg-in-space-mining-idUSKCN1QN1OQI>; and, Namrata Goswami, “China in Space: Ambitions and Possible Conflict,” 74-97.

challenges. Five declaration and legal principles concerning space have been adopted by the GA since 1961 and cover topics ranging from ideas codified in the OST, to satellite TV broadcasting, remote sensing of the Earth, use of nuclear power in space, and the use of space and the needs of developing states.¹²⁸ In legal literature, principles are described as either a source of legal norms or standards from which legal rules may be based; a general legal norm.¹²⁹ As legal principles, these articles are intended to shape international treaties and domestic laws, but often do not hold the same prescriptive or detailed nature as other legal mechanisms, like the five treaties discussed above or domestic legislation.

In addition to the legal principles, COPUOS has produced non-binding guidelines as governance tools. These include the 2009 Safety Framework for Nuclear Power Source Applications in Outer Space, the 2010 Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, and the 2019 Guidelines for the Long-Term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space. While non-binding, each set of guidelines provides space actors with best practices and measures to ensure activities in space are conducted in accordance with existing space law, sustainability, and state responsibility in mind. Though the guidelines address some critical issues affecting space sustainability, like debris, as non-legally binding these agreements reflect suggestions which states may or may not follow at their discretion.¹³⁰ Guidelines can become customary international law but this requires states to preform activities habitually and acceptance as law, which can be difficult to establish given the often nascent or limited nature of human endeavours in space.¹³¹ The non-binding guidelines also took a considerable amount of time to produce (the

¹²⁸ United Nations, *International Space Law: United Nations Instruments*, (Vienna: Office for Outer Space Affairs, 2017), 43-65; and, United Nations, *Compendium: Mechanisms Adopted by States and International Organizations in Relation to Non-Legally Binding United Nations Instruments on Outer Space*, (Vienna: Office for Outer Space Affairs, 2016).

¹²⁹ Jordan Daci. "Legal Principles, Legal Values and Legal Norms: Are They the Same or Different?" *Academicus International Scientific Journal* 2 (2010), 109-15, accessed May 2020, 10.7336/academicus.2010.02.11.

¹³⁰ For arguments on why non-legally binding guidelines do not have the same legal weight as formal treaties or qualify as customary international law see: Brian Wessel, "The Rule of Law in Outer Space: The Effects of Treaties and Nonbinding Agreements on International Space Law," *Hastings International and Comparative Law Review* 35, no. 2 (2012), 296–98, 2014 accessed May 2020; and, Steven Freeland, "For Better or Worse? The Use of 'Soft Law' Within the International Legal Regulation of Outer Space," *Annals Air & Space Law* 36, (2011) 409, 434, 444.

¹³¹ Steer, "Sources and law-making processes relating to space activities", 3.

Long-Term Sustainability Guidelines took nine years), which can further limit their value given the rapid pace of innovation and developing occurring in the space sector today.

Concluding thoughts - International Space Governance

The five treaties and voluntary guidelines discussed above make-up the core of international space governance. They reflect tenants related to the freedom to explore and use space for peaceful purposes and state responsibility therein. The broad or generalized nature of existing international space governance tools, like existing treaties, is a major limitation. The nature of the current governance regime often leaves states free to interpret the agreements in many different and conflicting ways. As a result, the treaties offer less utility for many new space activities, like small satellite constellations, ORPSAO, STM, among others, which are essential for the sustainable development of space.

These treaties and agreements are also not directly supported by any special court system for adjudication or means of enforcement.¹³² Whereas in maritime law through International Tribunal for the Law of the Sea (ITLOS), space law has no recognized dispute settlement mechanisms specific to the regime. The ICJ and the Permanent Court of Arbitration (PCA) do offer some help, but they are not specific to space law and have other limitations.¹³³ For example, the PCA and the ICJ both require states to voluntarily participate in cases brought before either judicial body. The ICJ also only recognizes states as claimants but not private actors.¹³⁴ Without a dispute settlement mechanism is it difficult to hold actors accountable under the current space governance regime.

Though these agreements provide broad guidance shaping the conduct of actor and activities in space, they fail to effectively govern many existing problems, like debris, and future activities

¹³² Henry R. Hertzfeld, Brian Weeden, and Christopher D. Johnson, "Outer Space: Ungoverned or Lacking Effective Governance?: New Approaches to Managing Human Activities in Space," *SAIS Review of International Affairs* 36, no. 2 (Summer 2016), 16, accessed May 2020, 10.1353/sais.2016.0017.

¹³³ The need for voluntary participation in the Permanent Court of Arbitration means if a state chooses not to, the court cannot compel the state nor move forward with the case. For more see: Permanent Court of Arbitration, *Permanent Court of Arbitration (PCA) Rules 2012*, (unlisted: Permanent Court of Arbitration, 2012), 5.

¹³⁴ "Frequently Asked Questions," International Court of Justice, updated 31 December 2013, accessed May 2020, <https://www.icj-cij.org/en/frequently-asked-questions>.

necessary to develop space further. Given the weakness of the existing space treaties as a governance tool, additional governance mechanisms will be necessary to develop space sustainably.

Space Governance Entities

There are several international, national, and private sectors groups that make up the entities charged with creating or influencing space governance. Through these groups treaties, guidelines, research, standards, and other means of governance are developed. In all, the number of entities that can and do influence space governance is quite extensive and far too numerous to detail completely in this research. The entities detailed below have the most influence over space governance and represent the spectrum of governmental and nongovernmental groups. Together the group of actors discussed below will provide a pragmatic overview of space governance entities aligned to this research.

United Nations General Assembly

The most prominent space governance organisation is the UN. Through several UN bodies, the organisation influences space governance through treaties, guidelines, standards, and educational programs covering the peaceful uses of outer space, global development and disaster response, arms control, and space resource allocation (i.e., radio spectrum). The UN has been at the centre for space governance from the beginning.

Starting with the UNGA, one of six main organs of the UN, the GA has passed resolutions on several space related topics over the years, including the first on the subject, GA resolution 1348 (XIII), Question of the Peaceful Use of Outer Space.¹³⁵ The GA was also responsible for establishing the Ad Hoc COPUOS before establishing it as a permanent committee in May of 1959. As a main organ of the UN, the GA does not have the capacity to focus on space in much detail, which is why it created COPUOS. The GA can contribute to topics that COPUOS addresses through agenda setting, and the GA will often need to vote on resolutions proposed by COPUOS or other UN bodies to pass them. GA resolutions include the five core space treaties as

¹³⁵ United Nations, *1348 (XIII) Question of the Peaceful Use of Outer Space*, (unlisted: Office for Outer Space Affairs, December 1958), 5-6.

well as other resolutions ranging from direct television broadcasting satellites (GA Res 37/92), remote sensing (GA Res 41/65) nuclear powered sources in space (GA Res 4768), among others.¹³⁶ While GA resolutions are non-binding, a simple majority voting process with 193 UN members suggests that what the body produces reflects at least general global perspectives on a given topic.¹³⁷

Committee on the Peaceful Uses of Outer Space

COPUOS is perhaps the most prominent UN body addressing space governance. The GA has charged it very literally with governing the exploration and use of space. The first meeting of the then 24-member Committee occurred on November 27th, 1961, and the Committee has continued to meet annually since. COPUOS consist of the Full Committee and two subsidiary bodies, the Scientific and Technical Subcommittee and the Legal Subcommittee. Its membership is comprised primarily of member states (95 at the time of writing) and “observers” which include intergovernmental and non-governmental organisations. COPUOS encourages states applying for membership to “consider the possibility of acceding to the five UN treaties on outer space, or at least some of them.”¹³⁸ States can ratify any of the treaties without becoming a member of COPUOS, however. For example, there are 109 parties to the OST, but only 95 members of COPUOS. Though initially productive, since COPUOS produced the Moon Agreement in 1979, the forum has failed to produce new binding agreements.

In some ways COPUOS’s growth in membership and its forum decision making procedure have hindered its ability to govern space affairs more effectively. The larger number of members—most of which have limited capacity to develop space¹³⁹—often have conflicting interests or seek to shape the agenda with activities that do not require specific technical

¹³⁶ For a list of resolutions passed by the GA see: United Nations, *International Space Law: United Nations Instruments*, (Vienna: Office for Outer Space Affairs, 2017).

¹³⁷ Some issues, like recommendations on peace and security, election of certain council members, and budgetary questions, require two-thirds majority to pass. All others require a simple majority to pass.

¹³⁸ United Nations, *Compendium on rules of procedure and methods of work related to the United Nations Committee on the Peaceful Uses of Outer Space and its subsidiary bodies*, (Vienna: Committee on the Peaceful Uses of Outer Space, June 2016), 9.

¹³⁹ Higgins, interview.

knowledge, like calls for new treaties or for benefit sharing.¹⁴⁰ The interest of individual states are not a burden on the Committee necessarily, but with 95 members seeking to develop or obstruct ideas or agreements as it suits their individual interests, many disparate interests do represent one reason why it often takes the forum so long to complete tasks and why it has failed to produce new agreements all together; there are simply a lot of members to appease. Meeting the needs (at least in part) of the 95 members is necessary considering COPUOS's consensus decision-making style.

COPUOS uses a consensus based decision-making structure where actual voting as a procedure is not preferred.¹⁴¹ Instead, the Committee relies on objections during the review process of a given proposal or item. Often, resolutions are developed through working groups which then propose their product for review to the Legal or Technical Subcommittee that established the working group. If there are no objections at the subcommittee level, the proposal goes forward to the full committee for review. If there are no objections at the full committee then the resolution goes forward to the GA for adoption. Should an objection be made at any point during the during the review process, then solutions would be entertained. This process often takes quite some time given the cadence at which COPUOS meets (annually) and the formal steps required during each phase of the process, like reviewing a proposed resolution paragraph by paragraph in front of the full committee.

Whether it is adding to or removing an item from the agenda or attempting to develop a new treaty or a set of non-binding guidelines, it requires consensus among COPUOS members and adoption by the GA.¹⁴² Indeed, each critical task associated with developing agreements can be stalled by a single objection from any of the Committee's 95 members. The complexity of this process is why some items, like definitions and delimitation of outer space, have been on COPUOS' agenda for more than 53 years!¹⁴³ While consensus decision-making does provide

¹⁴⁰ Hodgkins, interview.

¹⁴¹ United Nations, *Compendium on rules of procedure and methods of work related to the United Nations Committee on the Peaceful Uses of Outer Space and its subsidiary bodies*, 4.

¹⁴² Ibid.

¹⁴³ Except for sessions conducted between 1970-1976 resulting from a "lack of time and the prioritization of work", the topic of definitions and delimitations of outer space has been on the agenda at COPUOS in one form or another since 1967. For more see: United Nations, *Historical Summary on the Consideration of the Question on Definitions*

some credibility to the forum's outputs, a growing membership and the need for consensus from a diverse and often divergent group of member states has made it considerably more difficult to reach consensus on major decisions. Ultimately, the consensus decision-making style has become as much a troubling characteristic of COPUOS as it can be a positive sign of international cooperation.

Indeed, the complexity and formality of addressing topics through formal COPUOS activities, like working groups, sub-, or full committee meetings, has become a primary reason why informal meetings between delegates outside of formal sessions is so important to accomplishing diplomacy related to space activities. Through dinners, discussions over coffee or cocktails, or other forms of "margin" meetings, COPUOS members are able to discuss the topics on the agenda and other diplomatic needs they would otherwise be unable to discuss due to time, the discussion topic, or diplomatic limitations associated with formal COPUOS sessions.¹⁴⁴ According to the longest standing COPUOS diplomat (at the time of writing) Kenneth Hodgkins, "much of the work is actually done outside of the formal [COPUOS] meeting."¹⁴⁵ These informal sessions give members a sense of what each of their positions is on a given topic, how they might cooperate, or the ability to clarify statements made in session, among other things.¹⁴⁶ Discussing more sensitive or technical topics on the margin allows COPUOS members to further diplomatic dialogue efficiently despite the formality of the formal session. These side-bar discussions are not intended to replace formal COPUOS processes but are necessary for diplomatic dialogue, nonetheless.

The forum's mandate can also limit COPUOS's ability to affect space governance. With a specific mandate to address the "peaceful uses of space...for the benefit of all humanity," the forum is in some ways limited in the topics it can address.¹⁴⁷ For example, while some members have proposed topics related to weapons use in space, other members have found the topic to be

and Delimitation of Outer Space," (Vienna: Committee on the Peaceful Uses of Outer Space, 2002); and, United Nations, *Historical Summary on the Consideration of the Question on Definitions and Delimitations of Outer Space*, (unlisted: 2020).

¹⁴⁴ Higgins, interview; and, Hodgkins interview.

¹⁴⁵ Higgins, interview.

¹⁴⁶ Ibid.

¹⁴⁷ Ibid.

outside of COPUOS' remit.¹⁴⁸ The relevance of some space economic topics have also been debated as failing to fit within the forum's mandate, like those associated with the commercialization of space.¹⁴⁹ Because developing outputs requires consensus among COPUOS members, a single objection for nearly any reason can prevent a topic from being advanced through the COPUOS processes. With the economic development of space, and specifically the commercial sector's growth, being the most significant change since the development of COPUOS and the five core space treaties, an inability to discuss the topic at COPUOS is troubling. Economic cooperation on space activities is a critical area where new space governance is desperately needed. The forum's inability to address such an important topic is no doubt a bulwark to new governance.

COPUOS' growing membership, consensus-based decision-making process, its limited remit, and its infrequent meeting schedule, among other factors set against the backdrop of rapidly advancing space activities have made it too difficult for the forum to actively influence space governance on the most pressing issues, like debris or the commercialization of space.¹⁵⁰ In fact, the difficulty COPUOS has experienced in recent years has led the organisation to shift its focus away from treaties toward educational programs for non-spacefaring nations and learning about how states are governing their own space activities so the forum can provide recommendations and best practices through non-binding guidelines.¹⁵¹

¹⁴⁸ For statements from UN member state delegates in favour of COPUOS taking on issues related to weapons see: United Nations, *Canadian Statement: Space Issues First Committee of the 71st Session of the United Nations General Assembly*, (unlisted: Conference on Disarmament, 2016), 1-2; and, "The CD Should Assume Its Historic Responsibility for PAROS, Remarks by H.E. Ambassador Li Song in the CD on PAROS," Permanent Mission of the People's Republic of China to the United Nations Office at Geneva and Other International Organizations in Switzerland, June 2019, accessed May 2020, <http://www.china-un.ch/eng/hom/t1672128.htm>. For information on discussions of weapons in space through COPUOS see: Daniel Porras, "An Update on "Outer Space Security" and a Brief History of the Prevention of an Arms Race in outer Space," (paper presented to CD Subsidiary Body 3, Geneva, CH, 23 May 2018), accessed May 2020, <https://www.unidir.org/files/medias/pdfs/presentation-to-inform-cd-subsidiary-body-3-discussion-eng-0-778.pdf>; United Nations (Pericles Gasparini Alves), *Prevention of an Arms Race in Outer Space: A Guide to the Discussion in the Conference on Disarmament*, (Geneva: United Nations Institute for Disarmament Research, 1991), accessed May 2020, <https://www.unidir.org/files/publications/pdfs/prevention-of-an-arms-race-in-outer-space-a-guide-to-the-discussions-in-the-cd-en-451.pdf>; and, Higgins, interview.

¹⁴⁹ Higgins, interview; and, Hodgkins, interview.

¹⁵⁰ Hodgkins, interview.

¹⁵¹ Ibid.

Conflicting member interests combined with procedural limitations would bog down any multilateral forum, but such issues have proven particularly troubling for COPUOS when the space domain is experiencing rapid change. COPUOS will continue to be a major forum for developing space governance, though the utility of governance products it is ultimately able to produce will continue to depend on member states' willingness to cooperate. Given the rapid advancement of space development over the last decade, a renewed desire to cooperate among COPUOS members is feasible, though not guaranteed.

International Telecommunications Union

Another prominent, but specialized, UN agency involved in space governance is the ITU. The ITU was founded in 1865 as the International Telegraph Union before changing to its current name to reflect modern technology. The ITU is a technical body that allocates global radio spectrum, satellite orbital slots, and develops technical standards to ensure interoperability among communications networks.¹⁵² The ITU has 193 member states (at the time of writing) and hundreds of "sector members" which come from other regulatory bodies, academia, and private companies. Unlike most other UN agencies, at the ITU sector members have considerable influence over ITU matters, though decision-making is still left to member states.

The ITU's most significant role in space governance relates to its mission to manage global radio-frequency spectrum and geostationary satellite orbital slots (positions) as well as maintaining the Master International Frequency Register. Managed through the ITU Radiocommunications sector (ITU-R) and its Space Services Department, the agency has developed Radio Regulations and Regional Agreements through international treaties covering a wide variety of technical topics necessary for coordinating the use of international radiocommunications systems.¹⁵³ These instruments are updated periodically through World and Regional Radio Communications Conferences. Said to be one of the UN's more successful

¹⁵² "About International Telecommunication Union (ITU)," International Telecommunications Union, accessed May 2020, <https://www.itu.int/en/about/Pages/default.aspx>.

¹⁵³ "Welcome to ITU-R," International Telecommunications Union, accessed May 2020, <https://www.itu.int/en/ITU-R/information/Pages/default.aspx>.

agencies, the ITU faces an increasingly important and complicated mission as space is further developed.¹⁵⁴

Due to the increase in interest and development of satellite services, like large constellations of small satellites providing broadband internet or the development of 5th generation communications, the ITU is facing new governance challenges.¹⁵⁵ Not only are there an increasing number of satellites that need access to radio frequency spectrum—while avoiding unintentional radio frequency interference—certain new services require access to portions of radio frequency spectrum already allocated for different satellite services.¹⁵⁶ As new services come online, the ITU will be tasked with reconciling the needs of new space services and activities with those that already exist. The ITU is further challenged by the proliferation of organisations involved in the development of operational or technical standards; the inability to police actors through the ITU or other non-state organisations; and space debris and satellite collisions.¹⁵⁷

The ITU has begun to address many of these issues. As far as international organisations are concerned, the ITU is a relatively agile agency capable adapting its rules, processes, and procedures as needed.¹⁵⁸ While evolution is indeed a defining element of the ITU, many of these new challenges will require broad international cooperation that may be difficult to develop (e.g., providing the ITU the authority to police its member's use of spectrum). Moreover, many of the decisions the ITU wishes to enact will still require adoption and adherence at the national level. Challenges aside, the ITU is an asset to space governance and will likely remain highly relevant as space is developed further.

¹⁵⁴ Jahku and Pelton, *Global Space Governance an International Study*, 35.

¹⁵⁵ For a primer on emerging satellite services and governance, see: “Evolving satellite communications: ITU’s role in a brave new world,” International Telecommunications Union, November 2019, accessed May 2020, https://www.itu.int/en/itu-news/Documents/2019/2019-02/2019_ITUNews02-en.pdf.

¹⁵⁶ Debra Werner, “5G Trumps Weather in Spectrum Debate,” *Space News*, March 2019, accessed May 2020, <https://spacenews.com/5g-trumps-weather-in-spectrum-debate/>.

¹⁵⁷ Jahku and Pelton, *Global Space Governance an International Study*, 149.

¹⁵⁸ *Ibid.*, 161.

Other Space Governance Entities

In addition to the UN bodies listed above, other intergovernmental organisations and institutions and NGOs also contribute to governing space activities, each with a specialized focus or mission. These include, but are not limited to: the CD focused on multilateral arms control regimes, including the prevention of an arms race in outer space (PAROS) effort¹⁵⁹; the Inter-Agency Space Debris Coordination Committee (IADC) comprised of state space agencies focused on human-made and natural debris in space¹⁶⁰; the International Organization for Standards (ISO) focused on developing international standards, including for space debris¹⁶¹; the Institute of Electrical and Electronics Engineers (IEEE), the world's largest technical professional society, with some focus on space technology¹⁶²; and, regional cooperation efforts like, the European Space Agency (ESA) and the Asia-Pacific Space Cooperation Organizations.

While not meant to be exhaustive, the above list provides some of the more active or larger organisations that influence actors and activities in space. There are other organisations which also participate in similar activities or represent industry, like industry associations. For example, the Satellite Industry Association is a US-based trade association that advocates for major US satellite operators.¹⁶³ As space activities continue to advance, it should be expected that the organisations listed above will play a role in governing them. New organisations may also be developed to address novel space services and technology, like STM.

A robust community of international governmental and nongovernmental organisations is predominantly positive for space governance. With considerable expertise and some cooperation between entities, they contribute to the development of useful space governance. One limitation, however, is the generally disorganized or sometimes competing nature of these organisations.

¹⁵⁹ “Proposed Prevention of an Arms Race in Space (PAROS) Treaty,” Nuclear Treaty Initiative, updated April 2020, accessed May 2020, <https://www.nti.org/learn/treaties-and-regimes/proposed-prevention-arms-race-space-paros-treaty/>.

¹⁶⁰ “What’s IADC,” Inter-Agency Debris Coordination Committee, accessed May 2020, https://www.iadc-home.org/what_iadc.

¹⁶¹ Sandrine Tranchard, “ISO Standards for a Safer, Cleaner Space,” International Organization for Standards, October 2013, accessed May 2020, <https://www.iso.org/news/2013/10/Ref1784.html>.

¹⁶² “Mission and Vision,” Institute of Electrical and Electronics Engineers, accessed May 2020, <https://www.ieee.org/about/vision-mission.html>.

¹⁶³ “About SIA,” Satellite Industry Association, accessed May 2020, <https://sia.org/about-sia/>.

For example, the ISO and IEEE are just two of many global standards setting organisations. While there are cooperation agreements between many of these organisations, it remains a patchwork of organisations each with their own membership, agendas, and technical expertise.

Another limitation is the influence many of these organisations have over states. Regardless of whether it is an intergovernmental (i.e., CD) or nongovernmental (i.e., IEEE) organisation, states ultimately have the sole authority to adopt, support, or otherwise adhere to the outputs of the various organisations attempting to govern space activities. Commercial actors could choose to adopt standards sets by international organisations, but national regulations would still take precedent. So, while private sector space companies may choose to adopt technical standards proposed by the IEEE or similar organisations, they are under no obligations to do so unless national regulators require it. Moreover, when it comes to regulatory requirements that impose cost, for-profit companies are more likely to choose the least expensive method, which typically means meeting as few expensive requirements as possible.¹⁶⁴

Concluding thoughts – Governance Entities

From large international organisations and fora, like COPUOS, to smaller standards associations, the scale and diversity of actors capable of influencing space governance is distributed across governmental and nongovernmental organisations that cover a range of topics and vary in influence. While generally beneficial, a large numbers of space governance entities with different agendas, members, and missions does create some complexity for developing more effective international space governance. Each of the organisations listed above, and many not listed, intend to support effective governance, but what that looks like to each organisation often differs. The result can be competing ideas for regulations, guidelines, laws, and other governance measures. A diversity of options may also lead to forum shopping—where an actor chooses to subscribe to an organisation’s outputs based on what suits their self-interest rather than concern for generally good governance.¹⁶⁵

¹⁶⁴ Nodir Adilov, Peter J. Alexander, and Brendan M. Cunningham, “An Economic Analysis of Earth Orbit Pollution,” *Environmental and Resource Economics* 60, no. 1 (2015), 93, accessed May 2020, <https://doi.org/10.1007/s10640-013-9758-4>.

¹⁶⁵ Jakhu and Pelton, *Global Space Governance an International Study*, 136.

Nor is variance in regulatory tools, like standards or laws, likely to help solve major sustainability challenges, such as space debris. It is also unclear how a patchwork of standards produced by various organisations will impact the development of more consequential measures, like treaties, necessary for new activities. More influential international organisations, like COPUOS, can help overcome a patchwork-governance approach through multilateral agreements, but issues within these organisations suggest new multilateral agreements will be difficult to produce.

As new space governance is shaped to address the sustainable development of space the role these organisations play will likely depend on the degree to which each entity can be a source of progress rather than stagnation or complication. For some organisations, like COPUOS, this may mean significant changes to how it conducts business. For others, like the ITU, it may mean implementing minor changes. Regardless of the organisation, however, the pace at which space activities and challenges are advancing requires that space governance organisations be willing to change and adapt to the needs of their members and the domain that they govern.

National Space Governance

The growth in number of space-faring nations and commercial space actors and activities is spurring new interest in and need for national space policies, including laws, directives, and regulatory tools.¹⁶⁶ Indeed, national space policies are the fastest growing area of space governance.¹⁶⁷ The need for national space policy stems from the desire to adhere to international legal regimes, protect the state from liability, and ensure its interests are protected. National space policies typically take the form of regulatory tools, government guidance, or support for investments in space technologies or activities. Through government directives (like those seen in the U.S. or United Arab Emirates which permit space-based resource utilization) or

¹⁶⁶ Paul Stephen Dempsey, “National Laws Governing Commercial Space Activities: Legislation, Regulation, & Enforcement,” *Northwestern Journal of International Law & Business* 36, no. 1 (Winter 2016), 4, accessed May 2020, <http://scholarlycommons.law.northwestern.edu/njilb>.

¹⁶⁷ *Ibid.*, 5.

government incentives (like the economic incentives established by Luxembourg) national policies can regulate and support space activities.¹⁶⁸

At the time of writing, there are roughly 31 states with national space policies. These include: Algeria, Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, the People's Republic of China (PRC), Colombia, France, Germany, India, Ireland, Italy, Japan, Kazakhstan, Luxembourg, Netherlands, Nigeria, Norway, Russian Federation, South Africa, the Republic of Korea (South Korea), Spain, Sweden, Ukraine, United Arab Emirates, United Kingdom, United States, and Venezuela.¹⁶⁹ Of the national policies there are important similarities and differences, but they generally provide regulatory structure and national guidance for space activities important to the state that created them.¹⁷⁰

National policies establishing regulatory measures is one way states ensure they adhere to international agreements. How an international treaty is enforced at the national level can depend on the state, however of the five core space treaties none are self-executing, meaning states must adopt domestic policy to enforce the treaty.¹⁷¹ For instance, in order to adhere to the international obligations outlined in article 6 of the OST, which says states are responsible for their activities and actors in space, states must develop national policies (often regulations) to provide their judicial systems with the ability to enforce said responsibility.

Interest in national space policies also stems from the desire by some governments to overcome gaps that exist in international space governance. For example, ORPSAO activities

¹⁶⁸ For examples of these national policies see: U.S. Congress, House, *U.S. Commercial Space Launch Competitiveness Act of 2011*; "Legal Framework," Luxembourg Space Agency, updated 18 November 2019, accessed May 2020, <https://space-agency.public.lu/en/agency/legal-framework.html>; "UAE Looks to Regulate Asteroid Mining as it Aims to Lure Private Space Sector," *The Nation*, updated 27 November 2019, accessed May 2020, <https://www.thenational.ae/uae/science/uae-looks-to-regulate-asteroid-mining-as-it-aims-to-lure-private-space-sector-1.943028>.

¹⁶⁹ Paul Stephen Dempsey, "National Laws Governing Commercial Space Activities: Legislation, Regulation, & Enforcement," 16-19; United Nations, *Schematic Overview of National Regulatory Frameworks for Space Activities*, (Vienna: Committee on the Peaceful Uses of Outer Space, March 24-April 4, 2014) 2-10; and, "UAE's National Space Law Comes Into Effect," February 2020.

¹⁷⁰ Paul Stephen Dempsey, "National Laws Governing Commercial Space Activities: Legislation, Regulation, & Enforcement," 19.

¹⁷¹ Johnson, interview; and, Carlos Vázquez, "The Four Doctrines of Self-Executing Treaties," *American Journal of International Law* 89, no. 4 (1995), 695-723, accessed May 2020, DOI: 10.2307/2203933.

could spur the next economic revolution in space, yet there is little international governance to address these emerging development activities.¹⁷² States, therefore, may see a need to develop their own.

States also chose to develop national policies out of self-preservation. The development of government or private sector space activities is inherently dangerous and requires the use of technologies governments have chosen to regulate for matters of public safety or national security. Rocket components and parts used to launch a spacecraft into orbit may also be used to develop weapons and are capable of hurting people or destroying property if not handled properly. National policies can help to protect the state from liability or national security concerns.

Differences between national space policies highlights one of its key limitations as a tool of international space governance. States often develop policies in accordance with their interests, which may or may not enforce international agreements or account for emerging issues, like space debris, nor do they necessarily create or mature coherence among space governance mechanisms. This is evident by the fact that there is very little consistency in how states regulate space debris, if at all.¹⁷³ Moreover, a highly divergent body of national laws can complicate the development of customary international law.¹⁷⁴ Nonetheless, national laws are necessary based on the nature of international law and the need for states to protect and encourage their interests.

In sum, states have always been and will continue to be the most important actors affecting global space governance. The growing commercialization of space seems only to enhance the importance of the state and national space policies. But national policies alone cannot ensure space is sustainably developed. For all the value unilateral national policies may provide the

¹⁷² For on-orbit servicing and rendezvous and proximity operations see: David A. Barnhart, Rahul Rughani, et. el. "Using Historical Practices to Develop Safety Standards for Cooperative On-Orbit Rendezvous and Proximity Operations," (paper presented at the 69th International Astronautical Congress, Bremen, German, 1-5 October 2018), accessed April 2020, https://www.isi.edu/sites/default/files/centers/serc/CONFERS_IAC_Paper_PUBLISH.PDF; For satellite mega-constellations see: Jakhu and Pelton, *Global Space Governance an International Study*, 358.

¹⁷³ United Nations, *Compendium: Space Debris Mitigation Standards Adopted by State and International Organizations*.

¹⁷⁴ Jakhu and Pelton, *Global Space Governance an International Study*, 108.

state, they fail to provide effective means of international cooperation or coordination. A patchwork of unilateral national policies may also complicate the broader space governance landscape through overlapping and conflicting legal regimes.¹⁷⁵ Though a limitation in some ways, national policies also enforce international agreements and enable space development; which is why the GA encourages states to create such policies.¹⁷⁶ National space policies will continue to be a critical element of global space governance, but how they complement and support international space governance tools will be an important metric for evaluating their support of sustainable space development.

Conclusion

As the previous chapter has shown, the current space governance regime is complex and facing greater stress due to space development. The current regime includes international and national laws, non-binding guidelines, standards, and other measures and a host of fora covering several different but related topics. While there are many issues with the current regime, its most pressing problems are 1.) treaties with vague language or which are simply unable to properly account for many new space activities and challenges, and 2.) organisations, like COPUOS, which have missions or processes that greatly hinder their ability to govern the contemporary use of space. Charged with governing space activities during a period of rapid change, these treaties and organisations are failing to protect the space domain and its development.

Space activities necessary to encourage the sustainable development of space like, small satellites and constellations, ORPSAO, STM, are advancing and possess the ability to improve space security and development in lockstep. What is missing are governance mechanisms and organisations capable of producing new agreements. More effective governance tools and fora could replace the current laissez-faire approach to space development with a coherent and cooperative governance regime that provides responsive standards, best practices, and helpful agreements. This research will attempt to identify how such norms, organisations, and other

¹⁷⁵ Ibid.

¹⁷⁶ United Nations, *Res. 59/115, Application of the Concept of the Launching State* (New York: General Assembly, 10 December 2004), 2.

governance essentials may be advanced to protect the space domain while ensuring its development continues at pace and scale.

4. IMO, ICAO, AND INTERNET GOVERNANCE ORGANISATIONS

As this research considers how contemporary governance might be developed to ensure the sustainable development of space, it is helpful to analyse other international governance organisations to understand what makes them effective and what hinders their progress to apply useful lessons to space governance.

The proceeding discussion will detail the ways the IMO, ICAO, and the organisations governing the internet are constructed and managed, how they produce governance tools, and how their activities influence their individual domains. More on specific outputs or aspects of each organisation will be developed in proceeding chapters during discussions of specific activities and governance needs. The point of this chapter is not to discuss each organisation exhaustively, but to provide enough knowledge of each organisation so that subsequent chapters can focus on the aspects of each organisation relevant to governing small satellites and constellations, STM, and ORPSAO.

Each international organisation is discussed using the same themes. They include the actors relevant to each organisation, like states and NGOs; each organisation's structure to include relevant bodies within each organisation and their roles and influence; how each organisation develops output; its decision-making process; and finally, the impact each organisation has had on its respective domain or activities.

The International Maritime Organization

Shipping has long held prominent international qualities. From the international workforce to the majority of time that ships spend in international waters, and the international economic value of connecting commerce by sea. The inherently international act requires international governance. Indeed, there is a long history of international law and governance defining and regulating ships at sea. From Hugo Grotius' *The Free Sea* published in 1609 and 18th century treaties developed around increased trade from the industrial revolution, to the 20th century international conferences on the Law of the Sea and the international law and organisations

regulating the activity today. The history of law and policy governing international shipping is the oldest and most comprehensive of any global commons.

Over the years, international maritime governance has seen extensive change, including actors (be it states or the private sector), methods of designing and developing ships, shipping routes, and the tools used to govern each. Today, the use of the seas is governed by a handful of international treaties, organisations, and national policies. Internationally, IMO governs shipping, the Food and Agriculture Organization (FAO) governs fisheries, the International Labour Organization governs the workforce, and the International Oceanographic Commission governs oceanography and the environment. Each organisation has different mandates, organisational structures, and goals. While each of the organisations plays an important role in the governance of the sea, the activities governed by the IMO are most like the space activities discussed in this research. For example, the IMO is acutely focused on how the design, use, and regulations of ships affects commerce and environmental sustainability. The IMO also influences how shipping traffic is managed and addresses novel shipping activities, like autonomous ships, both of which are similar to the space activities discussed in subsequent chapters. Consequently, the IMO will be the focus of this research.

The history and importance of shipping meant creating a new international governance organisation for shipping would inevitably require dealing with politics and state power. Indeed, as far back as 1889 early efforts to govern shipping were met with scepticism and concern for unwanted influence over an industry critical to many countries.¹⁷⁷ Even as the international community came together to develop numerous international organisations in the late 1940s, an IO for shipping was still a contentious topic, and discussions were often narrow in scope to avoid opposition from states concerned about an international body interfering in what they considered to be domestic concerns.¹⁷⁸ The creation of the IMO was a product of the Geneva Convention, which was established in 1948 via international conference. The ratification process was a

¹⁷⁷ Convention on the International Maritime Organization,” International Maritime Organization, accessed January 2021, <https://www.imo.org/en/About/Conventions/Pages/Convention-on-the-International-Maritime-Organization.aspx>.

¹⁷⁸ Rosalie Balkin, “The IMO and Global Ocean Governance: Past, Present, and Future,” 2018 in the *IMLI Treatise on Global Ocean Governance: Volume III*, eds. David J Attard, Rosalie P. Balkin, Donald W. Greig, 12.

difficult one. States often voiced objections and concern over the influence of a new shipping governance regime. By the time the treaty entered into force in 1958, the remit of the IMO was confined to safety and efficiency of international shipping.¹⁷⁹ Expanding the IMO's remit would take a major natural disaster, the Torrey Canyon oil spill, which motivated the UK and French governments to lobby the international community to organize through the IMO to avoid similar future disasters.

The IMO is a specialized agency of the UN “responsible for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships.”¹⁸⁰ The IMO convened for the first time in 1959. The IMO's principal purposes at the time according to Article 1(a) of its convention are “to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety and efficiency of navigation”.¹⁸¹ IMO tools typically come in the form of regulations, conventions, guidelines, codes, and technical assistance, among others. To stay current and meet its mandate, the IMO convention has been amended at least seven times to create new subcommittees and expand its Council. It would not be an exaggeration to say the IMO has evolved considerably since its founding, expanding its scope, creating four new organs, developing 50 conventions and numerous codes, guidelines, and other tools, and expanding its membership.

The IMO, like other international governance organisations, requires laws to outline the necessary operative regulations it is charged with developing. For the maritime domain that agreement is currently the Convention on the Law of the Sea (LOSC) developed between 1973-1982 through the third UN Law of the Sea Conference (UNCLOS III). LOSC is a complex

¹⁷⁹ Ibid.

¹⁸⁰ “Introduction to IMO,” International Maritime Organization, Accessed January 2021, <https://www.imo.org/en/About/Pages/Default.aspx>.

¹⁸¹ Article 1(a) would eventually be amended to include the prevention and control of marine pollution from ships. “Convention on the International Maritime Organization,” International Maritime Organization, accessed January 2021; “Brief History of IMO,” International Maritime Organization, Accessed January 2021, <https://www.imo.org/en/About/HistoryOfIMO/Pages/Default.aspx>; and, “Introduction to IMO,” International Maritime Organization.

document with 400 articles covering fifteen major maritime topics from navigation, safety at sea, fishing, the exploitation of other sea resources, and the protection of the maritime environment from pollution.¹⁸² Though the IMO was established before the latest version of the LOSC, UNCLOS III was inclusive of the IMO as an adviser in the development of the latest version of LOSC and through treaty text.

During UNCLOS III the IMO Secretariat helped deconflict existing IMO agreements with the development of the new LOSC.¹⁸³ Though the IMO is only mentioned once in the LOSC text, “competent international organisation” is present in several places in LOSC to describe I for international cooperation and the development of complementary international agreements.¹⁸⁴ For example, Article 197 of the LOSC requires states to cooperate on a global and regional basis through the competent international organisation. It is widely held that when “competent international organisation” is used in singular form in the LOSC it refers specifically to the IMO.¹⁸⁵

The need for ‘competent international organisations’ is because while the LOSC is treaty law, it is an umbrella convention that details general obligations. To make the general obligations operative, LOSC requires “generally accepted rules and standards” but stops short of defining what those are.¹⁸⁶ According to Article 211 of LOSC, establishing general rules and standards should be done by states acting through “the competent international organization” (i.e., the IMO) or general diplomatic conference.¹⁸⁷ When considering that IMO membership represents more than 99% of merchant shipping tonnage and many of its conventions have been adopted by an equally dominate percentage of the world’s merchant fleet, it can be argued that IMO

¹⁸² Louis Sohn, Kristen Gustafson Juras, John Noyes, and Erik Franckx, *Law of the Sea in a Nutshell* (St. Paul: Thomas Reuters, 2010), 3-4.

¹⁸³ International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization LEG/MISC.8*, (London: IMO Secretariate, 2014), 11.

¹⁸⁴ Robert Beckman and Zhen Sun, “The Relationship between UNCLOS and IMO Instruments,” *Asia-Pacific Journal of Ocean Law and Policy* 2, no. 2 (2017): 220, accessed February 2021.

¹⁸⁵ International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization LEG/MISC.8*, 7; Beckman and Sun, “The Relationship between UNCLOS and IMO Instruments,” 236.

¹⁸⁶ Robert Beckman and Zhen Sun, “The Relationship between UNCLOS and IMO Instruments,” 225.

¹⁸⁷ Convention on the Law of the Sea, 397, 106.

governance tools are ‘generally accepted rules and standards’.¹⁸⁸ In sum, the IMO helps to make LOSC obligations operative.

IMO Actors

Like most UN organisations, the IMO’s membership is restricted to states. The IMO currently has 174 member states which represents more than 99% of merchant shipping by tonnage. To become a member a state must accept the IMO convention. IMO members are responsible for financing the organisation, but unlike other UN organisations which often associate financial contribution with a member’s GDP or position within the organisation, financial contributions at the IMO are based on the size of a country’s registered merchant fleet.¹⁸⁹ For this reason Panama, Liberia, and the Marshall Islands provide the largest financial contributions.¹⁹⁰

In addition to states, the IMO also permits consultative status to international non-governmental organisations (NGO) with “considerable expertise...the capacity to contribute...and without other means of access to the work the IMO does”.¹⁹¹ The consultative status allows them to submit documents for discussion, participate in discussion, participate in working and drafting groups, and ultimately inform and advise members. The IMO will also enter into agreements with intergovernmental organisations where interests overlap. The IMO currently has 80 international NGOs with consultative status and cooperation agreements with 63 intergovernmental organisations.¹⁹²

Finally, while not strictly members or consultants, “recognized organisations” play an important part in the IMO’s mission. As the IMO does not possess the ability to enforce its regulations (which falls to the flag state), it has permitted “organizations recognized by it” to administer inspections and surveys of ships on behalf of flag states and in support of IMO

¹⁸⁸ Robert Beckman and Zhen Sun, “The Relationship between UNCLOS and IMO Instruments,” 225

¹⁸⁹ “Frequently Asked Questions,” International Maritime Organization, accessed February 2021, <https://www.imo.org/en/About/Pages/FAQs.aspx>.

¹⁹⁰ Ibid.

¹⁹¹ “Member States, IGOs and NGOs,” International Maritime Organization, accessed February 2021, <https://www.imo.org/en/About/Membership/Pages/Default.aspx>.

¹⁹² Ibid.

agreements.¹⁹³ Recognized organisation (RO) must meet the IMO's RO code and reporting requirements.¹⁹⁴

In the IMO member influence can vary. States with larger maritime interests tend to have greater influence over outputs because they bring more resources to account for the fact that diplomacy is often time consuming and financially expensive.¹⁹⁵ Indeed, well-resourced states are more effective because they have time to prepare for the issues and large enough delegations to participate simultaneously in different working groups and other efforts.¹⁹⁶ Developing countries, or those who have smaller maritime interests, often must stretch limited diplomatic resources over many issues simultaneously, affecting their ability to address each topic.¹⁹⁷ With each state possessing equal voting weight, states with smaller interests do still hold influence over outcomes, though less involvement or expertise can diminish their influence relative to better resources members. Translation can also affect member influence. Should translation services be delayed or poor-quality, members may not get the written materials ahead of time, or communication can breakdown leaving some delegates out of the conversation or delayed in contributing.¹⁹⁸ In all, influence can depend on the topic in question as much as the state in question and the administrative support provided before and during meetings.¹⁹⁹

IMO Structure

The IMO is composed of an Assembly, Council, five main technical committees, and several sub-committees. The main forums are supported by a Secretariate of some 300 fulltime employees. Every member state is represented in the Assembly as the highest governing body of the IMO and convenes every two years. The Assembly is responsible for electing council members, approving the program of work, determining financial arrangements, and

¹⁹³ "Recognized Organization," International Maritime Organization, accessed February 2021, <https://www.imo.org/en/OurWork/IIIS/Pages/Recognized-Organizations.aspx>.

¹⁹⁴ Ibid.

¹⁹⁵ Nicholas Gaskell, "Decision Making and the Legal Committee of the International Maritime Organization," *International Journal of Marine and Coastal Law* 18, no. 2 (2003): 171, accessed February 2021; and, European Parliament, *Decision-making processes for ICAO and IMO in respect to environmental regulations* (Brussels: Directorate-General for Internal Policies, 2016), 16.

¹⁹⁶ European Parliament, *Decision-making processes for ICAO and IMO in respect to environmental regulations*, 15.

¹⁹⁷ Ibid., 15.

¹⁹⁸ Nicholas Gaskell, "Decision Making and the Legal Committee of the International Maritime Organization," 192.

¹⁹⁹ Ibid., 170.

recommending adoption of conventions and other agreements. The Council is the executive organ of the IMO composed of 40 members on two-year terms and performs functions of the assembly except making recommendations to members. The Council can meet as often as is necessary granted sufficient notice to members is given. The five main committees include, the Marine Safety Committee (MSC), Environment Protection Committee (MEPC), Legal Committee, Technical Cooperation Committee, and Facilitation Committee. Relevant Committees and the IMO's structure will be discussed in more detail in subsequent chapters.

Developing Outputs at the IMO

In accordance with its mandate, the IMO develops conventions; protocols; amendments; recommendations, codes, and guidelines; and resolutions. Conventions focused on major maritime affairs, like marine pollution and safety, are the principal instrument of the IMO and are legally binding. Protocols are treaty instruments used to amend existing conventions. Finally, Recommendations, Codes, and Guidelines are typically technical in nature, not legally binding, and intended to assist in the implementation of conventions or assist governments in developing national regulations.

The need for a new convention or amendments can be raised by any member state from within the IMO Assembly, Council, or committees. If a member raises an issue, for instance an amendment regarding compensation for victims following an incident at sea, there is typically debate on the topic's relevance. If there is agreement that the topic is relevant, then the process shifts to drafting. Drafting involves more debate addressing the structure of the instrument (e.g., convention or protocol), principles to be included, and the wording of the text. Each component can involve rigorous, and at times debilitating, levels of debate. For conventions, once a draft instrument is completed, the developing body submits it to the Council and Assembly and requests a diplomatic conference to consider the instrument. Conference attendees include IMO members, NGOs with consultative status, and representatives from intergovernmental organisations with relevance to the instrument in question. Discussion at diplomatic conferences can range from wording to more political issues, like financial liability limits. Changes can be made resulting from the Conference, and once a draft is considered acceptable by the majority of governments at the conference, the convention is deposited with the Secretary-General of the UN

and copies are sent to each government. A convention will enter into force, and bind states that have accepted it, after established requirements are met, for instance 12 months after conditions for entry into force have been met.

The process of developing or amending instruments can be a political one. Making time on the agenda for an item comes at the expense of other topics, and with many members, there is often conflicting prioritization of issues between members.²⁰⁰ The inherently political process of developing new instruments can render the IMO a more reactive body as it responds to the political interests and tensions among its members.²⁰¹ Regardless of the output, IMO members have articulated that a sense of ownership over an output can greatly encourage agreement, and conversely without a sense of ownership implementation may suffer.²⁰² Despite challenges, the IMO has developed more than 50 international conventions and agreements and well over 800 codes, recommendations, and guidelines.²⁰³

Decision Making and Compliance

The general IMO approach to decision making is consensus. During debate, delegates express a view on a given proposal and after each has done so, the Chairman will assess the “sense” of the discussion (i.e., in favour or not) and either move the proposal forward or revert it for additional work or debate.²⁰⁴ A delegate can call for a vote, but the general practices at the IMO reserves voting for the final states of diplomatic conferences.²⁰⁵

Amending a Convention initially required two-thirds of member states, however this often inhibited the development of necessary amendments, like those needed to keep pace with

²⁰⁰ For examples on how conflicting topics can stall proceeding or create tension within committees, see Nicholas Gaskell, “Decision Making and the Legal Committee of the International Maritime Organization,” 161.

²⁰¹ Ibid., 161.

²⁰² European Parliament, *Decision-making processes for ICAO and IMO in respect to environmental regulations*, 14.

²⁰³ International Maritime Organization, *Contribution of the International Maritime Organization (IMO) to the Secretary-General’s Report on Oceans and the Law of the Sea, 2009* (London, 2008), 1.

²⁰⁴ Nicholas Gaskell, “Decision Making and the Legal Committee of the International Maritime Organization,” 186

²⁰⁵ Ibid., 186.

technology or environmental security.²⁰⁶ Additionally, early IMO processes to revise existing agreements required member states to implement into national law, which slowed their adoption.²⁰⁷ The IMO eventually adopted the practice of ‘tacit acceptance’ removing the need for two-thirds support and for member state to seek national legislative approval. Under tacit acceptance technical details are placed in an annex to a convention and will enter into force on a specified date unless rejected by a specified number of member state (normally two-thirds or a percentage of shipping tonnage) before said date. Tacit acceptance has sped up the development of amendments and enables the IMO to keep pace with ever-changing member state or shipping industry concerns without resorting to less enforceable tools, like non-binding measures.²⁰⁸ Tacit acceptance has been used to amend most major IMO conventions.²⁰⁹ Though decision making at the IMO is based on consensus, which is said to encourage instrument compliance²¹⁰, compliance varies.

The IMO is not responsible for enforcing compliance, which is the responsibility of states who have agreed to IMO resolutions. The LOSC requires states to fulfil their obligation to the treaty by implementing domestic legislation to enforce “generally accepted rules and standards.”²¹¹ Considering the majority of merchant shipping by tonnage has agreed to most IMO conventions, one could argue prominent IMO agreements represent “generally accepted” rules and standards.²¹²

According to the LOSC, enforcement of maritime laws and regulations occurs through flag, coastal, and port state jurisdiction, but requires IMO agreements to specify how jurisdiction

²⁰⁶ “Conventions,” International Maritime Organization, accessed April 2021, <https://www.imo.org/en/About/Conventions/Pages/default.aspx>; and, “Frequently Asked Questions,” International Maritime Organization.

²⁰⁷ Rosalie Balkin, “The IMO and Global Ocean Governance: Past, Present, and Future,” 12.

²⁰⁸ “Conventions,” International Maritime Organization; and, Guggisberg, 2020, 528.

²⁰⁹ Robert Beckman and Zhen Sun, “The Relationship between UNCLOS and IMO Instruments,” 216.

²¹⁰ European Parliament, Decision-making processes for ICAO and IMO in respect to environmental regulations, 14.

²¹¹ Convention on Law of the Sea Article 94(5) requires domestic legislation to enforce “generally accepted” international regulations. See Louis Sohn, Kristen Gustafson Juras, John Noyes, and Erik Franckx, *Law of the Sea in a Nutshell*, 67; and, Beckman and Sun 225.

²¹² Sohn et al. 67; and, Robert Beckman and Zhen Sun, 225.

should be exercised.²¹³ This would suggest IMO regulations are applicable only to states who are a party to both LOSC and IMO agreements, however port state jurisdiction afforded by the LOSC and numerous IMO conventions allows states to control which ships have access to their ports and which ships leave their ports.²¹⁴ Meaning a state could deny a ship access to or departure from its port if that ship fails to comply with IMO conventions, even if said ship is not a party to it. Numerous IMO conventions also include a ‘no more favourable treatment’ provisions to ensure ships flying the flag of a non-party state [to an IMO convention] shall not be treated more favourably by port states than ships flying the flag who are party to a given IMO convention.²¹⁵

The use of port state control has been one of the biggest factors increasing compliance with IMO agreements. The IMO’s creation of the Flag State Implementation Sub-Committee in 1992 and the expansion of regional agreements through port state control Memorandum of Understanding have also improved compliance.²¹⁶ Commercial industry has also seen proper inspections lead to substantial cost savings through their ability to prevent casualties and pollution incidents, providing a powerful incentive for industry to conduct their own inspections.²¹⁷ In some instances, industry inspections can be more extensive than those afforded through port state control inspections.²¹⁸

Importantly, while port state jurisdiction sits as a cornerstone in maritime governance, the nature of IMO instruments suggests its responsive rather than entirely pre-emptive.²¹⁹ Meaning

²¹³ International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization LEG/MISC.8*, 12.

²¹⁴ *Ibid.*, 19

²¹⁵ For example, SOLAS 74 regulation I/19; Load Lines 66, Article 21; MARPOL, Articles 5 & 6; STCW, Article X; Tonnage 69, Article 12 are just a few examples of conventions which include the ‘no more favourable treatment’ provision.

²¹⁶ International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization LEG/MISC.8*, 12; and, “Port State Control,” International Maritime Organization, accessed August 2021, <https://www.imo.org/en/OurWork/MSAS/Pages/PortStateControl.aspx>.

²¹⁷ Organization for Economic Cooperation and Development, “International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation,” OECD Publishing, 2016, 100-101, accessed August 2021.

²¹⁸ *Ibid.*

²¹⁹ International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization LEG/MISC.8*, 19.

port state jurisdiction is only effective when ships enter ports that are interested in compliance, and which have the means and expertise to conduct proper inspections. While the IMO does provide assistance, a lack of national resources necessary to properly inspect ships and the wiliness of some flag states to neglect compliance are ongoing challenges negatively impacting compliance.²²⁰

Three key issues affect regulatory avoidance, they include: ‘re-flagging’ or ‘flags of convenience’; the fact that ships spend most of their time not in port; and the fact that crews are often not nationals of the ship’s flagging state.²²¹ IMO conventions often include general provisions that provide considerable leeway for interpretation and regulatory compliance. For example, the phrase “to the satisfaction of the administration” found in IMO instruments provides the flag state leeway when inspecting a ship.²²² Indeed, with an estimated 75% of the worlds merchant fleet by tonnage registered in a tax or regulatorily permissive state (e.g., open registries) a high level of broad member compliance can be difficult to achieve. Despite the challenges, compliance with IMO regulations has been improving in recent years²²³

One way to overcome poor state enforcement is through the use of ROs, permitted by IMO conventions, to help survey, inspect, issue certificates and documents, conduct the marking of ships, and other statutory work necessary to enforce IMO instruments.²²⁴ Hired by ship owners, classification societies often serve in the RO capacity. As private organisations, classification societies have varying standards, though their reputation directly impacts their business.²²⁵

²²⁰ Organization for Economic Cooperation and Development, “International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation,” 108-9.

²²¹ *Ibid.*, 86

²²² Lawrence D. Barchue, Sr., “The Voluntary IMO Member State Audit Scheme: An Accountability Regime for States on Maritime Affairs,” *WMU Journal of Maritime Affairs*, Vol. 8 no 1 (2009): 62, accessed July 2021.

²²³ Organization for Economic Cooperation and Development, “International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation,” 115.

²²⁴ “Recognized Organization,” International Maritime Organization; and, Organization for Economic Cooperation and Development, “International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation,” 99-100.

²²⁵ Organization for Economic Cooperation and Development, “International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation,” 89.

Indeed, because information on classification societies is shared widely, the reputation of a specific classification society can be an incentive to adopt stricter requirements for ships.²²⁶

Another important tool for improving compliance is the IMO's Member State Audit Scheme (IMSAS). Now mandatory through treaty obligation, the scheme provides "Member State with a comprehensive and objective assessment of how effectively it administers and implements those mandatory IMO instruments which are covered by the Scheme."²²⁷ Audits can cover specific challenges of the members state or topics, like ship construction, and are specific enough not to encourage different interpretations.²²⁸ A consolidated audit summary report containing best practices and lessons learned is shared to help member states implement and enforce IMO instruments. A weakness of the scheme is its inability to sanction or otherwise force change when audits reveal noncompliance. To some observers this means the scheme is a "paper tiger" and assumes states are unable rather than unwilling to meet their IMO obligations.²²⁹

Liability for incidents at sea, including loss of life, protection and preservation of the marine environment, and others is another major incentive for compliance with IMO instruments.²³⁰ Detailed in Article 235 (1)(2) of the LOSC and through numerous IMO instruments, there are instruments, funds, and other tools that place a financial burden on flag and port states for incidents at sea.²³¹ In some cases, like with oil tankers, liability instruments have led private industry to develop strict standards (sometimes stricter than government) to save money by avoiding casualty or pollution incidents.²³² Liability instruments have also led to private protection and indemnity insurance clubs, which insure ship owners through a collective fund.²³³

²²⁶ Ibid., 90.

²²⁷ "Member State Audit Scheme," International Maritime Organization, accessed July 2021, <https://www.imo.org/en/OurWork/MSAS/Pages/Default.aspx>.

²²⁸ Organization for Economic Cooperation and Development, "International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation," 105.

²²⁹ Solene Guggisberg, "Independent, Compulsory, and Centralized Verification of States' Obligations in Fisheries: Can the IMO Audit Scheme for Shipping Law Be Used as an Example to Follow?" *International Community Law Review*, 22, 3-4 (2020), 526. doi: <https://doi.org/10.1163/18719732-12341445>.

²³⁰ International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization LEG/MISC.8.*, 84.

²³¹ For examples see: Ibid.

²³² Organization for Economic Cooperation and Development, "International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation," 100-101.

²³³ Ibid., 90

As a collective fund, the clubs are incentivized to investigate ship owners for risk and permit only those who pose little risk.²³⁴ Liability as a motivation for port state enforcement would invariably fall short on issues unaffected by liability tools, like those where fault is difficult to prove.

Important to both enforcement and liability is dispute settlement. For shipping, there are four main forums used with varying procedures, degrees of utility, and outcome. The International Court of Justice (ICJ), an international arbitral tribunal, the International Tribunal for Law of the Sea (ITLOS), or a special technical arbitral tribunal for certain technical or scientific matters.²³⁵ Each forum has certain benefits and limitations. For example, ITLOS is designed around the state, limiting its value to private parties. The forums have had a positive impact on shipping, though it would not be unwarranted to suggest they could add more if states showed greater willingness to submit disputes to third party tribunals, and if the tribunals were more receptive of private industry.

The IMO's Impact on Shipping

According to the Organizations for Economic Cooperation and Development, the IMO has had a “generally positive” influence on international shipping because it has helped reduce accidents and pollution while improving safety.²³⁶ A key reason the IMO has had generally positive impact is due to its ability to evolve over the years as shipping does. In addition to accommodating new shipping technologies, environmental issues, and members, the IMO has been able to update its procedures, like with the adoption of tacit acceptance, and the organisation’s structure, as seen with the creations of new committees. The IMO’s ability to change as an organisation is critical to its ability to accommodate the ever-changing world of shipping, and not just to protect the economic interests but also the environmental interest of the marine domain.

²³⁴ Ibid.

²³⁵ Louis Sohn, Kristen Gustafson Juras, John Noyes, and Erik Franckx, *Law of the Sea in a Nutshell*, 498.

²³⁶ Organization for Economic Cooperation and Development, “International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation,” 86.

The IMO's ability to evolve with shipping needs is a key reason states support the organisation and its outputs. The IMO's impact is due, in large part, to the value states place on a single, near-universal framework for safe, efficient, and environmentally coconscious maritime trade.²³⁷ Indeed, as with any international organisation mandated to govern aspects of international activity, a state's willingness to participate in rules development and comply with them have overwhelming influence on the ability of an organisation to positively shape international governance.

Though the IMO has had a positive impact on the sustainable development of the maritime domain via shipping, there is still much to be done. Climate change is still being understood and requires decisive global action; member states still vary considerably in their inspection practices and compliance; open registries still permit far too great a loophole in the IMO's work; and, technology continues to reshape the whole industry.²³⁸ While there is still plenty of work to be done, as long as the IMO can change with the character of international shipping it will continue to be in a position that affords it a positive impact on international maritime governance.

International Civil Aviation Organization

Every few seconds somewhere in the world a plane takes off or lands.²³⁹ The frequency and global nature of this activity is a catalyst for the movement of people and goods all over the globe, spurring trade, tourism, and countless other activities and benefits. Despite the complex nature of international civil aviation, the industry operates with surprising uniformity, through shared standards, technology, and even expectations.²⁴⁰ The uniformity is no accident, nor would civil aviation offer the benefits it does without it. Indeed, coordinating air traffic, routes, cargo, passenger laws, and more is a prerequisite for international civil aviation's positive impact globally. At the centre of this coordination are shared international laws, standards, and recommended practices, managed by ICAO.

²³⁷ International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization LEG/MISC.8.*, 88.

²³⁸ For example, autonomous ships could radically change governance issues, from liability to safety at sea, and more.

²³⁹ "Making an ICAO Standard," International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/safety/airnavigation/pages/standard.aspx>.

²⁴⁰ Ibid.

Unlike shipping, international civil aviation does not have hundreds of years of international governance history. Instead, much of the groundwork for today's international civil aviation governance was laid between World War 1 and World War 2 through the Paris and Havana Conventions.²⁴¹ Important as the two conventions were, it took the use of aircraft during World War 2 to advance the aerospace industry and show the world the potential of aviation.²⁴² The war also showed the need for greater international coordination to organize routes, facilities, and standards necessary to protect people and harmonize activities as civil aviation grew. As a result, the US government organized an International Civil Aviation Conference in Chicago between November and December of 1944.

The development of modern civil aviation governance via the conference in Chicago was shaped against the political backdrop of WW2 and the newly reshaped distribution of state power and post-war European recovery. The United States had communicated a vision of a freer and more inclusive marketplace for international air commerce than what existed before WW2.²⁴³ As the country with largest aviation industry, open skies offered great opportunity for the United States. European countries were also interested in more inclusive international air commerce but were concerned that they would fall under America's influence given the size of America's aviation industry, and so preferred more state control than the US vision. Neither perspective was new, however. Competing ideas of freedom and openness vs sovereignty and control reflected positions held during the first conference to address air navigation held in Paris in 1910.²⁴⁴ The second world war, and the opinion that trade policy and aviation would be key to rebuilding countries and improving relations between them, was an important incentive to reach an agreement.

²⁴¹ David Mackenzie, *A History of the International Civil Aviation Organization* (Toronto: University of Toronto Press, 2010), 16.

²⁴² "Introduction," International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/ChicagoConference/Pages/chicago-conference-introduction.aspx>.

²⁴³ David Mackenzie, *A History of the International Civil Aviation Organization*, 3-23.

²⁴⁴ Ibid.

In the end, the political positions would allow the conference in Chicago to produce some of what the US wanted and some of what European countries wanted. It created the Chicago Convention, which matured aviation law for a new era, a provisional ICAO body, technical standards, and basic aviation principals that permitted a more free and open aviation sector. The convention was unable to produce multilateral agreement on commercial rights, which would later be made bilaterally. The first bilateral agreement, made between the US and UK known as the Bermuda Air Transport Agreement, was political as well. The US leveraged post-war economic aid to convince the UK to the negotiating table (and some concessions) to address economic aviation principles left out of the Chicago convention.²⁴⁵ The Bermuda Air Transport Agreement would shape bilateral arrangements between many other countries as well.

The Chicago Convention is the cornerstone legal document for international civil aviation today. The Convention contains 96 articles and 19 annexes that outline what are known as ‘Air Freedoms’, or reciprocal air rights between countries, and technical standards necessary for safe and coordination aviation services. Despite its relatively comprehensive nature, the Chicago Convention does not contain air freedoms of an economic nature because the topic proved too controversial for agreement at the time of negotiations.²⁴⁶ Economic agreements would take the form of mostly bilateral arrangements between countries. The limited focus on economic aspects would also shape ICAO and its role.

The inability to agree on economic features during the conference meant that ICAO would serve primarily as a technical organisation through the development of standards and best practices. Indeed, 17 of the 19 Annexes to the Convention are technical in nature while the remaining two focus on facilitation and security. According to ICAO, it’s mission is to “serve as the global forum of States for international civil aviation. ICAO develops policies and Standards, undertakes compliance audits, performs studies and analyses, provides assistance and builds aviation capacity through many other activities and the cooperation of its Member States and

²⁴⁵ Ibid., 110-111.

²⁴⁶ “Introduction,” International Civil Aviation Organization; and, David Mackenzie, *A History of the International Civil Aviation Organization*, 116.

stakeholders.”²⁴⁷ Today, ICAO is focused on five strategic objectives to achieve its mission: Safety, Air Navigation Capacity and Efficiency, Security and Facilitation, Economic Development of Air Transport (meaning the growth of civil aviation generally, not the specific economic agreements between countries), and Environmental protection.

Core to achieving ICAO’s mission are Standards and Recommended Practices (SARP), Regional Supplementary Procedures (SUPP), and Procedures for Air Navigation (PAN). According to ICAO, SARPs and PANs “provide the fundamental basis for harmonized global aviation safety and efficiency in the air and on the ground, the worldwide standardization of functional and performance requirements of air navigation facilities and services, and the orderly development of air transport.”²⁴⁸ ICAO has currently produced over 12,000 SARPs across 19 Annexes and five PANs to the Convention.²⁴⁹

By coordinating international cooperation and developing technical standards necessary to organize the safe and efficient use of global aviation, ICAO plays an invaluable role in governing international civil aviation today.

ICAO Actors

Like other international organisations ICAO membership is designed around states first and non-governmental actors, like aviation industry or NGOs, second. As a more technical organisation focused on shared standards, ICAO has little reason to exclude states from becoming members of the organisation. As of January 2019, ICAO membership sits at 193 countries with several industry groups and NGOs listed as “invited organisations”, which ICAO does not classify as “observers”.²⁵⁰ In general, ICAO actors have a strong technical background

²⁴⁷ “Vision and Mission,” International Civil Aviation Organization, accessed, July 2021, <https://www.icao.int/about-icao/Council/Pages/vision-and-mission.aspx>.

²⁴⁸ “How ICAO Develops Standards,” International Civil Aviation Organization, accessed, July 2021, <https://www.icao.int/about-icao/AirNavigationCommission/Pages/how-icao-develops-standards.aspx>.

²⁴⁹ Ibid.

²⁵⁰ “Organizations able to be invited to ICAO Meetings,” International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/about-icao/Pages/Invited-Organizations.aspx>.

in aviation, often participating through national regulatory organisations or the aviation industry.²⁵¹

Industry does play a prominent role within ICAO, with some observations suggesting industry plays too influential of a role.²⁵² Industry's primary role is to provide technical expertise that aligns with market expectations and value.²⁵³ The goal being for ICAO to develop standards and other tools that do not come at the expense of the sector, which can require the input of industry. Industry involvement can occur in various ways throughout ICAO activities, including working groups, as members of national delegations, or as influential industry associations, like the International Air Transport Association, which has strong ties to ICAO.²⁵⁴

Like industry, NGOs primary role is also to act as a source of information for members, though they are often afforded less access than industry. Where industry generally enjoys broad involvement, NGOs involvement often depends on the body or topic being discussed. For example, in ICAO's Environmental Advisory Group (EAG) NGOs were excluded from some discussions on a global market-based measure for reducing aviation emissions because some members felt the NGOs would stall the effort by advocating for policy change rather than assessing the global market based measure objectively.²⁵⁵ NGOs and industry actors are important to ICAO, though their involvement can depend on the ICAO body or topic in question.

ICAO Structure

ICAO is composed of an Assembly, including all member states; the Council, with 36 member states elected every three years; the Secretariat with five bureaus—the Air Navigation Bureau, Air Transport Bureau, Technical Cooperation Bureau, Legal Affairs and External Relations Bureau—; Administration and Services, and seven Regional Offices.²⁵⁶ The Assembly

²⁵¹ Alejandro Piera Valdes, "Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges," (PhD thesis, McGill University, 2014), 94

²⁵² Ibid., 98

²⁵³ Ibid.

²⁵⁴ Ibid., 99

²⁵⁵ European Parliament, *Decision-making processes for ICAO and IMO in respect to environmental regulations*, 30.

²⁵⁶ "ICAO Secretariat," International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/secretariat/Pages/default.aspx>.

is the chief body of ICAO with authority to elect states to the council, approve budgets, consider amendments to the Chicago Convention, and delegate privileges to the Council among a few other responsibilities.²⁵⁷ The Council acts as the main governing body of ICAO with the chief responsibility to adopt or amend SARPs and SUPPs.²⁵⁸ The Council is also responsible for annual reports to the Assembly, manages various ICAO committees, and oversees the execution of the budget. The Assembly meets once every three years while the Council meets three times annually.

The structure of the Assembly and Council, their responsibilities, and the frequencies at which they convene has caused some member participation controversy. Composed of only 36 of 193 ICAO member states, and responsible for ICAO's core activities (e.g., the development of SARPs, SUPPs, and PANs), the Council exercises considerable decision-making authority with only a fraction of ICAO's member involved comprehensively. The increase in the Council's role stems from the decision in the 1950s to reduce Assembly meetings from annually to every three years. The change led to less member state involvement (excluding those on the Council) due to the challenges member have staying informed.²⁵⁹ As a consequence, member states can be unwilling to support global proposals because they simply do not feel they are adequately consulted or informed on the issue.²⁶⁰ Indeed, the massive backlog of reports, proposals, and other work items has led to more passive participation from members who feel cannot act on an informed basis during Assembly sessions, and at the same time, shifted power from the Assembly to the Council.

In 2013, the Assembly considered the idea of holding sessions every two years, but the added financial costs of doing so prevented the change.²⁶¹ The elevated role of the Council has

²⁵⁷ "Assembly," International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/about-icao/assembly/Pages/default.aspx>.

²⁵⁸ "The ICAO Council," International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/about-icao/assembly/Pages/default.aspx>.

²⁵⁹ European Parliament, *Decision-making processes for ICAO and IMO in respect to environmental regulations*, 26.

²⁶⁰ *Ibid.*, 26.

²⁶¹ Alejandro Piera Valdes, "Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges," 92.

stoked feelings among some ICAO members that participation in the organisation really depends on being a Council member.²⁶² Such feelings can affect generating outputs and compliance.

Developing Outputs at ICAO

Focused primarily on developing standards and best practices, ICAO's most important outputs are SARPs and PANs.²⁶³ ICAO does produce other agreements, like the recent framework for a market-based measure to reduce CO₂ emissions from civil aviation, as well as modify existing instruments when it's necessary. A more detailed discussion on how ICAO produces specific agreements will take place in following chapters. This section will detail how SARPs and PANs are produced generally to give a sense of how ICAO generates its more influential and common governance instruments.

ICAO defines a standard as, "any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention; in the event of impossibility of compliance, notification to the Council is compulsory under Article 38 of the Convention."²⁶⁴ Similarly, a Recommend Practice is defined as "any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention. States are invited to inform the Council of non-compliance."²⁶⁵

SARPs typically focus on essential requirements and are detailed in broad terms. For more technical SARPs the process involves two sections, one of a regulatory nature and the other the relevant technical specifications.²⁶⁶ SARPs are intended to be widely applicable whereas SUPPs are specific to regions based on more unique qualities, which is why proposing or amending

²⁶² Ibid., 93.

²⁶³ "How ICAO Develops Standards," International Civil Aviation Organization.

²⁶⁴ "Making an ICAO Standard," International Civil Aviation Organization.

²⁶⁵ Ibid.

²⁶⁶ Ibid.

SUPPs is generally a regional matter supported by the ICAO Secretary General.²⁶⁷ Finally, PANs are intended to be global standards considered too detailed for SARPs, though they do amplify basic principles of SARPs.²⁶⁸

Modifying or creating new SARPs can be initiated by ICAO itself, member states, or international organisations. The Air Navigation Commission (ANC) is the first to consider the proposal. The ANC is composed of 19 members nominated by ICAO member states but who do not represent any single state or group while supporting the ANC. Instead, the ANC acts as an impartial group of experts.²⁶⁹ The ANC's main method for conducting work is meetings. The ANC can use study groups, council technical committees, panels, among other methods to consult with contracting states or external experts to understand issues and make recommends. Following the consultative process, and at the discretion of the ANC Secretariat, the ANC may discuss "controversial issues" noted during the consultative process before submitting to contracting states for review a proposal to modify or create a SARP. While all contracting states are invited to participate during the ANC's consultative process, the large scope of work undertaken by ICAO broadly can make participation in various committees, consultative processes, reviews, and etc. challenging for members, and especially those states with small delegations or limited diplomatic budgets.²⁷⁰ Therefore, the review stage following the consultative process can be the first time many ICAO member states see the proposal to create or modify a SARP.

States are given three months to review and comment on a proposal. Following the review period, the ANC undertakes a final review of all material and produces the final text for the new or amended SARP. Finally, ICAO's Council considers the SARP and adopts it with two-thirds of the Council in favour. Member States are then given four months to review the SARP and voice

²⁶⁷ International Civil Aviation Organization, *Regional Supplementary Procedures, Fifth Edition, Doc 7030* (Montreal: ICAO Secretary General, 2008), V, VII.

²⁶⁸ "Making an ICAO Standard," International Civil Aviation Organization.

²⁶⁹ "Air Navigation Commission," International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/about-icao/AirNavigationCommission/Pages/default.aspx>.

²⁷⁰ The challenge of staying informed was expressed by ICAO members following the change in Assembly meeting frequency and during efforts to address environmental issues through ICAO's CAEP. For examples, see: European Parliament, *Decision-making processes for ICAO and IMO in respect to environmental regulations*, 26, 30.

their disapproval or adoption. Unless a majority of states disapprove, the SARP will still take effect. States can also notify ICAO of any difference between the proposed SARP and their national regulations; differences are then published. It takes approximately two years to develop or modify a SARP.²⁷¹ Whereas SARPs are *adopted*, SUPPs are *approved* by the Council after ANC review. PANs are also approved, rather than adopted, by the President of the Council on its behalf.²⁷² Council *Adoption* holds greater expectation for compliance while *approval* creates a recommendation. The difference means SUPPs and PANs do not carry the status afforded to SARPs.²⁷³

For agreements other than SARPs, PANs, or SUPPs, the Assembly may need to weigh in. For example, developing ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) required an Assembly resolution. More on CORSIA will be discussed in the next chapter. While processes for outputs depends on the output in question, the bulk of ICAO's work related to standards and recommend practices.

Decision Making and Compliance

ICAO relies on a consensus decision-making style for nearly all outputs, with acceptations for administrative responsibilities or tasks, like attachments to Annexes or SUPPs, that require 'approval' rather than 'adoption'. To be fair, ICAO does leverage a consensus decision making style though how inclusive ICAO is when gaining consensus or the process it used to achieve consensus does encourage some criticism.

For instance, one of ICAO's most important governance tools are SARPs. But as we have learned from the previous section, SARPs are largely the product of the 19-person ANC and only require two-thirds approval of the 36-member Council. While all member states can provide input during development of SARPs during the consultative process or draft review and can reject the proposed SARP, the process does not ensure all 193 ICAO members have equal

²⁷¹ "Making an ICAO Standard," International Civil Aviation Organization.

²⁷² International Civil Aviation Organization, *Regional Supplementary Procedures, Fifth Edition, Doc 7030, V*.

²⁷³ International Civil Aviation Organization, *Air Traffic Management, Sixteenth Edition, Doc 4444* (Quebec: ICAO Secretary General, 2016), x; International Civil Aviation Organization, *Regional Supplementary Procedures, Fifth Edition, Doc 7030, V*.

influence over SARP development. In other words, input does not necessarily equal influence. The 19-person ANC has the authority to adjudicate member state feedback following the review phase and it is up to the ANC Secretariat to decide what constitutes a controversial issue. So, while input is welcome, its impact is not guaranteed.

Similarly, the influence of the Council is well documented.²⁷⁴ For the ICAO member's not on the Council, which is most members, their ability to share equal influence over important decisions and outputs is often less than those on the Council.²⁷⁵ Another factor affecting member influence in the production of outputs is member resource disparities. Members with the financial means to staff more experts, conduct independent research, and otherwise stay at the leading edge of the work have more influence than the members simply trying to keep up.²⁷⁶ While not all states have equal position to influence ICAO standards, there can be little consequence to states who are less involved because ICAO standards are non-binding.

Effectively, the nature of key ICAO instruments, like SARPs, permits a less inclusive process. While less inclusivity may be less ideal to some, the ability to quickly develop SARPs allows ICAO to keep pace with the changing character of international aviation without imposing a greater cost on states through frequent participation or obligatory measures. In this way ICAO is attempting to balance the transaction costs of producing new agreements with compliance.

One could suggest, if ICAO required a more comprehensive participation, it would not manage to produce SARPs as quickly given the processes would take longer from increased transaction costs associated with more countries being involved. Indeed, notable ICAO historian David Mackenzie believes ICAO's ability to make decisions as it does—balancing participation with non-binding standards—has become ICAO's “secret to success.”²⁷⁷

²⁷⁴ European Parliament, *Decision-making processes for ICAO and IMO in respect to environmental regulations*, 26.

²⁷⁵ *Ibid.*, 26.

²⁷⁶ *Ibid.*, 28.

²⁷⁷ David Mackenzie, *A History of the International Civil Aviation Organization*, 194

ICAO's strong ability to produce governance instruments, like SARPs, does not necessarily translate into high compliance rates. Historically, compliance has been difficult to achieve generally. In 1999, following 110 evaluations, ICAO learned that not a single country in the evaluation has fully complied with Annex 17—which outlines standards for safeguarding international civil aviation against acts of unlawful interference.²⁷⁸ This is due in part because there are no explicit consequences for non-compliance, nor do member states consistently notify ICAO when a SARP differs from national regulations.²⁷⁹ For many states, the financial or domestic political cost (i.e., legislation development) of implementing new technical standards across a range of safety, security, and other areas can be a major obstacle to compliance.

To improve compliance, ICAO developed the Universal Safety and Oversight Audit Program (USOAP). USOAP aims to improve global aviation safety by first determining the status of standards and procedures compliance, and second, persuading states to improve through the publication of global compliance reports.²⁸⁰ The audits are conducted in the context of a state's safety and oversight systems, which include eight critical elements including legislative, regulatory practices, organisational functions, technical guidance, qualified personnel, licensing and certification procedures, and continued surveillance, and the resolution safety concerns.²⁸¹

As of 2013 the USOAP program was supplemented with a Continuous Monitoring Approach to gather safety information on an ongoing basis between audits. Audits are followed up by an ICAO Coordinated Validation Mission to assess progress on areas found to be deficient during the audit. As of June 2020, 97% of member states representing 99% of all international air traffic has participated in USOAP activities.²⁸² From 2016-2018 effective implementation of ICAO safety standards and procedures increased across all eight critical elements, though

²⁷⁸ Ibid., 341.

²⁷⁹ Jeffery J. Smith and M. Tanveer Ahmad, "Globalization's Vehicle: The Evolution and Future of Emission Regulation in the ICAO and IMO in Comparative Assessment," *Climate Law* 8 (2018), 81, accessed August 2021.

²⁸⁰ International Civil Aviation Association, *Universal Safety Oversight Audit Programme: Continuous Monitoring Approach Results* (Montreal: Air Navigation Bureau, 2019), 10; and, Alejandro Piera Valdes, "Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges," 344.

²⁸¹ International Civil Aviation Association, *Universal Safety Oversight Audit Programme: Continuous Monitoring Approach Results*, 11.

²⁸² "Frequently Asked Questions about USOAP," International Civil Aviation Organization, accessed July 2021, <https://www.icao.int/safety/CMAForum/Pages/FAQ.aspx>.

improvements were greatest in areas like talent and least in areas associated with national legislation or regulatory structure.²⁸³ The audit program signals growth in ICAO's role as a governance body, adding 'assessor' to its role as a standards creator.²⁸⁴

Another tool to encourage compliance is the ability of states to revoke access to foreign aircraft operators who do not meet ICAO standards. The Chicago Convention and nearly all air service agreements, which outline air service rights, provide mechanisms that allow states to revoke access of foreign operators when they have "reasonable ground to believe" that the foreign operator is not meeting ICAO standards.²⁸⁵ Some states have leveraged this mechanism particularly when it relates to safety.²⁸⁶

ICAO's Impact on Civil Aviation

Today, international air services fuel the global economy through trade, tourism, and the generally ability to connect people and goods around the globe. Indeed, aviation is responsible for approximately one percent of international trade and 58% of international tourism.²⁸⁷ A further 1.9 billion passengers (or 41.6% of all passengers) were international.²⁸⁸ In total, aviation was a \$3.5 trillion dollar sector in 2018, or 4.1% of global economic activity.²⁸⁹ The magnitude and impact of aviation, which includes international and national activities, would be hard to achieve without the coherence of activities that are accounted for in the Chicago Convention and the thousands of standards and practices produce by ICAO. To be sure, international aviation is just a piece of the total aviation picture (which include national activities as well), still ICAO standards do impact aviation activities at all levels.²⁹⁰

²⁸³ International Civil Aviation Association, *Universal Safety Oversight Audit Programme: Continuous Monitoring Approach Results*, 19

²⁸⁴ David Mackenzie, *A History of the International Civil Aviation Organization*, 372

²⁸⁵ Alejandro Piera Valdes, "Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges," 345.

²⁸⁶ *Ibid.*

²⁸⁷ Air Transport Action Group, "Aviation: Benefits Beyond Borders," atag.org, (2020), 14, accessed August 2021, https://aviationbenefits.org/media/167517/aw-oct-final-atag_abbb-2020-publication-digital.pdf.

²⁸⁸ *Ibid.*, 11.

²⁸⁹ *Ibid.*, 14.

²⁹⁰ For examples of ICAO standards impact on national aviation activities, see: "How Changing ICAO Standards Impact Business Aviation," National Business Aviation Association, accessed August 2021, <https://nbaa.org/aircraft-operations/international/customs-and-regulatory-issues/changing-icao-standards-impact-business-aviation/>.

ICAO can certainly claim its work has helped aviation grow to what it is today and that it will have an impact on aviation for the foreseeable future. The future will prove challenging, however. Of increasing importance globally are environmental issues, and specifically those associated with climate change. International aviation has a significant role to play in reducing greenhouse gases and ICAO has been taking bold steps to do just that by creating international Co2 standards for commercial aircraft engines and the first industry wide market based mechanism (MBM) to reduce the increase in Co2 emissions from international civil aviation.²⁹¹ While both topics will be discussed in detail in the following chapter, they represent another example of how ICAO is able to produce new governance measures to address a wide range of complex issues affecting the sustainability and development of civil aviation.

Indeed, while ICAO's impact on aviation could be criticized (e.g., its limited inclusivity during SARPs development as previously discussed), the organisation's ability to regularly produce new measures through consensus to positively shape the sustainable development of civil aviation—even if imperfect—suggest ICAO has a generally positive impact on the aviation sector. Similar practices—like the use of SARPs, ICAO's decision-making approach, and inclusivity of industry—applied to new space governance could enable the development of standards for STM, ORPSAO, and large constellations of satellites. While leveraging lessons from ICAO will likely require some modification, there are many processes, governance tools, and membership features that would help COPUOS and other space governance organisations overcome barriers to new governance.

Internet Governance

The internet domain is considerably different from the air or maritime domains most notably because its humanmade, and therefore offers a different perspective on international governance. Though there are important differences, discussing international governance of the internet does not look all the much different from other domains. For example, how it is managed can affect how it is used and who it benefits. The internet has critical internet resources (CIR) that must be

²⁹¹ Richard K. Lattanzio, "Aviation, Air Pollution, and Climate Change," Congressional Research Service, 2022, accessed February 2022. <https://crsreports.congress.gov/product/pdf/IF/IF11696>.

managed just like one might find in other domains. And the internet is also essential to the modern global economy. So, like the air, maritime, or space domains, the internet requires governance. Before detailing how the internet is governed, and because it is humanmade, it is important to define what the internet is and how it works.

Understanding the Internet

Given how most people use the internet today, many might assume it is a single monolithic digital system, like a ‘superhighway’, as it has been colloquially labelled. In fact, the internet is not a single large system, nor does it have a single ‘core’ in a strict sense. Instead, it is an ecosystem of private networks which connect to one another via shared standards, known as protocols, to create a public common.²⁹² Each independent network is owned and operated by private companies which create, deliver, and provide access to information.²⁹³ For example, companies like Facebook and Google create or organize information while telecommunications companies, like Verizon or British Telecom, provide access to information as an internet service provider. In either case the networks are private but via common (or shared) standards, the private networks can connect to one another, allowing the flow of information between them.

The connection of separate private networks is what makes the internet global. Early in the internet’s development standards were not shared. So, while large companies had internal networks, the lack of shared standards meant the networks could not connect to one another; like two people speaking different languages. It was not until internet protocols became standardized that the internet we know today became possible.

Another common misconception about the internet is that the internet and the world wide web are the same thing. In fact, they are very different functionally, and were created at different times and by different people. Indeed, the internet existed before the web and could in a technical sense continue to function without it. The web, however, could not function without the internet.

²⁹² Laura DeNardis, *The Global War for Internet Governance*, 224; and, Milton Mueller, John Mathiason, and Hans Klein, “The Internet and Global Governance: Principles and Norms for a New Regime,” *Global Governance* 13 (2007). 2007, 244. Accessed September 2021.

²⁹³ Laura DeNardis, *The Global War for Internet Governance*, 109.

That's because the web is the interface while the internet is the network the interface requires.²⁹⁴ One could argue the web has become essential considering most people use the internet through its interface, the web.

The value the internet provides today is due in large part to the public domain created through shared standards known as protocols. Internet protocols provide instructions that hardware and software developers use make their products interoperable.²⁹⁵ Internet standards are created and not predetermined. Importantly, standards influence what is possible over the internet, from how information is shared, to permitting e-commerce, and even illicit activities. They are also very hard to changed one implemented. In all, it would not be an exaggeration to say internet standards are a central feature of the internet, and as and result, can hold incredible economic and political value.²⁹⁶

Internet standards are often developed through a three step processes based on peer review, institutional norms, and working technical competency.²⁹⁷ The Internet Engineering Task Force (IETF), which will be discussed in greater detail later in this section, plays a central role developing standards. While a standard could be proposed by anyone, many start within the IEFT. To develop a standard, a proposed standard undergoes several iterations of review and development between the internet community and the standard's author(s).²⁹⁸ Though straightforward from a process standpoint, it is more complicated in practice. According to the IETF, creating standards can be difficult “due to (1) the difficulty of creating specifications of high technical quality; (2) the need to consider the interests of all of the affected parties; (3) the importance of establishing widespread community consensus; and (4) the difficulty of evaluating the utility of a particular specification for the Internet community.”²⁹⁹ The process attempts to

²⁹⁴ Milton Mueller, John Mathiason, and Hans Klein, “The Internet and Global Governance: Principles and Norms for a New Regime,” 244.

²⁹⁵ Laura DeNardis, *The Global War for Internet Governance*, 63, 65.

²⁹⁶ Laura DeNardis, *Protocol Politics* (Cambridge, MA: MIT Press, 2009), 6.

²⁹⁷ Laura DeNardis, *The Global War for Internet Governance*, 73.

²⁹⁸ “Standards Process,” Internet Engineering Task Force, accessed August 2021, <https://www.ietf.org/standards/process/>.

²⁹⁹ Ibid.

balance the need for quality with the fast pace of internet technology development.³⁰⁰ Despite the rigorous process, standards are routinely developed.

At the centre of internet standards is the Transmission Control Protocol and the Internet Protocol (TCP/IP). These two protocols set the standard for how to format, address, and route information over the internet to other devices also using TCP/IP.³⁰¹ There are hundreds of other standards enabling various functions average internet users rely on, like Wi-Fi, email, video chat, and image files. While the internet could function without certain standards, like voice over internet protocol for video chat, it could not function without TCP/IP or an equivalent.³⁰²

With TCP/IP setting the standard for how to format, address, and route information, the domain name system (DNS) acts as a necessary directory. The DNS system connects domain names and with internet address numbers. Domain names, or website names, are the text used to identify a specific designation, (e.g., www.google.com or www.kcl.ac.uk). Each domain name is associated with a number known as an internet protocol address (IP address) which details a location. While the IP address in the form of a number is necessary for accessing or routing information, internet architects understood that remembering a series of numbers to access a website would be more complicated than remembering text. As a result, the DNS directs information by translating more familiar text (domain names) into address numbers (IP address).

The DNS plays an essential role in how the internet is used. In part because it makes it accessible but also because the nature of the DNS creates internet resources. Requiring names and numbers to access or share information over the internet makes those names and numbers unique and valuable. For example, there can be only one www.google.com with an equally unique number (IP address) to access Google's website. While other names could be associated with the same IP address, meaning a different name like www.google.com/about could take a user to the same google destination (web server) via the same IP address as www.google.com, names and numbers cannot be simultaneously associated with different web servers or addresses.

³⁰⁰ Ibid.

³⁰¹ Laura DeNardis, *The Global War for Internet Governance*, 67.

³⁰² Ibid.

That's because names and numbers represent specific locations just like a single home address could not represent two different homes.

The essential role of names and numbers makes them valuable and a critical topic of internet governance. For example, Amazonian states located in South America have protested the use of www.amazon.com by the US-based e-commerce business Amazon. The Amazon example is just a glimpse into the tension that exists around unique internet names. Adjudicating such issues is a matter of governance. Similar to the value of unique names, if DNS numbers cannot be shared, there must either be a limitless supply of IP addresses or the means to fairly allocate them. The internet's central IP address standard, internet protocol version 4 (IPv4), is designed around a 32-bit address space, so it only provides roughly four billion unique addresses. While a large number, the growth of the internet combined with poor address management during the internet's early years has led to the allocation of all four billion addresses.³⁰³ More on CIR will be discussed in the following chapter.

In addition to protocols, names, and numbers, the internet also relies on physical infrastructure. Some of the key physical infrastructure includes the power grid, fibreoptic cables, satellites, ground stations, servers, undersea cables, internet exchange points, among others. While this physical infrastructure is not entirely unique to the internet, for example undersea cables server other communication purposes as well, the internet could not function without it. As an essential element of the internet, it plays an important role in how the internet is governed.

Governing the Internet

The internet has been operational at some level since 1969 when the US ARPANET sent the first message, but the idea of internet governance did not come into prominence until the mid-1990s. Indeed, "internet governance" did not appear in scholarly work until 1995, though the idea was discussed indirectly through conversations of internet 'governance and law' as early as

³⁰³ Milton Mueller, *Networks and States*, 222; Brenden Kuerbis and Milton Mueller, "The Hidden Standards War: Economic Factors Affecting IPv6 Deployment," Internet Governance Project, Georgia Institute of Technology, School of Public Policy, February 2019, 3, accessed August 2021.

1993.³⁰⁴ The creation of an organisation to coordinate global internet names and IP addresses thrust the topic of internet governance into academic and policy discussion. Early discussions during the mid-1990s focused on the DNS and later the policy process and actor ecosystem capable of influencing how the internet functions and is used.³⁰⁵ These discussions were certainly global, but because the internet originated in the United States, and because the internet's central protocol IPv4 was a protocol developed and managed by US organisations, much of the early internet discussions also focused on what role individual countries or national organisations should play in governing the internet.

Very early in the internet's development the DNS was managed by a single man, Jon Postal, working out of the University of Southern California. At this early stage, there were few complicating factors allocating names and numbers to a relatively small number of various organisations or countries. As the internet grew and connected more people and organisations, the process of allocating names and numbers began to have serious political and economic ramifications. Jon's role overseeing the DNS meant Jon, and by extension the United States, managed one of the internet's few central points of control.³⁰⁶ As a result, in 1998 the United States government created ICANN as a non-profit public benefit corporation responsible for managing the DNS. A key motivation to create ICANN, versus assigning internet regulation to a government regulator, was the desire by the US government and the internet's architects to keep the internet as free from government control as possible; the idea has had lasting impacts on how the internet is governed.³⁰⁷ But the creation of ICANN caused issues internationally as other states grew concerned with US control over the internet. The desire to understand and discuss international internet governance was growing.

³⁰⁴ Milton L. Mueller and Farzaneh Badiel, "Inventing Internet Governance: The Historical Trajectory of the Phenomenon and the Field," in *Researching Internet Governance, Methods, Frameworks, and Futures*, Laura DeNardis, Derrick L. Cogburn, Nanette S. Levinson, and Francesca Musiani eds. (Cambridge, MA: MIT Press, 2020), 60, 63; Hofmann et al. 1407

³⁰⁵ Jeanette Hofmann, Christian Katzenbach and Kirsten Gollatz, "Between coordination and regulation: Finding the governance in Internet governance," *New Media and Society* 19 no 9 (2016), 1407.

³⁰⁶ Milton Mueller, *Networks and States*, 61.

³⁰⁷ Laura Munkler, "Paradigms of Internet Regulations in the European Union and China," *Frontiers of Law in China* 13 no. 3 (2018):418, accessed August 2021.

Partly in response to the creation of ICANN, in 1998 at an ITU Conference it was agreed that there would be a World Summit on the Information Society (WSIS) held to discuss aspects of the internet including governance.³⁰⁸ In 2001 the UN GA endorsed the idea, setting in motion the first international conference focused on the internet. Though the agenda included many topics, WSIS quickly became fixated on who should govern the internet. The debate fell between the states who wanted national governments to take the lead and the states who wanted the internet managed by an international organisation like the UN.³⁰⁹

WSIS was meaningful in a few ways. Its chief contribution was ushering the topic of internet governance into the international governance arena. Its work would also eventually lead to the first agreed upon definition of internet governance: “Internet governance is the development and application by governments, the private sector and civil society, in their respective roles, of shared principles, norms, rules, decision-making procedures, and programs that shape the evolution an use of the internet.”³¹⁰ Otherwise, the summit failed to change the United States’ or ICANN’s role, create any sort of binding treaty, or otherwise meaningfully change the state of internet governance.³¹¹

The internet has grown considerably since the first WSIS summit and its governance continues to evolve as well. According to DeNardis, Cogburn, et al, the central features of internet governance today revolve around:

- administration of CIR,
- establishing technical standards,
- coordinating access to the internet,
- policy-making role of private internet actors (i.e., platform terms of service), and
- intellectual property rights.³¹²

³⁰⁸ Milton Mueller, *Networks and States*, 59.

³⁰⁹ Ibid., 11

³¹⁰ Working Group on Internet Governance, “Background Report,” United Nations, 2005, 11, accessed August 2021, <https://www.itu.int/net/wsis/wgig/docs/wgig-background-report.pdf>.

³¹¹ Milton Mueller, *Networks and States*, 60.

³¹² Laura DeNardis, “Introduction: Internet Governance as an Object of Research Inquiry,” in *Researching Internet Governance, Methods, Frameworks, and Futures*, Laura DeNardis, Derrick L. Cogburn, Nanette S. Levinson, and Francesca Musiani eds. (Cambridge, MA: MIT Press, 2020), 3.

DeNardis, Cogburn, et al suggest the central features of internet governance are influenced by:

- technical design (e.g., the BitTorrent protocol challenged intellectual property enforcement),
- the disaggregated nature of internet infrastructure and how it challenges state jurisdiction,
- the ecosystems of state and non-state actors currently governing the internet,
- internet security and national security, and
- the interplay between internet control and national power.³¹³

These central features and influential factors play out against a decentralized internet governance regime. The rapid growth of the internet combined with US influence over it inhibited coordinated planning of an international internet governance regime. As a result, the internet is not governed by a central authority or curated system of organisations, instead it's governed by a mix of private, non-profit, government, and other groups who each have differing levels of influence over aspects of the internet from, standards, to cyber security, to public policy, content, and access.³¹⁴ This state of internet governance is most often referred to as a multistakeholder model.³¹⁵

Internet Actors

The nature of the internet permits a large pool and variety of actors to influence how the internet functions and is governed. This actor group consists of average individual users, corporations, federal regulators, internet service providers, non-profits, universities, non-governmental organisations with specific internet oversight responsibilities, legislators, and

³¹³ Ibid., 4

³¹⁴ Laura DeNardis, *The Global War for Internet Governance*, 226.

³¹⁵ Milton L. Mueller and Farzaneh Badiel, "Inventing Internet Governance: The Historical Trajectory of the Phenomenon and the Field," 465; Internet Governance Forum, "Enabling Inclusive and Sustainable Growth," 11th Internet Governance Forum Full Report, 2016, 57-28, accessed September 2021, <https://www.intgovforum.org/en/content/igf-annual-meetings-proceedings>; Milton Mueller, *Networks and States*, 65, 105; Milton Mueller, John Mathiason, and Hans Klein, "The Internet and Global Governance: Principles and Norms for a New Regime," 241; Laura DeNardis, *The Global War for Internet Governance*, 18.

more. In a sense, the group of actors capable of influencing internet governance reflects the diversity of the internet community. While there are certainly several key actors which will be discussed below, it is possible to influence key aspects of the internet, like standards, without any sort of formal affiliation to a company, government, or organisation. To this end, influence over internet governance is more democratized than what is typically found in international governance regimes which are primarily influenced by nation-states, NGOs, and large commercial organisations. Moreover, many of the most influential groups are relatively young even compared to the internet.

With hundreds of organisations of all types influencing internet governance around the world the following conversation will detail just the most influential. More on each will be discussed in following chapters as topics require.

The first organisations warranting discussion is perhaps the most notable because it resides over the internet's names and numbers. ICANN is a US-based non-profit public benefit corporation created in 1998 to formalize responsibilities for the DNS. The decision to create a public non-profit reflects the US government's desire to privatize control of the internet vs top down control through federal regulators or large international organisations, though ICANN did establish the Government Advisory Committee (GAC) to allow governments to provide input into ICANN decision making.³¹⁶ ICANN plays a central role in internet governance, but it is just one part of the larger internet governance regime.³¹⁷

ICANN manages the internet's names and numbers, giving it control over a central feature of the internet. Such control has proved to be a contentious issue for internet governance. On one hand, the internet's development, from protocols to content to ISPs, is driven largely by the private sector, so a public non-profit responsible for central features of the internet makes sense as a balance to total commercial for-profit control. On the other hand, the internet affects important economic, political, and security concerns which fall under the state's responsibility.

³¹⁶ Laura DeNardis, *The Global War for Internet Governance*, 48; Milton Mueller, John Mathiason, and Hans Klein, "The Internet and Global Governance: Principles and Norms for a New Regime," 239.

³¹⁷ Laura DeNardis, *The Global War for Internet Governance*, 62.

The tension has led to a disagreement between some states, private actors, and international organisations over whether ICANN is best suited to address the spectrum of commercial and state interests. Indeed, ICANN represents a unique departure from traditional forms of international governance because it reduces the power of states relative to non-state actors and centralizes governance of key features for a global common within a single NGO.³¹⁸

Leading ICANN is its corporate board. The board is composed of 15 members, 6 of which are appointed by ICANN supporting organisations and 8 are chosen by a committee composed of various stakeholders.³¹⁹ The CEO represents the last board seat. Board members can be international in origin and typically come from industry or other non-government internet stakeholders. ICANN's board is a stark departure from the state-centric control of other key governance organisations.

ICANN's board does incorporate government input on public policy issues through the GAC. The GAC is composed of representatives from inter-governmental organisations and one representative per country. Initially, the GAC only provided nonbinding input to ICANN's board on issues affecting public policy. After changes to ICANN's bylaws in 2001, however, the GAC's influence increased considerably. The changes required ICANN's board to take the GAC's advice into account and find a mutually acceptable solution in the event of a disagreement between the board and GAC. The change elevated the GAC's influence to "first among equals in the ICANN ecosystem" according to some GAC's members.³²⁰ The board oversees several important internet governance responsibilities.

³¹⁸ Milton Mueller, *Networks and States*, 61.

³¹⁹ Everton Frask Lucero, "Global Governance of Critical Internet Resources: A Perspective from the South," (paper presented at GigaNet: Global Internet Governance Academic Network, Annual Symposium 2010) 14, accessed October 2021, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2809226.

³²⁰ The claim that the GAC was "first among equals" was made by the United Kingdom, United States, and Portugal during GAC meeting June 21-24, 2015. See: "Buenos Aires – GAC Morning Sessions, June 21" ICANN, 2015, accessed September 2021, <https://archive.icann.org/meetings/buenosaires2015/en/schedule/sun-gac-morning/transcript-gac-morning-21jun15-en.pdf>; "Buenos Aires – GAC Afternoon Sessions, June 23" ICANN, 2015, accessed September 2021, <https://archive.icann.org/meetings/buenosaires2015/en/schedule/tue-gac-afternoon/transcript-gac-afternoon-23jun15-en.pdf>; and, "Buenos Aires – GAC Morning Sessions, June 25" ICANN, 2015, accessed September 2021, <https://archive.icann.org/meetings/buenosaires2015/en/schedule/wed-gac-morning/transcript-gac-morning-24jun15-en.pdf>

The bulk of ICANN's funding is produced through the services it provides around internet names and numbers.³²¹ In terms of funding, ICANN's 2021 adopted budget was \$129 million.³²² For comparison, ICAO had a \$323 million three-year (2020-2022) budget, the IMO budgeted \$53 million for 2021, and the ITU allocated \$165 million for 2019.³²³ COPUOS's 2021 appropriation was \$4.49 million.³²⁴ Comparatively speaking, ICANN is well funded.

A critical function of ICANN was initially managed by the Internet Assigned Numbers Authority (IANA), which allocated and maintained domain names, numbers, and protocol assignments.³²⁵ In 2016 the US government relinquished its remaining control of ICANN which spurred the creation of Public Technical Identifiers (PTI) to take over performing the IANA functions. PTI executes the IANA functions on behalf of ICANN. A key IANA function is to allocate unused addresses to five regional internet registries (RIRs) representing Africa, Asia-Pacific, North America, Latin America and the Caribbean, and Europe plus the Middle East and Central Asia. RIRs affectively assume a key governance role through their management of addresses. RIRs are private, nongovernment organisations with members representing ISPs, organisations with private networks, hosting and web services providers, and others with interest

³²¹ For 2020 funding sources see: ICANN Operations, "Funding by Source, Fiscal Year 2020," ICANN, October 2020, accessed September 2021, <https://www.icann.org/en/system/files/files/fy20-funding-source-29oct20-en.pdf>.

³²² ICANN Operations, "ICANN Unaudited Quarterly Financials – Fiscal Year 2021," ICANN, October 2020, accessed September 2021, <https://www.icann.org/en/system/files/files/fy21-unaudited-financials-30jun21-en.pdf>.

³²³ ICANN Operations, "Internet Corporation for Assigned Names and Numbers (ICANN) FY21 Adopted Budget," ICANN, May 2020, accessed September 2021, <https://www.icann.org/en/system/files/files/fy21-unaudited-financials-30jun21-en.pdf>; ITU Council, "Resolution 1396, Biennial Budget of the International Telecommunication Union for 2020-2021," International Telecommunication Union, June 2019, accessed September 2021, <https://www.itu.int/md/S19-CL-C-0122/en>; IMO Assembly, "Resolution A.1132(31), Results-Based Budget for the 2020-2021 Biennium," International Maritime Organization, January 2020, accessed September 2021, [https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1132\(31\).pdf](https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1132(31).pdf); and, "Budget of the Organization for 2020-2021-2022," International Civil Aviation Organization, accessed September 2021, <https://www.icao.int/annual-report-2019/Pages/supporting-strategies-finances-budget-2020-2021-2022.aspx#:~:text=The%20Regular%20Programme%20Budget%20of,the%20Council%20without%20any%20ame> ndment.

³²⁴ UN General Assembly, "Proposed programme budget for 2022, Part II Political affairs, Section 6 peaceful uses of outer space," United Nations, March 2021, 15/22, accessed September 2021, https://www.unoosa.org/res/oosadoc/data/documents/2021/a76/a766_sect_6_0_html/A_76_06_SECT-06E.pdf.

³²⁵ "About Us," Internet Assigned Numbers Authority, accessed September 2021, <https://www.iana.org/about>.

in IP address management.³²⁶ In 2003 RIRs created the Number Resource Organization to help cohere decision making among RIRs while elevating their role within ICANN.³²⁷

ICANN's role governing internet names and numbers through IANA functions and RIRs is a major focus of internet governance. ICANN has a unique ability to affect internet names and numbers on a global scale. That said, ICANN does not include the development of internet standards or protocols. An equally important aspect of internet governance, protocols and standards are developed by numerous organisations, some of which have few barriers to entry aside from the technical knowledge and time needed to create new standards. Standards are also constantly evolving as new technologies and activities change the way the internet functions and is used.

A key internet standards organisation is the Internet Society (ISOC), which was established in 1992 to provide corporate oversight and support to the IETF. The IETF's origin can be traced back to the 1970s when engineers and researchers worked together to develop the original ARPANET through what was at the time the Internet Configuration Control Board.³²⁸ Today, the IETF operating under ISOC develops internet protocol drafts. Membership is a voluntary activity open to anyone and anyone can contribute protocol drafts through the IETF, though the organisation does expect input to reflect "technical competence."³²⁹ Through "rough consensus and working code" the IETF established standards via working groups organized around topic areas.³³⁰ Various groups within the IETF adjudicate standards, manage IETF activities and long-range technical direction, promote research, and develop tools to support the IETF's work among other activities.³³¹ Private industry plays a major role in the IETF through various IETF groups and responsibilities. A defining characteristic of the IETF is the openness of its process and

³²⁶ Milton Mueller, *Networks and States*, 221.

³²⁷ "About the NRO," Number Resource Organization, accessed September 2021, <https://www.nro.net/about/>.

³²⁸ Laura DeNardis, *The Global War for Internet Governance*, 68.

³²⁹ "Mission and Principles," IETF About, accessed September 2021, <https://www.ietf.org/about/mission/>.

³³⁰ *Ibid.*; and, "Who we are," IETF About, accessed September 2021, <https://www.ietf.org/about/who/>.

³³¹ "Groups," IETF About, accessed September 2021, <https://www.ietf.org/about/groups/>.

output (e.g., IETF generally discourages strict intellectual property claims over standards) which remain from the internet's early years.³³²

There are numerous other organisations that set standards like the IETF or influence internet governance like ICANN. They include the Institute of Electrical and Electronics Engineers (IEEE), the World Wide Web Consortium (WC3), the ITU, the International Standards Organizations (ISO), Internet Governance Forum (IGF) among countless others which develop new standards, address access issues, monitor for illicit content, and generally affect the way the internet can and does function or connect people and groups. Many of these actors come from the private sector. As a key source of technical knowledge and ownership of internet infrastructure, the private sector has always played a leading role in how the internet is governed because it plays a leading role in how the internet is designed and evolves from a technical standpoint. The private sector's role is also growing. Issues of content oversight on social media, platform terms of service, service agreements between network hosts and data centres, among other topics have become more prominent in recent years as governments and private company's attempt to balance civil liberties and economic growth with protecting people and interests from illegal or harmful activities.³³³

Of course, the influence the private sector has not gone unnoticed by government regulators. Each country has their own system of regulating how private sector actors produce protocols, permit content, and protect civil liberties (or in some cases, like China, use the internet to infringe upon civil liberties³³⁴). Government regulations evolve as private sector activities do. Intergovernmental organisations also continue to develop and exercise control over internet governance. The interplay between private sector, government, and other actors constitutes the multistakeholder nature of internet governance, which is a key feature leftover from the internet's creation. But as we shall see in the next section, the diffusion of responsibilities

³³² "Intellectual property rights," IETF Internet Standards, accessed September 2021, <https://www.ietf.org/standards/ipr/>.

³³³ Laura DeNardis, *The Global War for Internet Governance*, 154.

³³⁴ Richard Fontaine and Kara Frederick, "The Autocrats New Tool kit," *Wall Street Journal*, March 2019, accessed September 2021, <https://www.wsj.com/articles/the-autocrats-new-tool-kit-11552662637>.

combined with the disaggregated nature of internet infrastructure makes governing the internet challenging for all actors.

Internet Governance Challenges

There are a few key issues at the centre of internet governance. These include intellectual property protection, cybersecurity, content regulation, privacy, the management of CIR, and access to the internet. A major challenge for governing these issues is the lack of central control and multistakeholder influence. For example, the contention and confusion resulting from the lack of clear roles and responsibilities between government and industry. Personal privacy is increasingly at odds with newer internet activities, like social media and targeted marketing, yet whether the private company collecting personal data is responsible for protecting privacy or the government is, is an ongoing debate occurring internationally. The exact approaches taken to address these governance challenges can vary by country, organisation, and individual user, and even occurrence.

This disaggregated nature of internet infrastructure and content generation complicates clear lines of governance responsibility.³³⁵ The private sector owns the majority of internet infrastructure and platforms. These private companies can have terms of service or other rules they require their users to abide by, but whether those rules follow domestic or federal laws in each country the website or platform operates within can vary and often there is conflict over which authority (company or government) should be followed. During the 2016 US Presidential election, the social media website Twitter, blocked tweets and eventually the account of sitting President Donald J. Trump over violations of Twitter's terms of service. The decision caused debate between civil liberty advocates who felt a private company should not possess the ability to silence free speech (especially the speech of a political leader) and those who felt Twitter was within it right to enforce its terms of service on user who agreed to them when joining the platform.

³³⁵ Milton L. Mueller and Farzaneh Badiel, "Inventing Internet Governance: The Historical Trajectory of the Phenomenon and the Field," 68.

The disaggregated nature of internet infrastructure can also create governance loopholes that make it easier for governments to take unilateral action. For example, it is not uncommon that a website may have registered its domain name in one country while housing the website's data through a company in a different country while be accessed by users in still different countries. Because the internet requires linking separate pieces (domain name, IP address, content, users, web servers, etc), governments often only need to access one piece to gain access to data or stop the website from functioning. In 2012 the US Secret Service took down the website JotForm over allegations of illegal activity by asking the domain name registrar, GoDaddy, to suspend the domain name. In other instances, the tactic of targeting local internet infrastructure has been used to gain access to user data of citizens from other countries without their or their government's consent.³³⁶

The private sector's ownership can also be a barrier to government efforts, however. Data hosted on Google's servers is Google's property and therefore requires a court order for law enforcement to obtain it. If the data is located in another country, it can be near impossible to get. Aside from data, proprietary software or hardware can be concealed behind intellectual property rights making governing new features of the internet's use difficult. Whether over access to data, control over content, or governance of infrastructure, the diffusion of responsibility between the private sector and governments is often blurred, requiring at times government to settle for less than what they need and at other times requiring the private sector to take a more pronounced role enforcing rules.

The internet governance is also challenged by its technical design.³³⁷ The governance challenges stemming from the internet's design relate in large part to the CIR, like domain names and IP addresses, and who controls them and who has access to the internet. As discussed earlier, internet names and numbers are a limited resource. Internet names can also have considerable economic or social value, like Amazon.com versus Amazonian countries in South America.

³³⁶ For example, Section 702 of the US Foreign Intelligence Surveillance Act permits the US government to access data of foreign individuals so long as that data is stored or passes through US internet infrastructure.

³³⁷ Sandra Braman, "The Irony of Internet Governance Research: Metagovernance as Context," in *Researching Internet Governance, Methods, Frameworks, and Futures*, Laura DeNardis, Derrick L. Cogburn, Nanette S. Levinson, and Francesca Musiani eds. (Cambridge, MA: MIT Press, 2020), 22.

Similarly, because the internet requires a connection via landlines or satellite, accessing the internet is also a key challenge particularly in developing countries. As the internet becomes more of a requirement to develop economically and for education, a lack of internet can be a crippling limitation to communities large and small. Control over internet resources can influence who has access. For example, if the private ISP do not see a reasonable business case for delivering internet to a poor and remote community, it is unlikely that community will have access to the internet.

In all, internet governance can be challenging for the entire ecosystem or actors. Indeed, balancing technical aspects with policy consideration can be a Sisyphean task, as one can affect the other in a zero-sum manner.³³⁸ There are certainly other aspects and issues affecting internet governance that were not covered in the section, like intellectual property rights or cybersecurity. However, the multistakeholder nature and confusion over roles and responsibilities plagues governing those issues as well. Indeed, what makes internet governance unique from other governance regimes is the multistakeholder nature, tension and unclarity over roles and responsibilities, and the interplay between technical aspects of the internet and policy. It is also unique because there is no central international organisation responsible for a large share of internet governance. Instead, it is private sector organisations, like ICANN, and federal regulators developing rules based on domestic factors. This point will be central in discussions in later chapters. Though there are challenges, they have not prevented the internet from being governed entirely or slowed its development.

The Impact of Internet Governance

From the very beginning of the internet the influence of the private sector was prominent in internet governance. Early architects, and even the US government, believed the internet's value would be the greatest if it was free and open with room to grow through innovations in protocols and uses cases. This motivated a system of internet governance defined by multistakeholderism, which has no doubt been a major factor in the internet's growth. The ability for anyone to contribute through protocols, software, hardware, and uses cases enabled an ecosystem of

³³⁸ Milton Mueller, *Networks and States*, 241.

innovation that grew the internet into a global tool that very literally reshaped the human experience and continues to do so.

Of course, the same opportunity to develop the internet through a variety of users has not been without consequence. Malicious actors have used the internet's free and open nature to their advantage as well. And while governments would generally prefer not to stymie the internet's value for society, they are also interested in ensuring it isn't used to harm society either. The interplay between top-down vs bottom-up governance has had important impacts on how the internet functions and who is responsible for governing it. Interestingly, the task of enabling the internet's growth and its many societal benefits vs stunting internet innovation to reign in malign activities is increasingly important when discussing internet governance.

The internet's lack of a centralized governance regime has limited international consensus on major governance issues. So, while there exist international forums with recognized oversight that allow the international community to agree on acceptable or unacceptable behaviour in the shipping or aviation domains, the same does not exist for the internet.³³⁹ The lack of coordinated cooperation can make it difficult to develop international consensus on issues affecting the internet, public policy, and the communities who use it.³⁴⁰ The way the internet is governed does not strictly permit or condone harmful behaviour and early internet architects intended the internet to be a force of good rather than ill. But, without more coordinated control tackling internet governance issues has become largely a patchwork effort. Perhaps the most apt way of describing how internet governance has affected the internet would be to suggest that internet governance has led to considerable growth with truly transformational benefits, but because that growth has been largely unconstrained outside of technical limits, internet governance has also led to incredible consequences as well.

³³⁹ While the IGF and other fora attempt to provide central oversight of the internet, they lack the authority, remit, and ability to affect internet governance like the IMO and ICAO can for their respective domains.

³⁴⁰ There are some issues, like child pornography, where international consensus against the activity does generally exist, however the example is unique. Other issues, like cyber crime or hacking, have less consensus.

Conclusion

Examining each governance organisation, or in the case of the internet, the ecosystem of actors, shows important similarities between them. For example, an inclusive and cooperative process is important to the IMO, ICAO, and internet organisations like ICANN and the IETF. Similarly, each organisation must address emerging challenges stemming from new technology and sustainability. Finally, each has had important impact on its respective domains despite important governance challenges. These similarities are important as they represent common practices as well as common assumptions for governance that will likely play important roles in the development of new space governance. For example, if inclusive and cooperative processes are seen across each organisation despite the uniqueness of each domain, then one can assume a similar cooperative and inclusive process will be expected when producing new space governance.

Though some themes are shared, there are still important differences that speak to how each organisation chooses to approach governance. These differences impact what is required to become a member of an organisation, which actors (i.e., states, private sector, or NGOs) can influence governance, how each organisation is financed, difference in process affecting member participation (i.e., Council vs Assembly influence), consensus requirements to advance an agreement, tools to reach consensus (e.g., the IMO's tacit acceptance procedure), preferences for binding vs non-binding measures, and how each encourages compliance among others. These differences are not a judgement of correct or incorrect, but simply different ways of working toward the same goal of governing. In considering these differences in the context of new space governance, they represent different options for governing the nuances and unknowns of space activities.

There is not one right way to develop international governance. Evident by the chapter's discussion, different processes, outputs, and cultures exist among international governance organisations each of which can be described as successful to a relative extent. As we know from chapter 2, effective international governance requires adaptation. So, as we compare each case study for useful insights, much of the analysis will draw on how each case study organisation and regime adapts overtime. Changes to an international organisation can come in many forms,

from membership growth to funding, processes, and choice of outputs. While changes can occur, not all change reflect efforts to improve or make governance more effective. To better understand how organisations are adapting, each case study will examine four key tenant important to organisational adaptation. These tenants were selected because they reflect core functions of an IO responsible for international governance. These assessment tools help to identify individual governance or organisational characteristics that can inform key governance challenges and solutions. Key tenants of a successful process often include:

- member state buy-in (to the processes and outputs) via member engagement, adoption, and adherence
- organisational agility via technically and scientifically competent members and effective decision-making processes,
- the effectiveness of outputs (how strong are the legal or other requirements of the output and whether the international organisation can assess and encourage compliance), and
- whether the domain can generally be assessed as better for the regime.

Each tenant alone does not provide a clear indication of how effective an IO is. For example, member state buy-in is typically high at COPUOS because the forum has growing membership, sessions are widely attended, and discussion is ongoing. Yet, COPUOS lacks organisational agility evident by its stalled decision-making and the effectiveness of outputs is low due to the lagging production of measures to address contemporary space governance needs. Therefore, it is important to consider these tenants together when evaluating the ability of an IO to adapt, which is critical for effective governance.

Conceptualizing each tenant such that it can be measured and compared is another reason why it is important to assess the tenant collectively. Each tenant represents general features of an IO that could be measured in many ways. For example, member state buy-in could be measured based on the number of members participating in committees or sub-committees or sessions. It could also be measured based on the number of members who adopt or enforce agreements. Still, there are other ways one could measure member state-buy in, and because each case study organisation is unique in certain ways, the comparisons may be loose. The uniqueness of each

case study organisation and the associated governance needs suggests measuring each tenant is likely to be different at times. How one participates in the development of internet protocols looks considerably different from IMO Council participation, for instance.

While each tenant can generally be compared across case studies, the comparison will not be perfect. By assessing them together, however, this research will provide a much clearer and informative picture of organisational adaptation. Like how a mosaic is made up of individually different pieces but together creates a portrait, measuring each tenant across IOs may look slightly different but when patched together they will offer insights into the ways the case study organisations manage to adapt or not.

As proceeding chapters consider specific space activities and how ICAO, the IMO, and internet governance have addressed similar challenges, it will be important to consider what common governance themes are present and how each organisation chooses to modify practices or procedures to develop necessary governance tools and encourage compliance. Together the case studies should provide a clearer picture of what major themes, like cooperative and inclusive processes, and unique approaches, like differences in membership, should be expected or used to develop new space governance.

5. SMALL SATELLITES AND CONSTELLATIONS FOR SUSTAINABLE DEVELOPMENT

The following chapter will draw comparative lessons from the maritime, air, and internet domains to understand how environmental issues from small satellites can be addressed while recognizing that the development of space requires the advancement of small satellite technologies and services. The chapter will first detail the environmental challenges and some solutions for reducing the environmental impact of constellations of small satellites on the space domain. The case studies will then outline how each governance regime is addressing the environmental issues unique to its domain. Aspects of the IMO, ICAO, and internet regime will be discussed, along with key outputs, like conventions, standards, or protocols.

The goal of the chapter is to identify lessons for balancing environmental protection with development to inform new space governance for small satellites. To do this, key themes will be discussed in the concluding portions of each case study section. They reflect the tenants of effective IOs discussed in the previous chapter, including: member state buy in (to the processes and outputs) via mutual trust and member engagement; organisational agility via technically and scientifically competent members and effective decision-making processes; the effectiveness of outputs (how strong are the legal or other requirements of the output and whether the IO can assess and enforce compliance); and, whether the domain can generally be assessed as better for the regime.

The conclusion will also assess tenants of ineffective organisations, including failure to produce outputs, inadequate implementation of agreements, and ineffectiveness of agreements to address the problems affecting the domain and its actors.

Findings from this chapter will highlight how IOs are often responsive, rather than proactive, when it comes to sustainability challenges, but once the topic becomes a focus for the IO it tends to remain one. They will also highlight how different governance measures applied

together are typically required for governing sustainability issues. Finally, this chapter will detail the need for sustainability measure to promote adherence and enforcement.

Small Satellites and Space Development

Developing space is increasingly achieved via small satellites and constellations. There is no agreed upon definition of small satellites, but they are often classified by their weight, normally less than 1000kg, or their development costs, scalability, and functionality.³⁴¹ An important tool for the next stage in space development, small satellites are not exactly new. By some definitions, the very first human satellite, Sputnik 1, was a small satellite. What makes them so transformative today is the miniaturization of technology³⁴² which allows satellites to be smaller, offer more affordable production and launch costs, and they can be developed iteratively over months or years. These innovations have allowed small satellites to match the rapid innovation life cycles of other technologies, like smart phones or computers, and usher in new use cases and business models.

The reduction in cost but improvement in functionality has made it possible to launch hundreds and thousands of small satellites in low and medium Earth orbit to provide satellite services in new ways. One major development area is low-latency broadband provided by large constellations of small satellites.³⁴³ There is a growing appetite for large constellations of small satellites to fill gaps in broadband coverage to rural areas or make high quality broadband more accessible all the time (i.e., on a plane). Another development area is Earth observation and related data analytics.³⁴⁴ Increased access to high quality images of Earth taken more frequently has spurred demand by industry, government, and NGOs alike.

³⁴¹ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, “Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM),” 1-3, 1-5.

³⁴² Specifically, the miniaturization of attitude and orbit determination controls, power generation and storage, fuel cells, batteries, thermal controls among others are helping change the cost and use case of smaller satellites. For more see: Ibid., 3-24.

³⁴³ Joseph R. Kopacz, Roman Herschitz, and Jason Roney, “Small satellites an overview and assessment,” *Acta Astronautica* 170 (2020), 94.

³⁴⁴ Ibid., 94-96.

Growing use of space through constellations of small satellites is also increasing growth in demand for sensing activities related to space situational awareness.³⁴⁵ As space becomes more populated by satellites with data flowing between them and ground stations, satellite operators and governments are increasingly in need of better situational awareness for radio frequency mapping, weather monitoring, automatic identification systems, and more.³⁴⁶ In addition to the use cases above, between 2011-2020 on average ~33% of small satellite applications were focused on technology development.³⁴⁷ Through small satellites it has become more affordable to conduct experiments and test new technology, which is essential to innovation in space.

The use of small satellites to further develop space and space services has the potential to encourage new activities and advance the domain's development. The change in satellite affordability and functionality drives greater interest in and access to space services from governments, commercial companies, and NGOs alike. We see this most acutely through the continued growth in public and private funding for small satellite activities and commercial space start-ups.³⁴⁸

Small satellites are without a doubt a principal source and central feature of modern space development. Though they are expected to change in size, capability, and use case, satellites will continue to be the primary means of developing space for the foreseeable future. It is therefore important to understand how international governance for small satellite activities will affect the sustainable development of space. Because for the major role small satellites play in the development of space, they also pose the most significant risk to space sustainability for their role related to debris and other issues of congestion and environmental degradation.

³⁴⁵ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, "Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)," 3-9.

³⁴⁶ Ibid., 3-9.

³⁴⁷ Bryce Tech, "Smallsats by the Numbers," 2021, 11, accessed September 2021, https://brycetek.com/reports/report-documents/Bryce_Smallsats_2021.pdf.

³⁴⁸ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, "Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)," 3-18.

Small Satellites as a Source of Debris

The increasing use of satellites places them at the centre of the space debris challenge. In fact, there is a direct correlation between the concentration of satellites in orbit and major increases in space debris.³⁴⁹ The issue of debris can be mitigated, however through thoughtful governance that addresses design, deployment, and use of satellites.

According to a European Space Agency study on space debris, propulsion has historically been the leading cause of fragmentation events.³⁵⁰ Debris resulting from propulsion issues often stem from leftover propellant or battery malfunctions.³⁵¹ These events occur due to electrical or chemical events which generate pressure beyond the satellite's structural limits.³⁵² Problems that may lead to accidental explosions from power sources or propellant are often not known for years after launch once the satellite has seen greater stress from the space environment or many duty cycles.³⁵³ Commonly, propulsion events take place within two years of launch and most often within ten years.³⁵⁴ While most satellites in LEO will naturally degrade back to Earth within 25 years,³⁵⁵ the creation of debris from propulsion events within the first two years can leave dead or inoperable satellites in LEO for a considerable amount of time before they naturally re-enter Earth's atmosphere. The problem of unknown power or propulsion issues and slow re-entry times becomes worse when considering many new small satellites use cases entail launching dozens of small satellites at once and hundreds over months. In such a scenario a propulsion issue could present itself a year or two into the constellation's mission, effectively rendering large segments of the constellation space junk or cause debris events across the constellation.

³⁴⁹ Office of Inspector General, "NASA's Efforts to Mitigate the Risks Posed by Orbital Debris," National Aeronautics and Space Administration, January 2021, 1, accessed September 2021, <https://oig.nasa.gov/docs/IG-21-011.pdf>.

³⁵⁰ ESA Space Debris Office, "ESA's Annual Space Environment Report," European Space Agency, April 2022, 78/120, accessed September 2021.

https://www.sdo.esa.int/environment_report/Space_Environment_Report_latest.pdf.

³⁵¹ Working Group 4, "Support to the IADC Space Debris Mitigation Guidelines," Inter-Agency Space Debris Coordination Committee, December 2019, 18-19, accessed September 2021.

³⁵² Ibid., 19.

³⁵³ IADC Steering Committee, "IADC Statement on Large Constellations of Satellites in Low Earth Orbit," Inter-Agency Space Debris Coordination Committee, September 2017, 8, accessed September 2021.

³⁵⁴ ESA Space Debris Office, "ESA's Annual Space Environment Report," 59.

³⁵⁵ Ibid., 67-70.

Another major source of debris, approximately 7%, occurs when objects are deliberately released during normal operation.³⁵⁶ Components, like lens caps or fasteners, are often released during the deployment or operation of a satellite becoming debris. In addition to propulsion and deliberate events, anomalies, unknown causes, and aerodynamics round out the top five sources of debris.³⁵⁷ The IADC has noted that it is “relatively easy, both technically and economically, to take mitigation measures against these objects.”³⁵⁸ The principal challenge is simply ensuring satellite operators adopt these measures, which there are often no laws or requirements to do so.

Collisions remain a relatively rare source of debris, but this could change.³⁵⁹ The number of small satellites being deployed in LEO is occurring at unprecedented speed and scale. Between three commercial companies alone, SpaceX, OneWeb, and Amazon’s Project Kuiper, approximately 100,000 satellites are planned for launch over the next decade.³⁶⁰ The most developed small satellite constellation operated by commercial company, SpaceX, is composed of 2419 active satellites as of July 2022.³⁶¹ According to analysis by Hugh Lewis, those satellites have experienced approximately one million close approaches with other objects with some 10,000 maneuverers.³⁶² The exponential increase in SpaceX Starlink satellites between 2020-2021 has had “disproportionate effect on the number of [satellite] conjunctions” in certain orbits.³⁶³ The incredible change occurring challenges the limited STM practices in use while increasing confusion over responsible behaviour. These changes arguably set the conditions for more debris causing collisions. Even if rare, collision events, like the 2009 Iridium-33 and

³⁵⁶ Working Group 4, “Support to the IADC Space Debris Mitigation Guidelines,” 15.

³⁵⁷ ESA Space Debris Office, “ESA’s Annual Space Environment Report,” 55.

³⁵⁸ Working Group 4, “Support to the IADC Space Debris Mitigation Guidelines,” 15.

³⁵⁹ ESA Space Debris Office, “ESA’s Annual Space Environment Report,” 55.

³⁶⁰ Caleb Henry, “SpaceX Submits paperwork for 30,000 More Starlink Satellites,” *Space News*, October 2019, accessed April 2020, <https://spacenews.com/spacex-submits-paperwork-for-30000-more-starlink-satellites/>; Jeffrey Hill, “OneWeb Explains FCC Application for 48,000 Constellation Satellites,” *Satellite Today*, May 2020, accessed April 2020, <https://www.satellitetoday.com/broadband/2020/05/27/oneweb-explains-fcc-application-for-48000-constellation-satellites/>; and, Caleb Henry, “Amazon Moving Project Kuiper Team to New R&D Headquarters,” *Space News*, December 2019, accessed April 2020, <https://spacenews.com/amazon-moving-project-kuiper-team-to-new-rd-headquarters/>.

³⁶¹ Jonathan McDowell, “Starlink Statistics”.

³⁶² Hugh Lewis, Twitter post, April 28, 2022 (10:14 a.m.), accessed April 28, 2022, <https://twitter.com/ProfHughLewis/status/1519681544671145984>.

³⁶³ Hugh Lewis, Twitter post, September 10, 2021 (10:06 a.m.), accessed April 28, 2022, <https://twitter.com/ProfHughLewis/status/1436330322807906306?s=20>.

Kosmos2251 event, can produce thousands of pieces of new debris, making collisions consequential debris causing events.³⁶⁴

Satellite Debris Mitigation and Remediation

Solving the debris problem takes two forms: mitigation and remediation. Mitigation looks to prevent the creation of new debris through design, operation, and use (e.g., post-mission disposal of satellites) while remediation refers to the active removal of existing debris.³⁶⁵

Various mitigation measures to limit propulsion malfunctions or other sources of debris must be designed into the satellite before it is launched and complemented by appropriate operating practices. For example, designing into a satellite active collision avoidance could help prevent collisions with other satellites or existing debris, while incorporating on-board redundancies for all functions required for post mission disposal can ensure in the event of a malfunction the spacecraft can still safely deorbit.³⁶⁶ Passivation of stored energy within a satellite is another relatively simple solution proposed by the IADC and other organisations to significantly reduce the occurrence of debris causing events from propulsion systems. Passivation typically occurs by burning or venting excess fuel, draining batteries, obviating pressure onboard the satellite, including redundant systems, and using high-pressure vessels.³⁶⁷ Passivation measures are not necessarily required to operate a satellite and therefore are not incorporated in all satellites; they must be designed into the satellite for the purpose of mitigating debris.

Post mission disposal is another mitigation measure. Research has shown that removing 90% or more of satellites within 25 years of completing their mission can have a significant impact on reducing the growth of debris in critical orbits.³⁶⁸ Given the altitude of LEO, most satellites will naturally fall back to Earth within the 25-year period, however, to control how and

³⁶⁴ https://www.esa.int/Safety_Security/Space_Debris/About_space_debris

³⁶⁵ Office of Inspector General, “NASA’s Efforts to Mitigate the Risks Posed by Orbital Debris,” 4.

³⁶⁶ IADC Steering Committee, “IADC Statement on Large Constellations of Satellites in Low Earth Orbit,” 8-9

³⁶⁷ IADC Steering Group and Working Group 4, “IADC Space Debris Mitigation Guidelines,” Inter-Agency Space Debris Coordination Committee, June 2021, 9, accessed September 2021, https://iadc-home.org/documents_public/view/id/82#u.

³⁶⁸ Office of Inspector General, “NASA’s Efforts to Mitigate the Risks Posed by Orbital Debris,” iii.

when satellites fall back to earth can require incorporating propulsion or drag features into satellites that provide an ability to affect the satellite's trajectory. In MEO and GEO active deorbiting measures are necessary to meet the 25-year timeline because satellites in those orbits would not otherwise naturally deorbit within the prescribed timeframe.

Currently, end of mission disposal rates varies by orbit. Though most LEO satellites will naturally deorbit within 25 years, only roughly half of the satellites that ended their mission in 2017 were actively deorbited.³⁶⁹ Given the increase rate at which small satellites are being launched into LEO, deorbiting satellites as soon as their mission is complete can be beneficial. In GEO, approximately 80% of satellites follow end of life disposal guidance.

The difference in compliance is due in large part to differences in the cost proposition of LEO and GEO satellites. LEO satellites are more affordable to produce and launch than GEO satellites, but end of life disposal can be more costly for LEO satellites than GEO satellites when compared to the satellite's overall value.³⁷⁰ For operators, the low production and operating cost of LEO satellites combined with relatively high cost of post-mission disposal can disincentivize designing in post mission disposal features. The opposite is true for GEO, where the high cost of GEO satellites combined with low cost of post-mission disposal can encourage deorbiting.

In addition to deorbiting 90% of satellites post-mission, removing existing debris is essential to stabilizing earth orbits.³⁷¹ As of the time of writing, active debris removal has yet to occur (though many technology demonstrations have taken place) due to technological and economic barriers.³⁷² Active debris removal could be accomplished in several ways, including lasers fired

³⁶⁹ OECD Science, Technology, and Industry, "Space Sustainability: The Economics of Space Debris in Perspective," Organization for Economic Co-operation and Development, April 2020, 31, accessed September 2021, <https://www.oecd-ilibrary.org/docserver/a339de43-en.pdf?expires=1658414312&id=id&accname=guest&checksum=913AB3DC3B31E43A49CE6C10B6E5F7EB>.

³⁷⁰ Ibid.

³⁷¹ Office of Inspector General, "NASA's Efforts to Mitigate the Risks Posed by Orbital Debris," 17.

³⁷² OECD Science, Technology, and Industry, "Space Sustainability: The Economics of Space Debris in Perspective," 33.

from Earth to slow debris causing them to fall to Earth³⁷³ or by grabbing debris with an active satellite and moving it appropriately.³⁷⁴ For large objects, which pose the greatest risk of collision,³⁷⁵ it will generally require advanced rendezvous operations to grab or attached the defunct object to an active satellite before using the active satellite to safely deorbiting it.³⁷⁶

While rendezvous operation will be discussed in greater detail in chapter seven, part of what complicates removing existing debris via rendezvous operations is the difficulty of attaching or grabbing a defunct object. Only very recently have satellite designs started considering features that allow them to be grabbed or connected to for the purpose of active debris removal.³⁷⁷ Without standards that streamline retrieval options, a spectrum of choices, from nets, to harpoons, claws, and lassos have all been proposed for capturing debris.³⁷⁸ As satellites are advanced it will be important that design features are incorporated into them that allow them to be easily removed.

For both mitigation and remediation, satellites will need to incorporate better passive and active tracking features to provide greater situational awareness to satellite operators. A more congested space environment will require greater fidelity of satellite performance, telemetry, and trajectory to avoid conjunctions and break-up events. Additional discussion of SSA and STM will be provided in the next chapter, but the design and operation of a small satellites should account for the need to ‘plug-in’ to a SSA network that provides a more comprehensive picture of space traffic.

³⁷³ Claude R. Phipps, Kevin L. Baker, Stephen B. Libby, et al, “A Laser-Optical System to Remove Low Earth Orbit Space Debris,” Presentation at 6th European Conference on Space Debris, Darmstadt, DE, 22-25 April 2013, accessed October 2021, <https://conference.sdo.esoc.esa.int/proceedings/sdc6/paper/29/SDC6-paper29.pdf>.

³⁷⁴ <https://astroscale.com/astrocales-elsa-d-successfully-demonstrates-repeated-magnetic-capture/>

³⁷⁵ <https://www.forbes.com/sites/jonathanocallaghan/2020/09/10/experts-reveal-the-50-most-dangerous-pieces-of-space-junk-orbiting-earth-right-now/?sh=3d94d30e7c21>

³⁷⁶ Office of Inspector General, “NASA’s Efforts to Mitigate the Risks Posed by Orbital Debris,” 12.

³⁷⁷ For example, the OneWeb constellation has been very vocal about the importance of debris mitigation and remediation measures and suggested it is considering features of active debris removal. See: One Web, “OneWeb’s Approach to Space Debris Mitigation,” Presentation at UN/UAE High Level Forum, 8 November 2017, accessed October 2021,

https://www.unoosa.org/documents/pdf/hlf/HLF2017/presentations/Day3/Special_Session/Presentation2.pdf.

³⁷⁸ Office of Inspector General, “NASA’s Efforts to Mitigate the Risks Posed by Orbital Debris,” 12.

How to design, operate, and dispose of small satellites to mitigate and remove debris is well enough understood to play a significant role in space sustainability today. What is less clear is how to develop measures and ensure actors act as part of the debris solution rather than the debris problem.

Conclusion

Small satellites are essential to future space development but only if they can be properly designed, operated, and disposed of to ensure satellites do not first overburden the space environment. Design features are required to both mitigate and remediate debris, but also ensure satellites can be properly coordinated through STM. Numerous barriers exist, however, to making these features common practice.

With much of space development occurring through commercial endeavours, private companies will either need laws requiring certain debris mitigation or remediation measures or the economic incentive to adopt debris conscious practices on their own. In a perfect world, both laws and economic incentives would complement one another. However, such a world does not exist, and generally private companies choose the least expensive means to comply with environmental considerations.³⁷⁹ Moreover, a patchwork of dissimilar domestic regulations would only have a limited effect. Therefore, the most likely route toward more sustainable practices will occur through international space governance.

Space is undergoing rapid change, and rapid change can be difficult for international governance to keep pace with. Rather than attempting to develop new space governance in isolation, it can be useful to learn from other domains which have faced similar sustainability issues. In doing so, the goal is to better understand what drives the need for new governance, what processes permit or discourage new governance, and what measures are effective. Using the three case studies below, the following sections in the chapter will draw out useful lessons to inform the development of new space governance for small satellites.

³⁷⁹ Nodir Adilov, Peter J. Alexander, and Brendan M. Cunningham, “An Economic Analysis of Earth Orbit Pollution,” 93.

Maritime Case Study

The IMO is responsible for governing important maritime services, like shipping. How it governs shipping can affect the marine environment and broader economic development. Balancing environmental preservation with economic development is therefore a key consideration for the organisation and the governance it produces.

The IMO's initial mandate focused on maritime safety and navigation. It quickly became clear that safety and environmental protection were interrelated, and so the IMO began taking responsibility for environmental protection issues as well.³⁸⁰ The IMO does this through conventions, protocols, guidelines, and other measures organized and produced through a series of IMO organs responsible for specific topics and issues areas. At the time of writing the IMO has produced 51 treaty instruments for the regulation of international shipping, of which 21 are environment related, and numerous codes, guidelines, and other governance tools.³⁸¹ The IMO addresses environmental security through regulations on commercial shipping focused generally on how ships are built, maintained, and operated.³⁸²

IMO Organs Focused on Maritime Safety, Security, and Marine Protection

IMO has several committees responsible for executing the organisation's mandate, which differs considerably from COPUOS' three committees. The Maritime Safety Committee (MSC) was the first committee created to support the Assembly and Council. Its role is to consider any issues affecting maritime safety, including navigation, construction and equipment of vessels, manning from a safety standpoint, rules for the prevention of collision, handling of dangerous

³⁸⁰For example, the 1967 grounding of the Torrey Canyon oil tanker triggered the development of the 1969 Convention on the High Seas Intervention in Oil Pollution Causalities. Similarly, the 1989 Exxon Valdez oil spill led the IMO in 1992 to amend MARPOL to include a double hull design requirement for tankers of certain sizes. For more see: "IMO and the Environment," International Maritime Organization, accessed October 2021, 2, <https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/IMO%20and%20the%20Environment%202011.pdf>; and, Louis Sohn, Kristen Gustafson Juras, John Noyes, and Erik Franckx, *Law of the Sea in a Nutshell*, 370.

³⁸¹"Marine Environment," International Maritime Organization, accessed October 2021, <https://www.imo.org/en/OurWork/Environment/Pages/Default.aspx>.

³⁸²Organization for Economic Cooperation and Development, "International Regulatory Co-operation: The Role of International Organizations in Fostering Better Rules of Globalisation," 88.

cargoes, marine casualty investigations, and many other related topics.³⁸³ The MSC is open to all member states and meets either once or twice a year depending on the Assembly's meeting schedule. Initially focused on maritime safety, the MSC eventually became responsible for topics related to maritime environmental matters due, in part, to the overlap between safety issues and environmental consequences (i.e., shipping sinking due to poor navigation practices).

The Marine Environment Protection Committee (MEPC) was created initially as a subcommittee before being elevated to a full committee to lead the IMO's work on "any matter within the scope of the Organization concerned with prevention and control of pollution from ships."³⁸⁴ It was established in 1973, is open to all members, and meets three times biannually. The LEG was the next committee born out of new issues affecting shipping. The Leg Committee (LEG) addresses legal issues, including liability and compensation related to operating ships, damage, pollution, passenger claims, and wreck removal.³⁸⁵ The LEG is open to all IMO members and meets three times in a two-year period. There are other full committees that aid the IMO's work, but they fall outside the focus of this chapter.

The MSC, MEPC, and LEG are supported by several sub-committees with more acute focuses, the Sub-Committee on Pollution Prevention and Response and the Sub-Committee on Ship Design and Construction are two examples. Through these IMO organs, the IMO has created a tapestry of convention, protocols, codes, guidelines, and other tools to safely and environmentally consciously advance international shipping.

IMO Conventions for the Design, Construction, and Operation of Ships

The IMO's initial focus on safety and navigation was intended to protect ships, property, and human life, but it quickly became apparent that poor safety and navigation standards also caused considerable environmental damage. There is a robust set of conventions that outline key regulations, processes, guidelines, and more to guide maritime actors toward safer and more

³⁸³ "Structure of IMO," International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Pages/Structure.aspx#3>

³⁸⁴ Ibid.

³⁸⁵ "Legal Committee (LEG)," International Maritime Organization, accessed October 2021, <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/LEG-Default.aspx>.

sustainable shipping practices. Of the conventions, the IMO identifies twelve which sit at the centre of safety and navigation governance. This section will discuss only a few which are most applicable to the design, construction, and operation of ships, and the discussion on the operation of ships will stop short of maritime traffic management because traffic management will be discussed in the next chapter.

One of the IMO's foundational conventions, the International Convention for the Safety of Life at Sea (SOLAS), was produced in 1914 in response to the Titanic disaster. SOLAS was updated (more than amendments) in 1928, 1948, 1960, and 1974. The current version, SOLAS 1974, has seen more than 180 amendments or additions since 1981.³⁸⁶ The purpose of SOLAS is to outline standards for construction, equipment, and operation of ships compatible with their safety.³⁸⁷ SOLAS also outlines port State control, a key feature for improving compliance with IMO agreements.³⁸⁸

A lengthy convention (178 pages), SOLAS includes eight articles and 14 chapters. The chapters detail the regulations. Chapter 1 of SOLAS covers regulations for the classification of ships and compliance documentation. Nearly half of the document, Chapter 2 is two parts and deals with construction through 117 detailed regulations.³⁸⁹ They cover subdivision and stability, machinery, electrical installation, and fire protection, detection, and extinction. Each of the main topics includes dozens of related subtopics. Chapter 3 addresses life-saving appliances and arrangements, chapter 4 radiocommunications, chapter 5 safety of navigation, 6 carriage of cargos, chapter 7 carriage of dangerous goods, chapter 8 nuclear ships, chapter 9 management of safe operations of ships, chapter 10 safety measures for high-speed craft, chapter 11 covers special measures to address maritime safety and security (specifically ROs, enhanced surveys, port State control requirements, and the International Ship and Port Facility Security (ISPS)

³⁸⁶ "Status of IMO Treaties," International Maritime Organization, 3-5, accessed October 2021, <https://wwwcdn.imo.org/localresources/en/About/Conventions/StatusOfConventions/Status%20-%202021.pdf>.

³⁸⁷ [https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-\(SOLAS\),-1974.aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx)

³⁸⁸ "International Convention for the Safety of Life at Sea (SOLAS), 1974," International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-\(SOLAS\),-1974.aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx).

³⁸⁹ Chapter 2 parts 1-2 cover 83 of the 178 total pages in the convention. Treaties and International Agreements Registered, 30 June 1980, *UNTS* 18961, Vol. 1184, 289-372.

Code), chapter 12 addresses additional safety measures of bulk carriers, chapter 13 outlines verification of compliance (i.e., the member state audit scheme), and chapter 14 enhances safety measures for ships operating in polar waters by making mandatory part 1-A of the Polar Code.³⁹⁰

The detailed regulations covering a wide variety of relevant topics complemented by implementation and compliance processes (e.g., port state control, member firm audit scheme, etc.) demonstrates why it is a cornerstone agreement within maritime governance. Additionally, the frequency at which it is amended through tacit acceptance allows the agreement to remain relevant despite frequent change in member firm preferences, safety and security concerns, or technology. As of the time of writing, 166 states (99% of merchant tonnage) are parties to SOLAS.³⁹¹

Acting as another cornerstone convention, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), standardized the varied and incoherent set of national training certification standards for seafarers at an international level.³⁹² The agreement, originally adopted in 1978 and amended in 1995 and 2010, prescribes standards for training certification and watchkeeping for seafarers, which adopting states are required to meet or exceed.³⁹³ The convention covers eight chapters detailing regulations on Master and deck department, engine department, radiocommunication and radio personnel, special training requirement for personnel on certain types of ships, emergency, occupational safety, medical care and survival functions, alternative certification, and watchkeeping.

In 1995 amendments were made to the convention to clarify language, change technical annexes into regulations, and produce a new STCW Code, which expands on the convention's

³⁹⁰ Ibid; and, "International Convention for the Safety of Life at Sea (SOLAS), 1974," International Maritime Organization.

³⁹¹ "Status of IMO Treaties," International Maritime Organization, 17.

³⁹² "International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)," International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers-\(STCW\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers-(STCW).aspx).

³⁹³ Ibid.

requirements.³⁹⁴ The original STCW convention was also updated to require contracting states to “provide detailed information to IMO concerning administrative measures taken to ensure compliance with the Convention, education and training courses, certification procedures and other factors relevant to implementation.”³⁹⁵ The information is then reviewed by experts nominated by parties to the convention who report to the MSC. The reporting requirement represent the first time the IMO was asked to undertake implementation measures, which are typically the responsibilities of states.³⁹⁶ The 2010 Manila amendments to STCW Convention and Code was another substantial change agreed to via tacit acceptance that not only updated the agreement but also sought to proactively address future issue.

The agreement holds a foundational place in maritime governance through its ability to cohere basic training and qualification practices at the international level. The incoherence in training and other standards made it tricky to adjudicate fault and prevent incidents at sea. Conversely, shared international standards and the ability to monitor compliance have enabled the IMO to govern more effectively by enabling the IMO and states to adjudicate practices against common standards. STCW has 166 contracting states representing 99% of merchant tonnage.³⁹⁷

The International Convention on Load Lines (LL 1966) was adopted in 1966 to ensure the watertight integrity of the ship’s hull given the ship’s load. The regulation accounts for different zones, areas, seasonal periods, and other safety measures addressing doors, freeing ports, hatchways, and more.³⁹⁸ Amendments to the LL convention were adopted in 1971, 1975, 1979, and 1983 but none received enough acceptance to come into force. In 2000 the 1988 Protocol (LL Prot 1988) was entered into force which, among other things, introduced the tacit acceptance

³⁹⁴ *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)*, International Maritime Organization.

³⁹⁵ STCW, Chapter 1, regulation 1/7, see: *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)*, International Maritime Organization.

³⁹⁶ *Ibid.*

³⁹⁷ “Status of IMO Treaties,” International Maritime Organization, 414.

³⁹⁸ “International Convention on Load Lines,” International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Load-Lines.aspx>.

procedures. There are 166 contracting states (99% of merchant tonnage) to LL 1966.³⁹⁹ For LL Prot 1988 there are 118 contracting states (98% of merchant tonnage).⁴⁰⁰

The 1972 International Convention for Safe Containers (CSC) was developed in response to the rapid increase in container use in shipping. The CSC convention provides “generally acceptable test procedures and related strength requirements” to ensure the safety in transport and handling of containers, and uniform international safety regulations applicable to all modes of surface transport.⁴⁰¹ The standards and regulations cover testing, inspection, and approval. Though container use is a central feature of modern shipping, only 84 states, or 65% of merchant tonnage, are party to the CSC convention; a clear limitation for the agreement.⁴⁰²

In a first, the IMO adopted in 1977 the Torremolino International Convention for the Safety of Fishing Vessels (SFV). The goal was to provide safety requirements for construction and equipment of certain new fishing vessel.⁴⁰³ Unfortunately, the topic proved controversial. For technical and other reasons, states were unwilling to support the agreement. In 1993 and again in the 2000s, the IMO attempted to resolve issues preventing ratification, however the latest iteration, the Cape Town Agreement of 2012, is still short of the necessary number of contracting states and required aggregate number of necessary fishing vessels to enter into force.⁴⁰⁴ Standing in the way are state’s concerns that new requirements will place a financial and technical burden on commercial fishing fleets, which for some states represent key economic interests. Drawing a parallel to space, a similar agreement might prohibit developing states from designing and operating their own satellites.

In addition to the SFV convention, the IMO has addressed safety of fishing vessels and personnel by modifying the STCW to create to the STCW for fishing vessels and personnel,

³⁹⁹ “Status of IMO Treaties,” International Maritime Organization, 207.

⁴⁰⁰ *Ibid.*, 225.

⁴⁰¹ “International Convention for Safe Containers (CSC),” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-Safe-Containers-\(CSC\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-Safe-Containers-(CSC).aspx).

⁴⁰² “Status of IMO Treaties,” International Maritime Organization, 326.

⁴⁰³ “The Torremolinos International Convention for the safety of Fishing Vessels,” International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/The-Torremolinos-International-Convention-for-the-Safety-of-Fishing-Vessels.aspx>.

⁴⁰⁴ *Ibid*; and, “Status of IMO Treaties,” International Maritime Organization, 500.

1995 (STCW-F). The STCW-F carries many of the same principles and tools (i.e., certification of key crew, emergencies procedures, etc.) as the STCW, but also includes some modifications relevant to fishing vessels and crews.⁴⁰⁵ The STCW-F has entered into force, but with only 33 contracting states, it represents a small portion of relevant fishing community.⁴⁰⁶

The IMO's work discussed above seeks to prevent issues through the design, construction, and operation of ships. It reflects a comprehensive set of treaties and codes nearly all of which have seen minor or significant modification over the years. Some, like the SFV have poor adoption due to the perceived economic impact the agreement may have on fishing communities. Other agreements, however, represent nearly all shipping by tonnage. Compared to existing space governance related to space sustainability, the IMO's work is far more comprehensive and considerably more mature.

IMO Conventions Related to Environmental Protection

The IMO uses eight central conventions to outline core measures to protect the maritime environment from vessel-source pollution. The conventions preform regulatory, jurisdictional, and cooperation functions.

The International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties 1969 (Intervention Convention) resulted from the Torrey Canyon disaster to extend jurisdiction to coastal states over foreign vessels so the coastal state may take measures to prevent, mitigate, or eliminate oil pollution dangers resulting from a maritime casualty.⁴⁰⁷ The Protocol of 1973 amended the convention to expand the list of substance covered by it. While the Intervention convention provide states additional jurisdiction, it is not boundless. The coastal state must act only after proper consultation with the flag state or states involved and can be liable for

⁴⁰⁵ "International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel (STCW-F), 1995," International Maritime Organization, accessed October 2021, <https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-F-Convention.aspx>.

⁴⁰⁶ "Status of IMO Treaties," International Maritime Organization, 426.

⁴⁰⁷ "International Convention Relating to Intervention on the High Seas in Cases of Oil pollution Casualties, 1969," International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/The-Torremolinos-International-Convention-for-the-Safety-of-Fishing-Vessels.aspx>.

compensation if the coastal state takes actions that are found to exceed the remit of the convention.⁴⁰⁸ As of 2021, the Intervention Convention has 90 contracting states representing 75.20% of merchant tonnage.⁴⁰⁹ The Protocol of 1973 has 58 contracting states representing 53.84% of the merchant fleet.⁴¹⁰

Also resulting from the Torrey Canyon disaster is the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (London convention). It prohibits the dumping of certain hazardous materials and requires a permit to dump other identified materials or waste or matter.⁴¹¹ ‘Dumping’ was defined broadly but includes substance from ships or platforms as well as disposal of ships and platforms.⁴¹² The convention’s annex includes a detail list of prohibited waste. In 1993 the convention was amended to include low-level radioactive wastes and again in 1995 to phase out dumping of industrial wastes and banned the incineration of industrial wastes at sea.⁴¹³

The most substantial evolution of the London convention was the 1996 London Protocol. The protocol sought to effectively replace the London convention and prohibit all dumping except for possibly acceptable wastes detailed in an annex to the Protocol. It also states that the polluter should “in principle bear the cost of pollution”. There are interests in expanding the Convention and Protocol to address concentrations of CO₂ in the atmosphere and that new climate engineering technologies do not harm the marine environment.⁴¹⁴ In 2021 the London Convention had 87 contracting states representing 60% of merchant tonnage. The London Protocol has 53 contracting states representing far less of the global merchant fleet by tonnage. The disparity in adoption suggests the stricter guidelines called for by the Protocol have created less incentive for state adoption.

⁴⁰⁸ Ibid.

⁴⁰⁹ “Status of IMO Treaties,” International Maritime Organization, 234.

⁴¹⁰ Ibid., 252.

⁴¹¹ “Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter,” International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter.aspx>.

⁴¹² Ibid.

⁴¹³ Ibid.

⁴¹⁴ Ibid.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is one of three core conventions identified by the IMO and the main convention covering “prevention of pollution of the marine environment by ships from operational or accidental causes”. It was adopted in 1973 and updated through two protocols (1978 and 1997) and other important modifications to Annexes.⁴¹⁵ It is regulatory in nature offering detail technical annexes detailing ship design requirements and specific operational controls to minimize pollution from ships during operation or from accidents.⁴¹⁶ MARPOL offers marine protection first through general standards and second through more specific requirements for special areas.

Adopting MARPOL requires states to become a party to the first two amendments (prevention of pollution by oil and noxious liquid substance), while the remaining four annexes (harmful substances via packages, sewage, garbage, and air pollution from ships) are optional. MARPOL has 160 contracting states representing 99% of merchant tonnage.⁴¹⁷ Though optional, annexes III-VI have also been adopted by enough states to cover ~95% of merchant tonnage.⁴¹⁸

The International Convention on Oil Pollution Preparedness, Response, and Co-operation (OPRC) was adopted in 1990 and complemented via protocol in 2000 (OPRC-HNS 2000). Its focus is planning and international coordination for the prevention and response to oil pollution emergencies.⁴¹⁹ The 2000 protocol expands from oil to include other hazardous or noxious substances. There are 115 and 41 contracting states to the OPRC and subsequent 2000 Protocol respectively.⁴²⁰ Adopting states have differed in their implementation of the OPRC and OPRC-HNS 2000 Protocol, leaving gaps in quality and preparedness among states.⁴²¹

⁴¹⁵ “International Convention for the Prevention of Pollution from Ships (MARPOL),” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-\(MARPOL\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx).

⁴¹⁶ Ibid.

⁴¹⁷ “Status of IMO Treaties,” International Maritime Organization, 234, 117.

⁴¹⁸ Ibid., 117, 122, 126, 129, 176.

⁴¹⁹ “International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC),” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Oil-Pollution-Preparedness,-Response-and-Co-operation-\(OPRC\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Oil-Pollution-Preparedness,-Response-and-Co-operation-(OPRC).aspx).

⁴²⁰ “Status of IMO Treaties,” International Maritime Organization, 492, 495.

⁴²¹ Karen Purnell, “4 Major Oil and HNS Spills: Measures Taken by the IMO to Promote Global Ocean Governance,” in *The IMLI Treatise On Global Ocean Governance: Volume III: The IMO and Global Ocean Governance* eds David Joseph Attard, Rosalie P Balkin, Donald W Greig (Oxford, UK: Oxford University Press, 2018), 80.

Adopted by the IMO in 2001, the International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention) regulates the use of anti-fouling paints once used to prevent sea life from attaching to ships.⁴²² These substances are known to be hazardous to sea life and were therefore prohibited under the convention. Specific anti-fouling systems covered under the convention are listed in the Annex. Importantly, the convention established a “technical group” to review proposals for the prohibition of substances not listed in the annex.⁴²³

Taking a somewhat more technical approach than other marine protection conventions, the IMO adopted the International Convention for the control and Management of Ships' Ballast Water and Sediments (BWM convention) in 2004. The BWM convention uses standards and procedures to control the spread of harmful aquatic organisms through ships' ballast water and sediments.⁴²⁴ The BWM convention requires all ships in international water to implement a Ballast Water and Sediments Management Plan, carry a Ballast Water Record Book, and carry out ballast water management procedures to certain standards.⁴²⁵ Convention articles address reception facilities, research and monitoring, survey, certification, and inspection, and technical assistance. The convention's annexes detail associated technical standards.

The BWM convention was produced while necessary technology to control ballast water and sediments safely, economically, and efficiently was still in its infancy and not widespread. The convention addresses this by allowing parties to the convention to impose additional measures on ships to prevent, reduce, or eliminate the transfer of harmful organism. It also permits the MPEC to approve “other methods of ballast water management...provided such methods ensure at least the same level of protection.”⁴²⁶ Through Regulation D-4, the BWM

⁴²² “International Convention on the Control of Harmful Anti-fouling Systems on Ships,” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-the-Control-of-Harmful-Anti-fouling-Systems-on-Ships-\(AFS\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-the-Control-of-Harmful-Anti-fouling-Systems-on-Ships-(AFS).aspx).

⁴²³ Ibid.

⁴²⁴ “International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM),” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-\(BWM\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx).

⁴²⁵ Ibid.

⁴²⁶ Ibid.

convention permits the testing and evaluation of new Ballast Water treatment technologies.⁴²⁷ Finally, the convention addresses the lack of technology by requiring the IMO to review the Ballast Water Performance Standard while considering safety, environmental, practicability, cost effectiveness, and biological effectiveness.⁴²⁸ Despite 86 contracting states representing 91% of gross merchant tonnage,⁴²⁹ the novel nature of the technology and practices outline in the BWM have made implementation tricky, especially for developing states.

The final of the eight IMO conventions focused on marine protection has not yet entered into force despite being adopted in 2009.⁴³⁰ The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (Hong Kong convention) is focused on regulating the “the design, construction, operation and preparation of ships so as to facilitate safe and environmentally sound recycling, without compromising the safety and operational efficiency of ships; the operation of ship recycling facilities in a safe and environmentally sound manner; and the establishment of an appropriate enforcement mechanism for ship recycling, incorporating certification and reporting requirements.”⁴³¹ The convention requires a series of plans and reviews to ensure the safety and sustainable recycling of ships. A set of guidelines will help with implementation once the convention enters into force.

Limitation of the agreement include cost of implementation, which is often higher than reflagging the ship to another state not party to the convention or other recycling practices like beaching, and the exclusion of military vessels which often contain hazardous materials.⁴³² The convention also does not address what to do with the hazardous materials collected during ship recycling. The agreement only applies to vessels over 500 gross tons that is not engaged in domestic trade. In all, higher implementation costs, a lack of downstream recycling waste

⁴²⁷ Ibid.

⁴²⁸ Ibid.

⁴²⁹ “Status of IMO Treaties,” International Maritime Organization, 531.

⁴³⁰ As of time of writing. “Status of IMO Treaties,” International Maritime Organization, 542.

⁴³¹ “The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships,” International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/The-Hong-Kong-International-Convention-for-the-Safe-and-Environmentally-Sound-Recycling-of-Ships.aspx>.

⁴³² Mohamed Hussein Nassar and Ahmed Hamdy Moursy, “Evaluation of Hong Kong Convention in the Maritime Industry,” *Journal of Shipping and Ocean Engineering* 6 (2016): 121, accessed October 2021, doi 10.17265/2159-5879/2016.02.006.

managements, and a narrow applicability has left the agreement largely unattractive to IMO members relative to other agreements.

Not strictly listed by the IMO as a convention relating to the prevention of marine pollution, the International Convention on Salvage (SALVAGE 1989) is no less important for safeguarding the marine environment from pollution. SALVAGE 1989's predecessor (law of salvage 1910) established compensation for salvage operations on a 'no cure, no pay' basis; meaning, to be compensated the salvage operation had to be successful. The no cure, no pay principle overlooked pollution. For a salvor, difficult salvage operations became risky business ventures. Yet salvaging ships is key to preventing pollution or other environmental damage. To encourage more salvage operations, SALVAGE 1989 established an enhanced salvage award where the salvor can earn its expenses plus 30% based on the skill and effort related to protecting the marine environment during salvage operations rather than overall success of the salvage operation.⁴³³ The convention has 75 contracting states.⁴³⁴

There are numerous other governance tools that the IMO uses to affect maritime protection governance. The nine agreements listed above are the heart of the IMO's marine protection governance, however. They represent a broad scope and diverse nature, speaking to regulations, preventative measures, guidelines, technical standards, procedures, evaluations, burden sharing, and more. They are not idle either, but routinely amended to ensure their relevancy.

IMO Conventions Related to Liability and Compensation

The ability to assess liability and collect damages for incidents at sea creates a strong incentive for compliance. The IMO has produced eight conventions and numerous amendments, codes, guidelines, and other tools to outline a robust liability and compensation framework for international shipping. Together, the liability measures tell a story of evolving liability needs related to protecting the marine environment and people.

⁴³³ "International Convention on Salvage," International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Salvage.aspx>.

⁴³⁴ "Status of IMO Treaties," International Maritime Organization, 480.

The 1969 International Convention on Civil Liability for Oil Pollution Damage (CLC) places a strict fault on the ship's owner for oil pollution that occurs in the territory of a State party and requires the ship to maintain insurance or other financial security in amounts equivalent to the total liability for a single incident.⁴³⁵ The CLC was updated via protocol in 1976, 1984, and 1992. CLC Prot 1992 was also amended in 2000. The evolution of the CLC has adjusted compensation units, increased liability limits, and expanded geographic coverage of the convention among other changes that reflect changing liability preferences of states. The CLC has 144 contracting states.⁴³⁶

International Fund for Compensation for Oil Pollution Damages (Fund) was drafted to supplement the CLC by providing additional coverage for victims and ship owners unable to be adequately covered by the CLC. Protocols to the Fund convention were adopted in 1976 and 1984 but superseded by the 1992 Protocol, which among other things, modified the entry into force requirements (requiring 4 rather than 6 large tanker-owning countries necessary for entry into force) and increased compensation limits.⁴³⁷ A supplementary fund was adopted via protocol in 2003 to provide third tier compensation on a voluntary basis.⁴³⁸ 95% of merchant tonnage is covered under the convention via 120 contracting states.⁴³⁹

Convention relating to the Civil Liability in the Field of Maritime Carriage of Nuclear Material (NUCLEAR) reconciles liability between ship owners and nuclear facilities responsible for transporting the nuclear material. The convention addresses a niche topic with considerable political and liability implications given the nature of nuclear technology and its impact on the environment should there be an incident. As a result, the agreement has only 17 contracting states representing 18% of merchant tonnage.⁴⁴⁰

⁴³⁵ [https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Civil-Liability-for-Oil-Pollution-Damage-\(CLC\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Civil-Liability-for-Oil-Pollution-Damage-(CLC).aspx)

⁴³⁶ "Status of IMO Treaties," International Maritime Organization, 278.

⁴³⁷ "International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND)," International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-the-Establishment-of-an-International-Fund-for-Compensation-for-Oil-Pollution-Damage-\(FUND\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-the-Establishment-of-an-International-Fund-for-Compensation-for-Oil-Pollution-Damage-(FUND).aspx)

⁴³⁸ Ibid.

⁴³⁹ "Status of IMO Treaties," International Maritime Organization, 309.

⁴⁴⁰ "Status of IMO Treaties," International Maritime Organization, 289.

The Athens Convention relating to the Carriage of Passengers and their Luggage by sea (PAL) provides liability coverage to passengers and their cargo.⁴⁴¹ The PAL convention sets strict liability limits unless fault or negligence can be proved. A series of protocols updated the convention between 1976 and 2002, with the latest (Prot 2002) introducing compulsory insurance coverage for passengers and raises the liability limits. The PAL and its protocols have relatively few contracting states, 25 and 31, respectively.⁴⁴²

The 1976 Convention on Limitation of Liability for Maritime Claims (LLMC) creates a virtually unbreakable system of limiting liability while also increasing coverage substantially for loss of life or personal injury and property claims.⁴⁴³ The Convention was updated via Protocol in 1996 to increase liability limits and introduces the tacit acceptance feature for updating compensation amounts. Amendments to the 1996 Protocol were adopted in 2012 to again increase compensation amounts. The 1996 Protocol covers some 69% of merchant tonnage through 63 contracting states.⁴⁴⁴

The 1996 International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substance by Sea (HNS) was developed to provide similar liability coverage as the CLC and Fund Conventions but for hazardous and noxious substances.⁴⁴⁵ By 2009 the convention had failed to enter into force so the IMO adopted the 2010 HNS Protocol to reconcile issues discouraging adoption of the

⁴⁴¹ “Athens Convention relating to the Carriage of Passengers and their Luggage by Sea (PAL),” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/Athens-Convention-relating-to-the-Carriage-of-Passengers-and-their-Luggage-by-Sea-\(PAL\).aspx](https://www.imo.org/en/About/Conventions/Pages/Athens-Convention-relating-to-the-Carriage-of-Passengers-and-their-Luggage-by-Sea-(PAL).aspx).

⁴⁴² “Status of IMO Treaties,” International Maritime Organization, 336, 348.

⁴⁴³ “Convention on Limitation of Liability for Maritime Claims (LLMC),” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/Convention-on-Limitation-of-Liability-for-Maritime-Claims-\(LLMC\).aspx](https://www.imo.org/en/About/Conventions/Pages/Convention-on-Limitation-of-Liability-for-Maritime-Claims-(LLMC).aspx).

⁴⁴⁴ “Status of IMO Treaties,” International Maritime Organization, 397.

⁴⁴⁵ “International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS),” International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Liability-and-Compensation-for-Damage-in-Connection-with-the-Carriage-of-Hazardous-and-Noxious-.aspx>.

convention. Still, as of the time of writing, neither had received sufficient support to enter into force.⁴⁴⁶

The 2001 International Convention on Civil Liability for Bunker Oil Pollution Damage (BUNKER) was drafted to ensure compensation is available to “persons who suffer damage by spills of oil when carried by ships in their bunkers” that occur on the territory of state parties.⁴⁴⁷ Modelled after the CLC convention, BUNKER requires ship owners to maintain insurance. There are 102 contracting parties to the convention.

The final convention is the 2007 Nairobi International Convention on the Removal of Wrecks, which established a legal bases for States to remove wrecks that have the potential to adversely affect people, goods or property at sea or the marine environment.⁴⁴⁸ The convention also makes ship owners financially liable and requires them to take out insurance or other financial means to cover the cost of wreck removal. It also provides states with the ability to take direct action against insurers. There are 56 contracting States to the convention.⁴⁴⁹

Conclusion

A few key themes become apparent when taking stock of the IMO’s approach to marine governance. These themes reflect the tenants of an effective governance organisation detailed in the introduction of this section, and tell the story of the IMO’s approach, successes, and shortcomings for protecting the marine environment.

The first theme to consider is member state endorsement. Member endorsement reflects support for the processes and output via trust among members and routine member engagement. Producing conventions and other governance measures is not without political or other

⁴⁴⁶ “Status of IMO Treaties,” International Maritime Organization, 504, 507.

⁴⁴⁷ “International Convention on Civil Liability for Bunker Oil Pollution Damage (BUNKER),” International Maritime Organization, accessed October 2021, [https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Civil-Liability-for-Bunker-Oil-Pollution-Damage-\(BUNKER\).aspx](https://www.imo.org/en/About/Conventions/Pages/International-Convention-on-Civil-Liability-for-Bunker-Oil-Pollution-Damage-(BUNKER).aspx).

⁴⁴⁸ “Nairobi International Convention on the Removal of Wrecks,” International Maritime Organization, accessed October 2021, <https://www.imo.org/en/About/Conventions/Pages/Nairobi-International-Convention-on-the-Removal-of-Wrecks.aspx>.

⁴⁴⁹ “Status of IMO Treaties,” International Maritime Organization, 538.

ramifications which can impose transaction costs on the IMO and its members. If the transaction costs grow too cumbersome, they can stall processes and progress. The IMO has been able to overcome this challenge, in part, through member state buy in identified through dozens of conventions, hundreds of amendments, countless other measures and tools, and a general ability to routinely produce separate but complementary agreements. With a large membership and divergent state interests, producing agreements on controversial issues is a testament to the IMO's ability to encourage buy-in and avoid impasse to keep outputs moving forward. Of course, producing an agreement is only half the processes. The other half is adoption and several agreements discussed previously had limited or insufficient adoption. Still, the IMO's responsibility is not to tell states what to do, but to give them the tools and measures to facilitate governance.

The next comparative theme is organisational agility. The IMO has evolved over the years to cover environmental new issues, update measures, and otherwise keep pace with a changing shipping industry and marine environment. Since its first session, the IMO has grown organisationally by expanding the number of committees and subcommittees focused on marine protection, growth in membership, using new processes to advance governance, and expanding its remit to cover various features related to environmental protection, from marine life, to liability, and prevention of accidents. It has also shown important adaptability in its governance outputs by leveraging a spectrum of tools from conventions, amendments, and protocols to codes, guidelines, and educational resources. At the heart of the IMO's agility are processes that enable the IMO to make changes with member firm support, like tacit acceptance, and the capacity through its member's technical and scientific competence and participation in various committees, working groups, and other organs to address the increasingly complex and important work related to marine sustainability governance. The IMO's adaptability has been a key feature allowing the organisation to accommodate the ways international shipping has changed.

Member state endorsement and agility speak to the IMO's ability to produce agreements, but the effectiveness of outputs speaks to the ability of those agreements to affect governance. Like nearly all IOs, there is little the IMO can do to ensure states comply with agreements. The IMO has developed an imperfect, but useful set of measures to encourage compliance. By

incorporating concepts like port state authority into agreements, through audit schemes and reporting, and by making agreements easier to adopt through detailed technical requirements and knowledge sharing, the IMO uses numerous, if not all, of the tools that an IO can be expected to use to encourage compliance.

Finally, can one say the maritime domain is better for the IMO? The regime is not perfect. Issues with implementation and enforcement do limit the effectiveness of some agreements, but that does not mean it is a failed or feeble regime. As stated throughout this research, international governance is not an end-state but a process wherein governance tools are developed or evolved to address a spectrum of evolving issues. As a process, rather than an end state, success can be hard to measure. In this case, through member buy in, IO agility, and the effectiveness of outputs, the IMO has many important and positive metrics showing the maritime domain is better for the organisations. Through numerous environmental, liability, and other measures, the IMO has shaped actor behaviour to cohere shipping activities to save lives and protect the environment while growing the shipping industry. There is always more that can be done or improved upon; however, the IMO stands in contrast to the qualities of an ineffective organisation (e.g., organisations that fail to produce new agreements, inadequate agreement compliance, and inability to address underlying domain problems).

Civil Aviation Case Study

The growth of aviation has always been a core focus for ICAO while environmental concerns were not originally central to its mission. The Chicago Convention emphasizes aviation “growth” and “development” but does not mention the word “environment”.⁴⁵⁰ Over the years, through Assembly and Council efforts the environment has become an organisational priority for ICAO.

ICAO has focused on environmental issues since the 1970s, however since 1992 climate change has taken centre stage.⁴⁵¹ Aviation is the second largest transport sector contributor to

⁴⁵⁰ Alejandro Piera Valdes, “Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges,” 87.

⁴⁵¹ Ibid. 85.

climate change behind road transportation.⁴⁵² Without change, emissions from air transport will grow from 13 to 23 percent by 2050.⁴⁵³ International flights account for 60 percent of all aviation emissions and 1.3 percent of global CO₂ emissions.⁴⁵⁴ In short, civil aviation affects the entire planet's sustainability.

But the need to limit the effects on the environment must be balanced with the economic value of the industry. According to a 2020 US Federal Aviation Administration report, the aviation industry amounts to more than 5 percent of global GDP and supports roughly 11 million jobs around the world.⁴⁵⁵ The economic value of aviation was brought into crisp focus during the COVID-19 pandemic which saw staggering declines in passengers flown and airline revenue, which had downstream impacts on tourism, trade, and many other important economic sectors.⁴⁵⁶

ICAO's environmental focus areas include aircraft noise, local air quality, and climate change. Each focus area is addressed through operational measures and technology standards designed to improve aviation practices and technology to advance environmentally conscious outcomes. Standards often include design and operational features as well as compliance and reporting.

ICAO Organs Related to Environmental Protection

ICAO's Air Transport Bureau is responsible for environmental issues. According to ICAO, the Air Transport Bureau "focuses on quantifying the impact of aviation on the environment

⁴⁵² Ibid. 20.

⁴⁵³ Ibid. 20.

⁴⁵⁴ International Civil Aviation Organization, "Destination Green: The Next Chapter," International Civil Aviation Organization, 2019, accessed October 2021, 349, <https://www.icao.int/environmental-protection/Pages/envrep2019.aspx>; Environment. "Frequently Asked Questions," International Civil Aviation Organization, accessed October 2021, 1.2, <https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-FAQs.aspx>.

⁴⁵⁵ The report uses 2016 data and does not reflect the negative consequences the COVID-19 pandemic had on aviation. For more see: Federal Aviation Administration, "The Economic Impact Report of Civil Aviation on the U.S. Economy," Federal Aviation Administration, January 2020, accessed October 2021, 3, https://www.faa.gov/about/plans_reports/media/2020_jan_economic_impact_report.pdf.

⁴⁵⁶ Economic Development. "Economic Impacts of COVID-19 on Civil Aviation," International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/sustainability/Pages/Economic-Impacts-of-COVID-19.aspx>.

through the development of methodologies, tools, models and databases; and establishing policies, standards and recommended practices to address the impact of aviation on the environment through technological, operational and market-based measures.”⁴⁵⁷ ICAO’s Technical Cooperation Bureau also plays a role in environmental protection by “providing advice and assistance in the development and implementation” of aviation projects focused on, among other things, “environmental protection and sustainable development of national and international civil aviation.”⁴⁵⁸ The majority of ICAO’s environmental work is conducted through the Committee on Aviation Environmental Protection (CAEP), a technical committee of the ICAO Council.⁴⁵⁹

CAEP was established in 1983 to “assists the Council in formulating new policies and adopting new Standards and Recommended Practices (SARPs) related to aircraft noise and emissions, and more generally to aviation’s environmental impact.”⁴⁶⁰ CAEP takes direction from the Council on matters of agenda, work program, meetings, and terms of reference.⁴⁶¹ CAEP is composed of 31 member states from all regions of the world and 21 Observers (six states and 15 organisations).⁴⁶² The Committee’s structure includes a chair- and vice-chairperson, membership, and a Secretary. Its activities are conducted through various groups focused on specific issues, for example, Working Group 1 is focused on aircraft noise and technical issues while Working Group 3 is focused on engine emission standards. There are additional groups focused on research, goal setting, and other activities relevant to addressing environmental matters.⁴⁶³ The assessments and proposals CAEP produces are developed against technical feasibility, environmental effectiveness, and economic reasonableness.⁴⁶⁴ CAEP works

⁴⁵⁷ “Air Transport Bureau,” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/secretariat/air-transport/Pages/default.aspx>.

⁴⁵⁸ Technical Cooperation, “Technical Cooperation Bureau,” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/secretariat/TechnicalCooperation/Pages/default.aspx>.

⁴⁵⁹ Environment, “Committee on Aviation Environmental Protection (CAEP),” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/environmental-protection/pages/caep.aspx>.

⁴⁶⁰ Ibid.

⁴⁶¹ Alejandro Piera Valdes, “Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges,” 95.

⁴⁶² Membership figures as of 2021, see: Ibid.

⁴⁶³ Ibid.

⁴⁶⁴ Ibid.

on a three-year work cycle, which can include many meetings and hundreds of teleconferences, and reports directly to the Council.

CAEP's organisational structure and processes do invite some criticism. CAEP is responsible for measures that can affect all ICAO members but has a relatively small sample of representation through its 31 member states and 21 observers. Of the 37 member and observer states 16 are from Europe while four are from South America, seven from Asia, five from Africa, three from the Middle East, and two from North America. Of the nine NGO observers, only two are environmentally focused. Any member state can request to join CAEP, but admittance is at the Council's discretion, and some member states have suggested the process is too long and discourages engagement in CAEP's decision making.⁴⁶⁵

Another criticism is that CAEP's three assessment criteria outlined in its terms of reference make it too easy to discourage new standards. Technical feasibility and economic reasonableness can often come into conflict. For example, new standards that require new technology or different operational procedures can increase cost. Similarly, assessing environmental effectiveness can be a matter of perspective as much as quantitative measurements. Does adopting more efficient aviation fuel, which reduces aviation emissions constitute a more environmentally affective approach if the upstream production of those fuels has adverse environmental impacts outside of the aviation industry? Some have argued that the issues around assessment criteria limit CAEP's work to informational efforts and conducting studies and understanding the issues, rather than a standard setting body.⁴⁶⁶ CAEP has produced numerous standards, including some for a major market-based measure.

⁴⁶⁵ European Parliament, Decision-making processes for ICAO and IMO in respect to environmental regulations, 27.

⁴⁶⁶ Elizabeth Duthie, "ICAO Regulation: Meeting Environmental Need?" *Air & Space Europe* 3 No 3 (2001), 28, accessed October 2021.

ICAO Measures Related to Environmental Protection

The Chicago convention does not specifically address the environment but under Article 90, it empowers the ICAO Council to adopt Annexes to the Convention.⁴⁶⁷ Annex 16 was created in 1971 to address Aircraft Noise but has since been developed further to include three additional volumes focused on Aircraft Emissions, Aeroplane Co2 Emissions, and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).⁴⁶⁸ Annexes 16 and its four volumes primarily include SARPs and SARP related materials.⁴⁶⁹ In addition to standards, the work of each environmental focus area includes some form of research into related trends, technology goals, and operational measures. Conducting studies, understanding technology, and creating technical standards for Annex 16 falls largely to CAEP.

Since 2010 ICAO has used environmental trends to “form the basis” for Assembly considerations and decision.⁴⁷⁰ They are updated and presented at every Assembly session. The most recent (2019) trends were developed based on a range of scenarios that reflect possible futures and the implications for environmental issues. The approach can certainly help inform ICAO design making, though it may warrant some questions concerning the use of scenarios to make assessments.

The scenarios used in the 2019 trends report were rather optimistic. One scenario assumed no further technology or operational efficiency, while the remaining scenarios assumed some level of improvement through operational and/or technology advancement.⁴⁷¹ The 2019 report

⁴⁶⁷ International Civil Aviation Organization, *Convention on International Civil Aviation ninth edition, doc 7300/9*, International Civil Aviation Organization, 2006, 40, accessed October 2021, https://www.icao.int/publications/Documents/7300_cons.pdf.

⁴⁶⁸ International Civil Aviation Organization, *Annex 16 to the Convention on International Civil Aviation, environmental Protection, Volume IV, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), First Edition*, International Civil Aviation Organization, 2018, vii, accessed October 2021, <https://elibrary.icao.int/reader/229739/&returnUrl%3DaHR0cHM6Ly9lbGlicmFyeS5pY2FvLmludC9ob21lL3Byb2RlY3QtZGV0YWlscy8yMjk3Mzk%3D?productType=ebook>.

⁴⁶⁹ Ibid, xi.

⁴⁷⁰ International Civil Aviation Association, *ICAO Global Environmental Trends – Present and Future Aircraft Noise and Emissions* (Montreal: Assembly - 40th Session, May 2019), 1.

⁴⁷¹ Environment, “Global Trends in Aircraft Noise,” International Civil Aviation Organization, accessed October 2021, https://www.icao.int/environmental-protection/Pages/Noise_Trends.aspx; Environment, “Trends in Local Air Quality,” International Civil Aviation Organization, accessed October 2021, https://www.icao.int/environmental-protection/Pages/LAQ_Trends.aspx; and, Environment, “Trends in Emissions that Affect Climate Change,”

found that “lower long-term projections for fuel burn, noise, and NOx” than previous findings which “can be attributed to a combination of aircraft with better technology entering the fleet, as well as a reduction in the forecasted long-term traffic demand.”⁴⁷²

While it is likely technology and operational advancements will continue to occur in aviation—if only because it makes business sense for the aviation sector to seek efficiencies—that all but one scenario assumes parameters that will improve trends, suggests a rather selective research methodology. It also fails to assess aviation’s environmental impact against non-aviation trends. For example, while aviation may be projecting trend improvement across its three focus areas, other industries related to aviation may be seeing negative trends which would then require aviation to adjust its metrics for assessing the impact of aviation trends.

As a complement to understanding trends ICAO sets technology goals. The goals are intended to “foster the development of new technologies...with the purpose of providing targets for industry research and development.”⁴⁷³ Technology goals are assessed against the latest technology in use at the time, and ultimately serve to develop standards. Goals are developed by a panel of independent experts nominated by CAEP members, which can include NGOs.⁴⁷⁴ The experts release a report on their findings as appropriate. The latest report (2019) was the first to assess technology goals as an integrated assessment to understand how technology and environmental focus areas (noise, local air quality, and climate change) were related.⁴⁷⁵

In addition to research and goal setting, a key focus of ICAO’s environmental work is the development of standards found in Annex 16. Volume 1, which addresses aircraft noise, was originally the focus of Annex 16. As ICAO began to consider engine emissions it was decided

International Civil Aviation Organization, accessed October 2021, https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx.

⁴⁷² International Civil Aviation Association, *ICAO Global Environmental Trends – Present and Future Aircraft Noise and Emissions*, 2.

⁴⁷³ Environment, “Technology Goals and Standards,” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/environmental-protection/Pages/technology-standards.aspx>.

⁴⁷⁴ Nick Cumpsty, Dimitri Mavris, Michelle Kirby, “Aviation and the Environment: Outlook,” International Civil Aviation Organization, 2019, 24, accessed October 2021, https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg24-38.pdf.

⁴⁷⁵ Ibid.

that Annex 16 was the best place to address environmental areas of aviation, and so Annex 16 was renamed to “Environmental Protection” and volume 1 selected to address noise.⁴⁷⁶ Volume 1 addresses aircraft noise through a “balanced approach” scheme. The scheme includes, identifying noise problems at airports and identifying how to reduce them through four focus areas, reduction at source, land-use planning and management, noise abatement operational procedures, and operating restrictions.⁴⁷⁷ The balanced approach is executed through SARPs and guidelines. Part II of Volume 1 contains SARPs and guidelines for noise certification while Parts III, IV, and V contain SARPs and guidance material for measurement of noise. SARPs are focused and specific. They address specific types of aircraft, like supersonic jets or propeller-driven, and can vary by specific aircraft features, like weight. Each SARP typically details applicability, noise evaluation measures, noise measurement points, maximum noise levels, trade-offs or certification procedures, and test procedures. Volume 1 also includes appendices and attachments with additional guiding material, like evaluation methods or equations for relevant calculations. Volume 1 has been amended eighteen times since its creations in 1971.⁴⁷⁸

Volume 2’s origins date back to 1977 when ICAO produce Circular 134, *Control of Aircraft Engine Emissions*.⁴⁷⁹ The initial effort was developed further after the ICAO Council agreed more was needed to address the topic than objective technical issues, so in 1980 the Council made Aircraft Engine Emissions Volume 2 of Annex 16. Much like Volume 1, Volume 2 consists primarily of SARPs and guiding materials. Part 2 of Volume II contains standards related to vented fuel, Part III contains standards related to emissions certifications based on class of aircraft engine, and Part IV provides recommendations for non-volatile particulate

⁴⁷⁶ International Civil Aviation Organization, *Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume IV, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), First Edition*, xii.

⁴⁷⁷ International Civil Aviation Organization, *Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume I, Aircraft Noise, Eighth Edition*, International Civil Aviation Organization, 2017, xii, accessed October 2021, https://www.iacm.gov.mz/app/uploads/2018/12/an_16_VI_Environmental-Protection_8ed_2017_rev.-12_01.07.17.pdf.

⁴⁷⁸ *Ibid.*, xv-xvii.

⁴⁷⁹ International Civil Aviation Organization, *Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume II, Aircraft Engine Emissions, Fourth Edition*, International Civil Aviation Organization, 2017, xi, accessed October 2021, <https://ffac.ch/wp-content/uploads/2020/10/ICAO-Annex-16-Environmental-protection-Vol-II-Aircraft-Engine-Emissions.pdf>.

matter assessment for inventory and modelling purposes.⁴⁸⁰ Like Volume 1, the subject of the SARPs is fairly specific to certain types of aircraft engines and types of emission, though widely applicable based on popular aircraft technology. Volume 2 appendices contain additional guiding materials on measurements, evaluations, instrumentation and measurement techniques, and compliance procedures. Volume 2 has been amended fifteen times since its creation.

At the 36th Session of the ICAO Assembly in 2007, Contracting states adopted a resolution establishing a Program of Action on International Aviation and Climate Change and a strategy to limit and reduce greenhouse gas emissions from international civil aviation.⁴⁸¹ In 2010, in line with the Program of Action, the ICAO Council approved a plan to develop SARPs for aeroplane CO₂ emissions. Volume 3 of Annex 16 was subsequently adopted in 2017.⁴⁸² The Volume is composed of two parts, the first addresses definitions and symbols, and the second certification standards for aeroplane CO₂ emission based on the consumption of fuel for subsonic jets over 5700kg and propeller-driven plans over 8618kg. The standards discuss applicability, CO₂ emissions evaluation metrics, reference Aeroplan masses, maximum permitted CO₂ emission evolution metric value, conditions for determining aeroplane specific air range, and test procedures. The Volume's appendices cover determination of CO₂ emissions evaluation values. Volume 3 contains the fewest number of SARPs in Annex 16 and has only been amended once.⁴⁸³

Volume 4 contains SARPs and other Implementation Elements for CORSIA, which is complex measure with many pieces in addition to the SARPs. CORISA is a MBM to curb CO₂ emissions from international civil aviation. CORSIA “relies on the use of emissions units from the carbon market to offset the amount of CO₂ emissions that cannot be reduced through the use

⁴⁸⁰ Ibid., ix.

⁴⁸¹ International Civil Aviation Organization, *Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume III, Aeroplane CO₂ Emissions, First Edition*, International Civil Aviation Organization, 2017, vii, accessed October 2021, <https://elibrary.icao.int/reader/265193/&returnUrl%3DaHR0cHM6Ly9lbGlicmFyeS5pY2FvLmludC9leHBsb3JlO3NIYXJjaFRleHQ9QW5uZXglMjAxNiUyMGVudmlvcn5tZW50YWwlmjBwcm90ZWNoaW9uJTlwdm9sdW1lJTlwaTtYWluU2VhcmNoPTE%3D?productType=eBook>.

⁴⁸² Ibid., x.

⁴⁸³ Ibid.

of technological and operational improvements, and sustainable aviation fuels.”⁴⁸⁴ Effectively, airlines expecting to produce CO₂ emissions above the set cap purchase offset units from a global carbon market. Those purchases support projects that aim to reduce CO₂ in other sectors thereby ‘offsetting’ international aviation CO₂ emissions. The approach was selected after much debate, but principally because CAEP identified that technological and operational improvements would not negate increases in international air travel.⁴⁸⁵ The motivation for developing CORSIA came from similar efforts proposed outside of ICAO.

In 2003, prior to the creation of CORSIA, the EU established an Emissions Trading Scheme to curb aviation emissions. In 2005 the EU made plans to include international aviation in the scheme, which caused countries outside the EU to push-back.⁴⁸⁶ In an effort to avoid the EU’s scheme, ICAO member states positioned ICAO to develop a program that would replace a patchwork of differing national or regional efforts.⁴⁸⁷ In 2010, the 37th ICAO Assembly tasked the Council to develop a framework for a MBM.⁴⁸⁸ At the 38th session in 2013, the ICAO Assembly—feeling compelled to produce results⁴⁸⁹—agreed to develop the international MBM for aviation.⁴⁹⁰ In 2016, during the 39th session, ICAO adopted CORSIA.⁴⁹¹ To initiate and adopt a complex, first of its kind, global MBM scheme in six years (two Assembly sessions) is a notable accomplishment by international governance standards. There are currently 107 states participating in CORSIA as of January 2022.⁴⁹²

⁴⁸⁴ Environment, “Frequently Asked Questions”.

⁴⁸⁵ Environment, “Frequently Asked Questions”.

⁴⁸⁶ Alejandro Piera Valdes, “Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges,” 35.

⁴⁸⁷ *Ibid.*, 109.

⁴⁸⁸ *Resolution A40-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection - Climate change*, International Civil Aviation Organization, 3, accessed October 2021, https://www.icao.int/environmental-protection/Documents/Assembly/Resolution_A40-18_Climate_Change.pdf.

⁴⁸⁹ Alejandro Piera Valdes, “Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges,” 116.

⁴⁹⁰ “Resolution A40-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection - Climate change,” International Civil Aviation Organization, 1.

⁴⁹¹ *Ibid.*, 1.

⁴⁹² ICAO Document, “CORSIA States for Chapter 3 State Pairs,” International Civil Aviation Organization, 2, accessed October 2021, https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_States_for_Chapter3_State_Pairs_Sept2020.pdf.

CORISA is a complex plan with three phases designed to accommodate special circumstances and capabilities of states while minimizing market distortions.⁴⁹³ A voluntary pilot phase from 2021-2023, the first phase (also voluntary) runs from 2024-2026, followed by a non-mandatory second phase from 2027-2035.⁴⁹⁴ Supporting the three phases are several Implementation Elements detailed in fourteen documents found in Volume 4 of Annex 16, which was adopted by the Council in 2018. These documents include: a list of participating states;⁴⁹⁵ a set of equations necessary for aircraft operators to monitor and report their CO2 emissions;⁴⁹⁶ a list of CORISA eligible fuels which can aide aircraft operators in reducing offsetting requirements;⁴⁹⁷ approved Emissions Unit Programs for satisfying the provisions set out in CORSIA-related SARPs⁴⁹⁸; and, a scheme central registry with relevant benchmark and other data, like airplane operators and state affiliations and CORSIA Annual Sector's Growth Factor.⁴⁹⁹ Volume 4 also contains several appendices detailing administrative procedures, reporting, verification, and other relevant procedures intended to help states understand and carry out CORISA.⁵⁰⁰

Volume 4 is complemented by the Environmental Technical Manual (ETM). The purpose of the ETM is to “promote uniformity of implementation of the technical procedures of Annex 16, Volume 4” through guidance on standards, methods, and equivalent procedures.⁵⁰¹ Given the complexity of CORSIA the ETM can generally be described as a “how to” manual for CORSIA.

⁴⁹³ “Resolution A40-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection - Climate change,” International Civil Aviation Organization, 3

⁴⁹⁴ Ibid.

⁴⁹⁵ ICAO Document, “CORSIA States for Chapter 3 State Pairs,” International Civil Aviation Organization, 2.

⁴⁹⁶ Environment, “ICAO CORSIA CO2 Estimation and Reporting Tool (CERT),” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/environmental-protection/CORSIA/Pages/CERT.aspx>.

⁴⁹⁷ Environment, “CORSIA Eligible Fuels,” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx>.

⁴⁹⁸ “Resolution A40-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection - Climate change,” International Civil Aviation Organization, 6.

⁴⁹⁹ Environment, “CORSIA Central Registry (CCR),” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/environmental-protection/CORSIA/Pages/CCR.aspx>.

⁵⁰⁰ International Civil Aviation Organization, *Annex 16 to the Convention on International Civil Aviation, environmental Protection, Volume IV, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), First Edition*, app 1-1 – app 6-5.

⁵⁰¹ Secretary General, “Environmental Technical Manual, Volume IV – Procedures for demonstrating compliance with Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), doc 9501, Second Edition,” International Civil Aviation Organization, 2019, 1-1, accessed November 2021, <https://elibrary.icao.int/reader/234240/&returnUrl%3DaHR0cHM6Ly9lbGlicmFyeS5pY2FvLmludC9ob21lL3Byb2R1Y3QtZGV0YWlscy8yMzQyNDA%3D?productType=ebook>.

ETM is complemented by the ICAO Assistance, Capacity building, and Training program on CORISA (ACT-CORSIA), which provides leaflets, videos, seminars, online tutorials, and other information to promote capacity building.⁵⁰²

In addition to SARPs and related materials outlined in Annex 16, ICAO has also overseen the development of a few multilateral liability and compensation conventions related to damages to aircraft, 3rd parties, and related matters, but they have little to do with environmental issues specifically. Of the agreements not all have gained enough support to enter into force while others, like the Rome Convention, have relatively few parties (51).⁵⁰³ While generally important to the international aviation governance regime, because they have little relevance to the environmental measures underdiscussing here they do not warrant further discussion.

Conclusion

In terms of the first comparative theme, member state buy-in, ICAO offers many useful observations. ICAO continues to advance environmental standards and recommended practices to aid environmental issues. Along the way there has been notable member state buy in to create new committees, agreements, and generally advance aviation governance. CORSIA is a good example of member state support with 102 participating parties to a novel and first of its kind agreement. The speed (relative to international governance) at which ICAO can act is another testament to member state support with SARPs taking on average just two years and CORSIA requiring only two assembly sessions. None of these outputs would be possible if member states did not buy into the processes and draft agreements. The frequency at which ICAO advances new measures is antithetical to an ineffective organisation often paralyzed and unable to realize new governance measures.

⁵⁰² Environment, “COVID-19 impacts and 2022 CORSIA periodic review,” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-and-Covid-19.aspx>.

⁵⁰³ For a complete list of multilateral air law treaties see: “Current lists of parties to multilateral air law treaties,” International Civil Aviation Organization, accessed October 2021, <https://www.icao.int/secretariat/legal/lists/current%20lists%20of%20parties/allitems.aspx>.

When considering ICAO's organisational agility, it has shown an aptitude to adapt itself to environmental issues in some key areas but not others. Developing new forums, like CAEP, expanding its environmental focus from aircraft noise to emissions and climate change, adjusting processes, and developing new standards and capacity building measures, among other tools are all examples of an adaptive organisation. The agility is due to ICAO's effective decision-making processes. One feature that empowers ICAO's decision-making style is the organisation's ability to adjust how decisions are made depending on the output (e.g., SARPs follow a different decision-making process than CORSIA). This allows the organisation to balance transaction costs with compliance based on the purpose of an agreement. For example, the role SARPs play in affecting state behaviour is different than the role CORSIA is expected to play, and therefore can require balancing transaction costs and compliance differently.

There are other areas where ICAO has been slow or unable to adapt, however. For instance, its inability to weigh equally environmental issues with aviation's advancement. Indeed, a common criticism of ICAO's environmental work is that it favours sector development above all else. A consequence of ICAO's original mandate, the organisation has changed to accommodate environmental issues. Still, the emphasis on advancing international civil aviation has been hard to overcome to advance more aggressive environmental protection measures. CORSIA represents a major effort, but even it does not address the reduction of CO₂ emission in aviation, it simply aims to offset them. Offsetting can certainly help broadly, but it consigns responsibility to other sectors to balance aviation emissions. Moreover, some argue much of aviation's work to protect the environment is largely a product of industry seeking more efficient aircraft to improve profits rather than to address climate change or other environmental issues.⁵⁰⁴

When examining the third theme, effectiveness of outputs, ICAO has qualities to emulate and weaknesses to account for. As a standard setting organisation, many of the measures produced to address environmental issues fall neatly into familiar territory for ICAO and its members. SARPs, PANs, and education tools provides highly detailed standards and supporting

⁵⁰⁴ D.I.A. Poll, "21st Century civil aviation: Is it on course or is it over-confident and complacent? – thoughts on the conundrum of aviation and the environment," *The Aeronautical Journal* 121 no 1236 (2017): 135, doi: 10.1017/aer.2016.140.

materials—including draft regulatory guidance—to provide states with information to make compliance easier. ICAO has also increased its capacity building efforts. These measures improve compliance, but as ICAO’s own assessments show, compliance with SARPs and related materials can be weak.

When considering the effectiveness of CORSIA, it may be too early to assess compliance given the early stage of the agreement’s implementation, but the effort has the potential to play an important role in curbing CO2 emissions. Though the Chicago convention allows states to revoke access for not following ICAO standards, the convention’s mechanisms would not apply to ICAO’s environmental measures, limiting the enforceability of CORSIA by other states.⁵⁰⁵ There is no question that ICAO measures have helped to cohere and advance international civil aviation broadly, but the effectiveness of its measures intended to protect the environment is less clear.

The last measure of a successful IO is whether the air domain is better because of ICAO. In general, there is little doubt ICAO has greatly aided the advancement of international aviation since the organisation’s founding, and the advancement of international aviation has had incredible economic impact around the world. Environmentally speaking, however, aviation’s growth has had negative impacts on climate change. ICAO has wrestled with a changing aviation sector, but the IOs general deference to development over environment sustainability limits the effectiveness of its environmentally focused measures. Still, the organisation continues to reflect strong member state buy in and a persistent ability to adapt offering important potential for change.

Internet Case Study

The internet is a collection of private networks, which means addressing governance challenges must almost always be done without the central coordination that exists via large international organisations, like ICAO or the IMO. What links separate networks to allow them to operate together are common standards known as internet protocols. In many ways, internet

⁵⁰⁵ Alejandro Piera Valdes, “Greenhouse Gas Emissions from International Aviation: Legal and Policy Challenges,” 345.

standards are what constitutes a global common because without them separate networks could exist but the global connectivity and sharing of information among them would not be possible.⁵⁰⁶ For this reason, addressing internet governance, and specifically sustainability, requires focusing on internet standards, like IPv4 and CIR, like domain names and internet addressing numbers (internet names and numbers). Addressing internet names and numbers and protocols requires doing so through various private, public, non-profit, and government organisations who play different roles influencing how internet standards are designed and adopted.

Recalling from the previous chapter, one focus area of internet governance is the administration of CIR.⁵⁰⁷ Managing CIR is a key requirement for domain sustainability. Managing CIR is one example where internet governance does resemble some centralized control. Whereas most of the internet is governed by a multistakeholder group, CIR are managed by a single organisation, ICANN. This allows a closer comparison of ICANN with other international organisations, like the IMO and ICAO. The other feature of managing CIR are the protocols that create the resources. For this reason, the transition from IPv4 to IPv6 is one of the most prominent examples of how the internet, as technical architecture, has been adjusted to overcome resource shortages.

Despite some difference between the internet and the air and maritime domains, internet governance relies on similar themes, like the need and challenge of creating high quality standards, the need to consider the interests of all affected parties, the need for consensus, and the challenge of evaluating the utility of a given governance measure.⁵⁰⁸ Similar to ICAO or the IMO, the internet governance community attempts to balance the need for quality standards and governance measures with the rapid pace at which the internet and internet technology are advancing.⁵⁰⁹

⁵⁰⁶ Milton Mueller, John Mathiason, and Hans Klein, “The Internet and Global Governance: Principles and Norms for a New Regime,” 246.

⁵⁰⁷ Laura DeNardis, “Introduction: Internet Governance as an Object of Research Inquiry,” 3.

⁵⁰⁸ “Standards Process,” Internet Engineering Task Force.

⁵⁰⁹ Ibid.

Critical Internet Resources

The internet is human made, so it exists as it is developed to exist. As something that was created, and is routinely updated and modified, it may not be intuitive to learn the internet operates using limited internet resources. Afterall, why not just make more? Objectively, one could simply make more internet resources and where more could not be made, one could create new ways for the internet to operate to overcome the lack of resources. However, just because something can be created or changed within the internet does not mean those changes will be adopted by the internet community widely enough to overcome resource shortage. Indeed, as a network of interconnected private networks, wide scale adoption of new protocols, standards, and software is required to constitute meaningful change to the internet. Adopting new standards requires agreement among the internet community, and just like in other domains, agreements require people, time, money, and knowledge. So, while new technical designs could be developed to add internet resources, doing so will not always solve internet resource shortages.

CIRs are “virtual, internet specific, and globally unique” resources, and not physical infrastructure (i.e., fibre optic cables) or virtual resources not specific to the internet.⁵¹⁰ Following the World Summit on the Information Society (WSIS), discussions of CIRs became closely aligned with internet standards, domain names, and IP addresses.⁵¹¹ From a governance perspectives internet names and numbers are finite given the technical design of IPv4/6 and the DNS. Standards are not finite technically speaking but given the integral role they play in using the internet affecting everything from video conferencing, images, WiFi, and more, changing a standard often requires substantial buy-in from the internet community to have any effect on how the internet functions or governance issues. In terms of the internet names and numbers, ICANN has control over how these two CIRs are governed. ICANN does not develop standards nor does anyone organisation reign over the development of standards, though there are a few organisations that feature more prominently in standards development (see the previous chapter for these organisations).

⁵¹⁰ Laura DeNardis, *The Global War for Internet Governance*, 36.

⁵¹¹ Milton Mueller, *Networks and States*, 215.

The interplay between technology and public policy is closely connected for CIRs. Internet names and numbers are not only valuable in a financial (and even cultural) sense, but certain standards, like IPv4 and DNS, are so ingrained into the internet that changing them requires substantial technical orchestration and support from the whole internet community. In a sense, changing internet standards can be equivalent to creating new multilateral treaties in other domains while allocating internet names and numbers can be as important as allocating air routes or sovereign rights for maritime geography. The essential role of CIRs combined with their limited nature is why they warrant greater centralized control than other aspects of the internet and why they are a key focus of the sustainable development of the internet, and subsequently its governance.

Internet Names: The Domain Name System

Unique internet names and numbers are a prerequisite for being on the internet. Based on the DNS, names have hierarchical ordering. Internet names are most often associated with a website URL, like `www.kcl.ac.uk`. At the top of the DNS is the root zone followed by the Top-level domains, Second level domain, Third level domain, and host. The hierarchy acts as an addressing system by navigating from the top of the hierarchy (root zone) down through the host using each sub-level to refine the location. The root zone locates the root zone server, which contains the global list of Top-level domains. Top level domains include “.com”, “.edu”, “.gov”, among others. Second level domains are what most users recognize as the website name. For instance, in `www.google.com`, “google” represents the second level domain while “.com” represents the Top-level domain. Finally, the third level domain help specify locations within a second-level domain, and include “www” among others.

Each level is managed by a different organisation and comes with different rules or requirements for allocation. There are 12 root server operators responsible for the root zone, and ICANN oversees the 12 operators. Top level domains are managed by registries who allocate them based on rules outlined by ICANN. Second level domains are managed by domain name registrars, which are organisations accredited by ICANN to sell second level domain to people or organisations. Allocations of DNS resources typically requires purchasing them from the appropriate entity, like a registry or registrar.

ICANN employs the Generic Names Supporting Organization (GNSO) to oversee policy development for Top level domains. The GNSO “strives to keep generic Top-level domains operating in a fair, orderly fashion across one global Internet, while promoting innovation and competition.”⁵¹² The GNSO includes a council composed of two houses (like the US Congress) and several stakeholder groups, including commercial, non-commercial, registrars, registries, and a nominating committee and liaisons. The goal of the council is to provide a system of “checks and balances so no single group can dominate the council.”⁵¹³ The GNSO operates through a policy development process that includes, issue identification, issue scoping, initiation, working group, council deliberations, board vote, and implementation.⁵¹⁴ The bulk of the work is completed in working groups supported by ICANN staff and subject knowledgeable volunteers.⁵¹⁵ Working groups explore issue and develop recommendations using a consensus decision making style to advance outputs. Working groups report to the GNSO Council which reports to the ICANN Board.

The GNSO consensus process is elaborate. It includes several designations, including full consensus, consensus, strong support but significant opposition, divergence, and minority view.⁵¹⁶ Each designation has a unique definition that helps characterize the group’s perspective on a work item. A working group can also develop its own consensus policy at the outset of a working group so long as it is stated in the working group’s charter.⁵¹⁷ Policies developed

⁵¹² Generic Names Supporting Organization, “About the GNSO,” International Corporation for Assigned Names and Numbers, accessed November 2021, <https://gnso.icann.org/en/about>.

⁵¹³ Generic Names Supporting Organization, “GNSO Council,” International Corporation for Assigned Names and Numbers, accessed November 2021, <https://gnso.icann.org/en/about/council>.

⁵¹⁴ Generic Names Supporting Organization, “GNSO Policy Development Process (PDP),” International Corporation for Assigned Names and Numbers, accessed November 2021, <https://gnso.icann.org/en/basics/consensus-policy/pdp>.

⁵¹⁵ Generic Names Supporting Organization, “GNSO 101,” International Corporation for Assigned Names and Numbers, accessed November 2021, <https://gnso.icann.org/en/basics/101>.

⁵¹⁶ Generic Names Supporting Organization, “Annex 1: GNSO Working Group Guidelines,” International Corporation for Assigned Names and Numbers, 2019, 8, accessed November 2021, <https://gnso.icann.org/sites/default/files/file/field-file-attach/annex-1-gnso-wg-guidelines-24oct19-en.pdf>.

⁵¹⁷ Ibid., 9.

through the consensus process are considered binding on organisations that contract with ICANN, like registries and registrars.⁵¹⁸

ICANN's role in governing the DNS is similar to a national regulator in that ICANN accredits DNS relevant organisations, like registries and registrars, and then outlines the policies those organisations must follow. ICANN has less influence over other actors like end users or companies that purchase domains. ICANN's influence over parts, but not all of the DNS ecosystem, can limit its ability to govern the DNS comprehensively.

Adjusting the DNS can take considerable effort and involve more than just the GNSO or ICANN Board. Initially there were seven generic Top-level domains, like “.com” or “.edu”. Over the years ICANN permitted the creation of additional Top-level domains, like “.museum” or “.jobs”. In 2012 when ICANN accepted submissions for new generic Top-level domains it received nearly 2000 applications, and many for the same Top-level domain, like “.app”.⁵¹⁹ To resolve the issue, ICANN auctioned the contested Top-level domains. The registration and operating cost for new generic Top level domains is estimated at nearly \$2 million USD, which is the responsibility of the registrant.⁵²⁰ The duration a Top level domain or second level domain can be owned depends, but generally it is between one and ten years and it is not typically prohibitive to reacquire a domain over time because ICANN has adopted procedures to allow registrants to challenge new registrations if the new registration might produce trademark issues. There are now more than 1500 Top level domains and over 350 million Second level domains.⁵²¹ The GNSO plays a central role in governing the DNS, but ICANN and the GNSO are not the only major actors capable of influencing the DNS or issue of DNS scarcity.

⁵¹⁸ Generic Names Supporting Organization, “GNSO 101”.

⁵¹⁹ New Generic Top-Level Domains, “New GTLD Weekly Update,” International Corporation for Assigned Names and Numbers, December 2012, <https://newgtlds.icann.org/en/announcements-and-media/announcement-21dec12-en>.

⁵²⁰ Patricia Vargas-Leon and Andreas Kuehn, “The Battle for Critical Internet Resources: South America vs Amazon.com, Inc.,” *The Law, State, and Telecommunications Review* 7, no 1, (2015), 44, DOI: <https://doi.org/10.26512/lstr.v7i1.21538>.

⁵²¹ Roslyn Layton, “MIT Researchers Estimate The Value of Domain Name System (DNS) At \$8 Billion,” *Forbes*, 2021, accessed November 2021, <https://www.forbes.com/sites/roslynlayton/2021/03/23/mit-researchers-estimate-the-value-of-domain-name-system-dns-at-8-billion/?sh=92d25b665d2a>.

The DNS process is straightforward, but the economic and political implications are not. The need to create and manage the DNS inherently makes them a scarce resource. With scarcity comes influence, which can affect the financial value of the DNS and the market it operates within.⁵²² Conversely, to simply create more Top-level domains would not necessarily adjust the influence of DNS managers, like registries. For example, the creation of new generic Top-level domains, like “.jobs” will not necessarily undermine the prominence of original Top-level domains like “.com”. So, the existing structure which permits points of influence would still exist even with the addition of new Top-level domains. Influence is important when considering the DNS financial value.

It is estimated that the total DNS ecosystem market is valued at approximately \$8 billion.⁵²³ Revenues from the DNS flow to several public, private, and other organisations in addition to ICANN. Verisign is a publicly traded company and Top-level domain name registry responsible for “.com” and other prominent domains. Verisign reported nearly \$1.3 billion in revenue in 2020.⁵²⁴ The value the DNS creates is not equally distributed either. Verisign manages some 76% of legacy Top-level domains while 55 of the 2496 ICANN accredited domain name registrars control roughly 95% of second level domains.⁵²⁵ The DNS is not only essential for using the internet, but as a CIR it comes with significant financial value.

The GNSO plays an important role in deciding how the DNS is governed, but so too does the market. This creates some governance limitations. First, not all actors hold equal position in a free market system. As noted by the examples above, Verisign has considerable market share that necessarily means other registries have less. Similarly, a wealthier organisation interested in the rights to a new generic Top-level domain likely has the financial means to outbid smaller

⁵²² William Lehr, David Clark, Steve Bauer, “Changing markets for Domain Names: Technical, Economic, and Policy Challenges,” Presented at the 48th Research Conference on Communication, Information and Internet Policy, December 2020, 13, <https://dx.doi.org/10.2139/ssrn.3746594>.

⁵²³ Ibid., 16.

⁵²⁴ Trefis Team, “Steady Revenue Growth To Drive Verisign Stock To Fresh Highs,” Forbes, April 2021, accessed November 2021, <https://www.forbes.com/sites/greatspeculations/2021/04/20/steady-revenue-growth-to-drive-verisign-stock-to-fresh-highs/?sh=7a65b65b664f>.

⁵²⁵ William Lehr, David Clark, Steve Bauer, “Changing markets for Domain Names: Technical, Economic, and Policy Challenges,” 25; and, “List of Accredited Registrars,” International Corporation for Assigned Names and Numbers, accessed November 2021, <https://www.icann.org/en/accredited-registrars?filter-letter=a&sort-direction=asc&sort-param=name&page=1>.

organisations in a domain auction. When domains can influence internet traffic, and subsequently profits, the DNS resource allocation process can perpetuate a ‘haves’ and ‘have nots’ ecosystem.

A second limitation is that ICANN’s policies to adjust practices to encourage innovation or bolster CIRs must contend with the market. Adding new generic Top-level domains was initially thought to encourage innovation and reduce the competition over legacy Top level domains, but that is not what happened. To some extent new generic Top-level domains offered new CIRs to expand the DNS, but there is still strong preference for legacy domains, like “.com”, while new Top-level domains, like “.biz” or “.info” struggle to capture market share.⁵²⁶ This line of thinking is supported by the market forces that encourage a company to keep its domain name rather than switch. For Google to change its domain name, even from “.com” to “.search” would have a significant impact on its business. In many ways the market forces influencing the DNS can make it difficult to change the nature of DNS and reduce CIR scarcity because economic incentives can discourage change.

These factors ultimately affect how the DNS evolves and is governed. ICANN’s ability to influence the DNS is important and only ICANN has certain authorities to make important changes or otherwise govern certain features of the DNS. And while ICANN will continue to play a role governing the DNS, the market forces impose restraint on what ICANN can or cannot influence. While ICANN can approve the creation of new genetic Top-level domains, it cannot force their adoption at scale or provide new Top-level domains with equal market share to legacy domains. Moreover, while registrar and registries have important influence as well, their influence can pale in comparison to large internet dependent companies, like social media or e-commerce giants. The confluence of actors and market forces make governing the DNS similar to the limitations imposed on the IMO and ICAO, where they set out to create new measures to affect actor behaviour but are generally unable to force change. Financial markets play an important role in each case study but given the multistakeholder model of internet governance they do appear to play a more significant role in CIR governance.

⁵²⁶ William Lehr, David Clark, Steve Bauer, “Changing markets for Domain Names: Technical, Economic, and Policy Challenges,” 25, 33.

Internet numbers: IPv4 and IPv6

In February of 2011 ICANN announced it had allocated all available 4.3 billion internet IPv4 addresses. Though there were still available addresses through RIRs, the announcement signalled the use of IPv4 had reached a new level of scarcity and a place of no return. Use of one of the internet's most critical resources had reached its limit.

4.3 billion unique addresses have been allocated by IANA and RIRs in just 30 years between IPv4's adoption in 1981 and ICANN's accountment in 2011. IPv4's technical design and early administration contributed to resource depletion more than simply the growth of the internet. For technical reasons, like simplifying the routing process, IPv4 addresses were allocated in large blocks of addresses.⁵²⁷ Allocating large blocks, which occurred for free in the early years, meant early IPv4 internet users, like US universities and large businesses, ended up with a substantial number of addresses. In 1989, for instance, despite there being a reported 159,000 internet connected hosts there were some 600 million addresses allocated.⁵²⁸ Even as recently as 2000, the uneven distribution of addresses was still prevalent. Until 2000 the entire country of China held fewer IPv4 addresses than the University of Stanford.⁵²⁹ By some estimates, nearly 40% of IPv4 addresses were allocated inefficiently.⁵³⁰

With the internet's and IPv4's development occurring in the US, geographic distribution was also generally uneven, especially between developed and developing countries. Once allocated, there was no requirement—and little incentive—to return unused addresses. In fact, when Stanford relinquished a large block of addresses in the late 1990s, it was one of the only examples of an organisation returning such a large number of addresses.

⁵²⁷ Laura DeNardis, *The Global War for Internet Governance*, 80.

⁵²⁸ Laura DeNardis, *Protocol Politics*, 151-152.

⁵²⁹ Sean Gallagher, "NSA 'Touches' more of Internet than Google," *Ars Technica*, August 2013, accessed November 2021, <https://arstechnica.com/information-technology/2013/08/the-1-6-percent-of-the-internet-that-nsa-touches-is-bigger-than-it-seems/>.

⁵³⁰ Brenden Kuerbis and Milton Mueller, "The Hidden Standards War: Economic Factors Affecting IPv6 Deployment," 10.

In retrospect, one could question why such large blocks of addresses were allocated so unevenly and seemingly without concern for the conservation of IPv4, but the internet's architects did not envision the internet would become what it is today. Instead, they were more interested at the time in establishing common standards that would allow the internet to move beyond separate individual networks. As a result, governing IPv4 tended toward generous allocations rather than strategies of conservation.

As conservation issue became apparent network operators began developing strategies to conserve IPv4 addresses and extend the standard's life. A prominent approach, known as network addressing translation (NAT), translates a large number of private non-globally routable IPv4 addresses into a small number of public globally routable IPv4 addresses when connecting outside the private network. In other words, NAT allows private networks to use non-unique IPv4 addresses internal to the private network and translates them into unique IPv4 addresses when connecting to the internet outside the private network. The ability to use non-unique addresses in a private network is one of a few key reasons why 28.5 billion IoT devices can be served by only 4.3 billion IPv4 addresses.⁵³¹

Developed in 1991 through the IETF, NAT continues to serve an important role today, though not without some criticism. When developed, it was not standardized so various forms of NAT capabilities exist offering different technical and operational trade-offs.⁵³² NAT also represents a single point of failure where all traffic must pass through a NAT box before being sent to its intended host. NAT can also come with added financial cost through scaling, maintenance, and other issues.⁵³³ The internet technical community organized through the IETF never planned for NAT (or similar tools) to be long-term solutions.⁵³⁴ Instead, they were

⁵³¹ Some of the 28.5 billion IoT devices are served by IPv6, but it represents a fraction of the IP address space. For IoT devices see: Cisco Public, "Cisco Visual Networking Index: Forecast and Trends, 2017–2022," Cisco, 2019, 1, accessed November 2021,

<https://twiki.cern.ch/twiki/pub/HEPIX/TechwatchNetwork/HtwNetworkDocuments/white-paper-cl11-741490.pdf>.

⁵³² <https://www.ietfjournal.org/a-retrospective-view-of-nat/>

⁵³³ Brenden Kuerbis and Milton Mueller, "The Hidden Standards War: Economic Factors Affecting IPv6 Deployment," 24

⁵³⁴ Lixia Zhang, "A Retrospective View of NAT," *IETF Journal*, October 2017, accessed November 2021, <https://www.ietfjournal.org/a-retrospective-view-of-nat/>.

developed as temporary remedies while a new internet protocol was viewed as the long-term answer for address scarcity.⁵³⁵

As early as 1992 the internet's technical community began deliberating on IPv4s replacement. The goal was to increase the number of available addresses to accommodate the internet's growth. The decision came with incredible economic, political, and technical ramifications. At a time when many internet users, whether government, private companies, or individuals, were just beginning to understand the value and potential of the internet, the technical community was discussing a major change that could affect all users.

In 1993 the IETF formally took responsibility for developing IPv4's successor.⁵³⁶ At the centre of the decision making was the Internet Protocol Next Generation (IPng) Directorate supported by the IETF Secretariat. According to Directorate meeting minutes, the Directorate would perform "the white paper reviews, review of the various proposal documents, work with the co-directors in the establishment of working groups under the area, participate in big-internet discussions, do outreach when offered the chance, review working group documents, and etc,"⁵³⁷ Governments were not represented on the IPng Directorate. Instead, the group was composed of industry and academic representatives. The directorate met via teleconference monthly while most of the directorate's work occurred outside Directorate meetings. The IPng development processes followed IETF processes. The Directorate solicited white papers from the internet technical community, provided Directorate and external reviews, circulated feedback and opinions on drafts, and eventually advanced proposals.⁵³⁸ Though Directorate meeting notes

⁵³⁵ Other examples include classless inter-domain routing and secondary IP address markets where owners could sell unused addresses to others. For more see: Brenden Kuerbis and Milton Mueller, "The Hidden Standards War: Economic Factors Affecting IPv6 Deployment," 26; and, Lixia Zhang, "A Retrospective View of NAT".

⁵³⁶ For a history of the IPng process see IP Directorate presentation: Scott Bradner and Allison Mankin, "IP Next Generation (IPng)," Sobco.com, July 1994, accessed November 2021, <https://www.sobco.com/ipng/presentations/ietf.7.94/report.txt>.

⁵³⁷ Steve Coya, "INPG Directorate Teleconference," Sobco.com, November 1993, accessed November 2021, <https://www.sobco.com/ipng/directorate.minutes/ipng.93-11-22>.

⁵³⁸ Mark Knopper, "IPNG Directorate Teleconference," sobco.com, February 1994, accessed November 2021, <https://www.sobco.com/ipng/directorate.minutes/ipng.94-02-14>.

allude to the group's appreciation for larger political and economic ramifications of IPng, the Directorate's focus was limited to the technical design and functionality of the new standard.⁵³⁹

In 1994 the IEFT announced IPv4's replacement would be another IP based standard known as IPv6.⁵⁴⁰ In 1998 the IEFT released the draft standard for IPv6. The new standard included many new features thought to solve shortcomings of IPv4.⁵⁴¹ Most prominently, IPv6 extended the number of available addresses exponentially by increasing from 32 bits to 128 bits which supplies some 340 undecillion unique addresses.⁵⁴² A year after the IETF released the core IPv6 protocol, IANA assigned the first block of IPv6 addresses.⁵⁴³

Perhaps one of the most important design features of IPng was that IPv6 was not backwards compatible with IPv4. This meant to adopt IPv6 would require translation capability with IPv4 to make both work together.⁵⁴⁴ Effectively, IPv6 did not upgrade the existing internet, IPv6 was the creation of a separate internet. Of course, the internet community could not simply flip a switch and transition from IPv4 to IPv6. There were requirements to develop along with hardware and software among other technical needs that would take time and money to resolve. This meant IPv6 and IPv4 would need to coexist for some time, and that the market would influence the speed and scale of IPv6's adoption.

The announcement of a new internet protocol echoed around the world influencing commercial and government policy alike. For commercial companies, the transition required balancing cost of upgrading systems with the opportunity IPv6 provided. For many private companies, especially those in the United States, there was not enough economic incentive to motivate large scale upgrading. Companies with enough IPv4 address space were not constrained

⁵³⁹ Jim Bound, "IPNG Directorate Teleconference," sobco.com, January 1994, accessed November 2021, <https://www.sobco.com/ipng/directorate.minutes/ipng.94-01-25.mbone>.

⁵⁴⁰ "IPNG (ipngwg) Charter," Internet Engineering Task Force, accessed November 2021, <https://www.ietf.org/proceedings/33/charters/ipngwg-charter.html>.

⁵⁴¹ "Internet Protocol, Version 6 (IPv6) Specification," Internet Engineering Task Force, December 1998, accessed November 2021 <https://datatracker.ietf.org/doc/html/rfc2460>.

⁵⁴² Ibid.

⁵⁴³ "IPv6 Global Unicast Address Assignments, RFC 7249," Internet Assigned Numbers Authority, November 2019, accessed November 2021.

⁵⁴⁴ Jim Bound, "IPNG Directorate Teleconference".

like newer companies struggling to find necessary internet resources. Given the number of IPv6 addresses there was also little reason to worry about address scarcity, which meant there was no need to rush into the transition if one possessed enough IPv4 address space. Additionally, government policies were not necessarily encouraging IPv6's adoption in countries where IPv4 was plentiful.

Government policies were influential in countries trying to leap ahead and take advantage of the next phase of the internet, but the commercial market's influence would be difficult for even governments to overcome. In 2000 Japan created a national plan for upgrading much of Japan's internet infrastructure to IPv6. The plan included spending billions of government yen on programs, tax incentives, and other efforts to encourage adoption across Japan. The goal being to become more competitive in IoT. The EU, China, South Korea, and a few other nations took similar approach believing IPv6 was the next area of internet influence.⁵⁴⁵

While noble attempts, many government efforts to speed adoption of IPv6 failed to produce a near-term return on investment.⁵⁴⁶ The internet is a series of connected private networks, so for IPv6 to provide the influence and the economic return countries like Japan were looking for, IPv6 would have to be the dominate protocol connecting private networks. But the internet is highly influenced by commercial markets.⁵⁴⁷ In such markets dominate actors can influence the broader market through individual decisions. In the case of IPv6 adoption, because the US was at the time the economic and technical hegemon of the internet and possessed ample IPv4 address space, there was little market incentive for US companies and organisations to adopt IPv6 rapidly. With much of the global internet ecosystem connecting through the US, the adoption of IPv6 globally was greatly impaired by the limited adoption across the US. Effectively, the multistakeholder nature of the internet governance also made it too difficult to centralize a global transition from IPv4 to IPv6. Today, adoption of IPv6 is increasing but slowly. Only 32% of

⁵⁴⁵ Laura DeNardis, *Protocol Politics*, 97-110.

⁵⁴⁶ Ibid.

⁵⁴⁷ Brenden Kuerbis and Milton Mueller, "The Hidden Standards War: Economic Factors Affecting IPv6 Deployment," 16-17.

those who access Google.com do so through IPv6.⁵⁴⁸ Moreover, of the Alexa Top 1000 websites, only 30% support IPv6.⁵⁴⁹

The IPv4 transition highlights central features of the internet governance regime. Principally, the role of technical stakeholders relative to governments, and the influence of commercial markets on the adoption of strategies designed to govern the internet. As a humanmade domain, solving sustainability challenges is in part a matter of creating new technical approaches, but as an integral part of our modern way of life, touching economic, government, national security, and more, the internet is also influenced by social factors, like economic markets. Neither the technical nor the social factors are entirely capable of driving internet governance individually. Instead, both must come together as a complement to see new governance resolve challenges.

Conclusion

On the surface the internet governance regime is noticeably different from the air and maritime domains. It is a bottom up, multistakeholder regime rather than a top-down state-centric scheme. While unique in important ways, internet governance exists for the same reasons as the other governance regimes: to cohere disparate practices to preserve and advance the internet and related interests of internet actors. So, despite some important differences, it is still possible to evaluate the internet based on familiar metrics, like member buy in, agility, compliance, and the regimes benefit to the internet.

The internet has been in a constant state of change since its creation in the 1970s. Internet governance has managed to change with it in important ways while remaining stagnant in others. The number of internet connected devices has ballooned since the internet came online and growth shows no signs of stopping. The number of internet users grows daily, while the need for more internet infrastructure spanning land, sea, and space grows at an equal portion. To meet these changes the internet community has maintained a regular cadence of developing new

⁵⁴⁸ Google IPv6, "Statistics," Google, accessed November 2021, <https://www.google.com/intl/en/ipv6/statistics.html#tab=per-country-ipv6-adoption>.

⁵⁴⁹ "The Future is Forever," World IPv5 Launch, updated 8 June 2022, accessed July 2022, <https://www.worldipv6launch.org/measurements/>.

protocols, software, and hardware to adapt as the needs of the internet community change. When it comes to managing CIRs, however, the ability to change quickly is not something ICANN or the technical community can influence beyond developing the tools for internet users to adopt as they see fit.

Key to governing change is internet stakeholder endorsement. The bottom up, multistakeholder nature of internet governance certainly empower stakeholder buy in by reducing barriers to entry. There is ample opportunity for the internet community to contribute to the development process through feedback and participation in relevant organisations. The need for technical knowledge is required, but there are no requirements to be part of a state delegation or an approved NGO to participate in prominent internet governance organisations, like the IETF. Such a process sits in sharp contrast with other international government organisations which often impose membership requirements that limit participation. There is some criticism that could be placed on ICANN because it is a US company rather than a global organisation, but ICANN has changed significantly since its creation both in government and international inclusivity and its responsibilities related to the DNS.

The low barrier to entry complements the internet community's agility. The bottom-up approach encourages solutions while detailed processes with clear definitions and objectives help mature and complete them. As was the case with both new Top-level domains and the development of IPv6, the internet community organized around the issues through mandated groups supported by larger organisations, like the IEFT Secretariat or ICANN's GNSO. Processes can take years to mature into outputs, but that is not uncommon in international governance. In all, the inclusivity combined with organisational support, clear definitions and objectives, and technically competent member community allows the internet governance regime to advance governance solutions effectively, though as discussed previously what the technical community produces may face implementation limitations due to market forces.

An adaptable internet technical community may do well producing new tools for internet governance, but the bottom-up approach of internet governance means other factors, like the free market, holds equal influence over the implementation of said tools. Technical requirements are

important features of the internet governance regime but creating new protocols or systems for managing CIRs does not necessarily mean they will be implemented as desired by the technical or policy communities, as can be seen with the IPv6 transition. Similarly, while new Top-level domains can be created, they may not hold the same value as legacy Top-level domains. And with no centralized authority to encourage adoption of new standards or similar technical solutions, the internet governance community falls subservient to the economic markets often indifferent to major internet governance issues. Indeed, the implementation of important new internet governance measures is driven by equal parts technical demand and market demand. Governments do continue to hold authority over their internet users, however because one country cannot be assured that its choices will influence the broader internet ecosystem (as was the case with IPv6 policy in Japan discussed previously), governments are also likely to see their influence limited when it comes to implementing new measures across the internet ecosystem.

In all, the internet governance regime represents a different manifestation of international governance from what might be considered more traditional regimes, like those that govern the air or maritime domains. Internet governance is not state-centric, not always advanced through a centralized international organisation, governance tools are often technical rather than legal, and market forces have an equal influence as technical features. While different in character, the internet regime still requires member buy in, regime agility, and effective governance tools. Though there are imperfections, the internet regime would still represent an effective governance model due to its ability to advance outputs, address new issues, and encourage change.

Analysis and Conclusion

There is much that can be considered from the previous comparative analysis. Each case study offers unique and similar features which could inform new satellite constellation governance. For instance, while no two sustainability challenges were exactly alike, the need for consensus and the need to balance governance with development permeated throughout all three case studies. Similarly, while each domain faced sustainability challenges, the governance measures often took different forms, from SARPs and conventions to market-based measures and entirely new technical standards. The goal of this analysis, therefore, is to better understand what lessons from the case studies can help overcome key shortcomings in the development of

governance that balances space sustainability with space development concerning satellite constellations. A key comparative measure for identifying useful lessons will be adaptation, and specifically, what each case study shows for how to adapt the governance regime. The importance of adaptation stems from chapter 2 where it was identified that effective governance of a global commons requires adaptation. The following section will first briefly recall key small satellite governance gaps followed by comparative lessons gleaned from the case study domains.

Governance Challenge and the Need to Adapt: Reactive environmental protections

A key limitation to protecting the space environment from satellites constellations is the lack of governance focused on preventing and removing space debris. Satellites are a leading cause of debris and as more satellites are deployed the risk of debris increases. As we look at each case study against domain sustainability challenges it is clear that producing environmental protection measures almost always occurs reactively, and in many instances requires considerable environmental damage from a crisis to spark action. Reacting to environmental degradation rather than pre-empting it through proactive governance is a worrisome characteristic, but one that provides important lessons to improve space governance.

Though COPUOS does recognize the need for sustainable space development,⁵⁵⁰ existing space governance, like the OST, does not pragmatically address environmental sustainability. Article IX of the OST does require states to avoid harmful contamination of the moon and other celestial bodies and requires consultations between states if a state is conducting activities that may interfere with other state's space activities, but to date these consultations are rare if conducted at all.⁵⁵¹ The language is also vague and less about prohibiting harmful contamination of Earth orbits than discussing activities to avoid interfering with other actors. Other measures like the Space Debris Mitigation Guidelines lack the regulatory teeth to encourage compliance and fail to adequately address leading causes of satellite born debris, like propulsion issues. Moreover, COPUOS has remained stalled and unable to produce new binding agreements. It also lacks the organisational capacity to measure or improve compliance.

⁵⁵⁰ Office for Outer Space Affairs, "Roles and Responsibilities," United Nations, accessed November 2021, <https://www.unoosa.org/oosa/en/aboutus/roles-responsibilities.html>.

⁵⁵¹ 1967 Outer Space Treaty, Article IX.

The lack of environmental protection measures is not unique to space governance. In all three case studies there was negligible consideration for domain sustainability at the time each organisation was developed. In 1948 when the Geneva Convention was developed to create what would become the IMO, the text did not mention marine pollution or the environment.⁵⁵² Similarly, the Chicago Convention does not include provisions specific to environmental sustainability, nor did early internet pioneers care much about resources preservation based their IP address allocation practices. Instead, each governance organisation's earliest concerns related to the development of the domain largely for economic reasons. For the IMO this meant a focus on "economic action to promote 'freedom' and end 'discrimination'";⁵⁵³ for ICAO the focus was the development of civil aviation while reducing concerns related to civil aviation and state security;⁵⁵⁴ and for the internet the goal was to coordinate technical aspects of the internet to ensure its global reach, or "one world, one internet."⁵⁵⁵

Only after environmental issues arose did each organisation assume responsibility for domain sustainability. Tragic events like the Torrey Canyon disasters motivated the IMO to create cornerstone treaties addressing features of shipping affecting marine sustainability, including the London Convention. For ICAO to adopted measures affecting the environment would require decades of civil aviation greenhouse gas emissions and the Kyoto Protocol. The internet community was similarly reactive and only took action to preserve internet numbers once it was clear they would be depleted. Environmental issues are common in international governance. Unfortunately, so too is waiting too long to take appropriate measures.

The current state of space debris is such that even acting now would resign COPUOS or any other space governance bodies to a similar reactive character. Space debris is already a major problem affecting space development, but so far even major debris causing events have not motivated any serious international efforts to address the issue; including the November 2021

⁵⁵² "Introduction to IMO," International Maritime Organization.

⁵⁵³ "Convention on the International Maritime Organization," International Maritime Organization.

⁵⁵⁴ Convention on International Civil Aviation, 7 December 1944, *UNTS* 15, 295, preamble.

⁵⁵⁵ "Welcome to ICANN!," Internet Corporation for Assigned Names and Numbers, accessed November 2021, <https://www.icann.org/resources/pages/welcome-2012-02-25-en>.

Russian anti-satellite weapons test that destroyed a defunct Russian satellites creating thousands of pieces of debris and putting the international space station crew in jeopardy.⁵⁵⁶ The apathetic concern for space debris even following major events leaves little optimism that space governance can avoid falling into a similarly reactive state when it comes to protecting the space environment from growing numbers of small satellites and subsequent debris.

Producing new agreements through COPUOS has been a near impossible task for much of the last forty years.⁵⁵⁷ The inability to produce new agreements is due in large part to the strict and exhaustive processes required in the forum and too few resources to address a growing set of governance needs. As evident by the case studies, IO process is critical to evolving sustainability governance. What space governance needs now is more member endorsement in and organisational adaptability through better processes that empower COPUOS to address the debris risk of small satellites proactively.

Governance Solution via Adaptation: Developing Proactive Small Satellite Governance

As the case studies show, each organisation was not initially developed to address environmental concerns, and to do so, they had to adapt. Based on the case studies, at the heart of effective organisational adaptation is decision making. Each case study organisation requires the use of consensus to produce new governance measures or make organisational changes to its structure, remit, among other changes. As discussed, consensus can come with increased transaction costs in exchange for increased agreement compliance or member buying. The key to balancing transaction costs with compliance is to understand *where* in the processes consensus is required (i.e., should COPUOS require consensus to add a working item to the agenda or at a later stage when adopting a new agreement?), and *how* consensus is achieved (i.e., through a form of tacit acceptance or a full member vote).

⁵⁵⁶ Amanda Miller, "US Officials: Russian Anti-Satellite Test Created Extensive New Orbital Debris Field," Air Force Magazine, November 2021, accessed November 2021, <https://www.airforcemag.com/u-s-officials-russian-anti-satellite-test-created-extensive-new-orbital-debris-field/>.

⁵⁵⁷ Kenneth Hodgkins and Adam Routh, "Emergence of and perspectives for a new paradigm in space diplomacy," 37-52.

There is not one right way to achieve consensus. In the IMO's case, tacit acceptance has been instrumental in amending existing conventions hundreds of times. ICAO's main output, SARPs, are approved by two-thirds vote of the Council while providing states a set period of time to indicate why they may not adhere to a SARP or need to modify it. ICAO and the IMO save more comprehensive consensus approaches for Assembly products, like new conventions. For ICANN and the GNSO, consensus exists on a spectrum and working groups can define at the outset what sort of consensus they are seeking for a given task. The à la carte approach to achieving consensus taken by the GNSO allows for working groups to customize the process for the output to balance transaction costs more effectively with compliance needs.

Similarly, the IMO, ICAO, and ICANN have different expectations for when during the development of a governance output consensus is required. For example, consensus is not required to propose the development of a new SARP. The IMO and IETF also tend to require consensus at later stages of governance development rather than throughout. Limiting the number of processes steps that requires consensus reduces transaction costs while requiring consensus to adopt a governance measure preserves the value consensus provides agreement adherence.

For highly technical and rapidly evolving small satellites and based on the leading cause of space debris (i.e., propulsion anomalies), a mix of technical standards, like SARPs, supplemented by more comprehensive agreements, like conventions, would go a long way to preserving the space environment. And as the case study organisations show, various outputs can be aided by different processes and decision-making requirements. Flexibility in how each organisation chooses to achieve consensus allows each to thoughtfully balance transaction costs with adherence requirements to avoid decision paralysis and advance governance more rapidly. This flexibility sits in sharp contrast to COPUOS' rigid and comprehensive consensus requirements. Processes can change, however.

The consensus flexibility currently demonstrated by the IMO and ICAO were the product of procedural change undertaken by each organisation as transaction costs grew too cumbersome and began to stall the production of new governance measures. To proactively address

sustainability issues COPUOS could benefit from adjusting its consensus decision making style to better balance transaction costs with adherence based on the governance measure in question.

Based on what has enabled the IMO, ICAO, and internet governance organisations to advance measures in each respective domain, COPUOS could more effectively meet governance needs by avoiding a one-size-fits-all consensus style for each governance output. Rather, catering consensus approaches based on balancing transaction cost with adherence needs is shown to be an effective way to produce governance outputs. For example, it is evident from ICAO that the technical specificity of SARPs does not justify high transaction costs associated with a laborious consensus process because adhering to SARPs can depend on a number of factors from national regulatory requirements to commercial market incentives. The same can be said for the IETF and many new internet protocols. Conversely, given the importance of adherence to more complex legal instruments, like foundational conventions, greater transaction costs may be required through more robust consensus requirements because member state adherence is essential to the success of the convention. Adjusting the decision-making style is a necessary step to improving organisational adaptability without sacrificing member buy in.

The case studies have shown the role of census in producing agreements, but they also show that even with consensus adhering to governance measures can be difficult to guarantee.

Governance Challenge and the Need to Adapt: Enforcing Sustainability Measures

Another governance challenge reflects the IO's limited ability to ensure agreement compliance and enforcement. The gap is born primarily from the limited influence IOs have relative to states which reflect the Westphalia state system that defines international relations today.

The topic of agreement compliance is a complex one. A multitude of factors influence a stakeholder's decision-making process to support a governance measure or not. As detailed in the case studies above, domestic concerns, politics, among other reasons can all influence a stakeholder's decision to support the development of an agreement while the same or alternative reasoning can affect a stakeholder's decision to enforce or adhere to an agreement. For example,

while a state may adopt a maritime convention related to protecting the environment, for one reason or another, the state may not institute the domestic regulatory measures to enforce it. Because of this, the case study IOs routinely adopted measures to help member states assess compliance and adhere to agreements.

The vague and general nature of existing international space governance makes it nearly impossible for COPUOS to measure adherence let alone enforce compliance of familiar space activities, like registering a satellite. The problem grows even more protracted when considering many emerging space development activities, like small satellite operations, may be too nascent to confidently develop comprehensive governance. Space is also a difficult place to conduct visual inspections to confirm or refute compliance. To do so requires inspecting satellites on the ground, which can create intellectual property concerns, or the use of ground-based systems, like telescopes, or on orbit systems that can manoeuvre close enough to image a satellite. In all, it is a complicated process requiring a multitude of actors and technology. Indeed, most of the information gleaned about activities in space is self-reporting from the satellite operator who is not obligated to share all information necessary to assess sustainability features. These factors make agreement enforcement for space activities uniquely difficult compared to the challenges experienced in the case study domains, where measuring compliance of a ship, plane, or internet domain name can be more strait forward. The ability to physically touch a ship or plane or simply inspect the usage of certain internet resource aids measuring compliance. Not to mention the role sovereignty plays. Still, measuring compliance requires IOs to develop agreements and tools.

The IMO has several tools to help states adhere to agreements and measure compliance. ROs, the IMSAS and consolidated audit summary report, and several liability agreements all empower the IMO and states to encourage and enforce compliance with IMO conventions. The IMO has developed tools through conventions and other means that empower states to use their port state authority to encourage adherence to IMO convention even upon states not party to IMO conventions. The complement of legal and somewhat free market (e.g., reputational value of ROs) options is an imperfect but robust set of adherence and enforcement tools.

Similarly, ICAO has adopted the Universal Oversight Audit Scheme with the Coordinated Validation Mission and the Continuous Monitoring Approach to assess compliance with ICAO measures and support greater adherence where shortcomings are identified. For ICAO, like the IMO, sovereignty also plays a role. Air routes require access approval by states and states may choose to block access if measures adopted by ICAO are ignored.

ICANN has a more market-based approach to enforcement given the technical and generally commercial nature of the internet. Organisations that contract with ICANN, like registries and registrars, have domestic legal requirements like business contracts that can easily be adjudicated in court should compliance become an issue. More importantly, the technical and multistakeholder nature of the internet can prevent noncompliance from occurring in the first place. For instance, once a name or number is allocated it would require broad multistakeholder coordination to break the rules and allocate it a second time, a situation unlikely to occur given the risk to each organisation for breaking the rules and the complexity of coordinating such a plan.

In each of the case studies, adherence to governance measures can prove tricky and IOs or multistakeholder groups are inherently limited in their ability to influence actor behaviour. Doing so requires legal and other enforcement measures that provide member state with the tools to make compliance easier or enforcement easier. Through audit schemes, reporting, and liability conventions the IMO and ICAO have developed tools to address compliance and enforcement. Importantly, these tools do not exist as one-offs, but as suites of agreements and other resources that create a complementary enforcement scheme. For the internet, compliance is almost designed into how the internet functions from a technical standpoint. Such a scheme (aside from the outdated Liability Convention) does not exist for space governance or satellite constellations specifically.

Governance Solution via Adaptation: Improving Satellite Governance Compliance

Ensuring that new space governance agreements designed to limit debris from small satellites and constellations would require a mix of new tools that address audits, reporting, state authorities, and liability.

There are lessons from the case studies that can be applied to new satellite governance. Recalling from earlier in the chapter, space debris is addressed through mitigation, measures taken to prevent the satellite from causing debris, and remediation, measures to remove existing debris. An audit scheme followed by a report like those used by the IMO and ICAO would provide transparency for mitigation and removal of space debris by actor or activities. These audits could be carried about by COPUOS, or a third-party organisation like ROs. The goal being to draw international attention to positive and negative instance of compliance while highlighting why some choose not to comply.

Enforcing governance tools for small satellites is equally difficult. Granting access to domestic markets predicated on compliance with agreements could improve enforcement of new agreements, however. Increasingly, small satellites are being developed with the goal of providing global services, like broad band internet or earth imagery. To provide such services requires regulatory approval by the state. Like how port state authorities or air routes provide leverage to states seeking to enforce sustainability governance, states could require commercial small satellite service providers to adhere to small satellites sustainability measures before granting permission to access markets. While there are currently few commercial companies providing important services globally, the number is expected to increase, and as it does small satellite governance should include measures that empower states to require commercial actors to follow sustainability measures in exchange for commercial access to markets. COPUOS could improve effectiveness through the means to hold states accountable through audits and reports. Like the IMO, COPUOS could include provisions in agreements that reflect terrestrial state authority while national regulators would be responsible for enforcement.

Accommodating new compliance and enforcement measures would require COPUOS to adapt as an organisation. Currently, the forum is not equipped to handle the administrative burden of audits and nor does it have the necessary agreements in place to empower state authorities through concepts akin to port state control. Establishing new COPUOS subcommittees, like MEPC or CAEP, could offers a helpful solution. Another solution could include third-party organisations, like ROs, which once approved by COPUOS, could aid states

in assessing compliance. COPUOS will also have to develop new agreements that enable audit schemes, ROs, and other necessary legal tenants required to more adequately govern space debris from satellites constellations.

Based on the case studies, and principally the IMO, liability and compensation agreements can also help improve compliance. In the IMO case study, there are several complementary, and at times, overlapping liability and compensation agreements that can make it challenging for states or commercial companies to avoid costly penalties if at fault. A key lesson from the development of the IMO's liability and compensation scheme is the focused scope of each agreement. Rather than broad agreements looking to address a wide range of liability and compensation topics, the scheme involves agreements addressing specific issues. Limiting the scope of agreement can reduce transaction costs but when complemented by several specific agreements still provide a comprehensive regime. Space governance could benefit from specific debris liability and compensation agreements that address specific aspects associated with debris mitigation and remediation.

In addition to changes to COPUOS' processes or ability to monitor or enforce measures, COPUOS, and the space governance community broadly, could benefit from a perspective change. The frequency and volume at which new measures are produced through ICAO, the IMO, and the internet community suggests each organisation or group does not look at governance as an end state but a process. A process where an agreement developed to address an issue today is not necessarily viewed as a long-term solution or even a comprehensive solution, but a solution that adds value and which future agreements can complement or replace. The perspective is one desperately needed in the space governance community.

Decades of stalled processes and diplomatic impasse in COPUOS has altered the forum's perspective of space governance. The sheer volume of work necessary to advance even non-binding guidelines requires the full attention of the forum and its member states. The effort required has prevented the forum from adopting an evolutionary perspective of sustainability governance; one that is comfortable with an agreement having a short half-life or only addressing parts of a problem, like those used in the case study domains. The consequences of the

perspective have left the value of outputs elevated, raising transaction costs and the diplomatic stakes around which the agreement is negotiated.

More than just stalling the development of new governance, COPUOS' perspective discourages member buy in. After decades of stalled outcomes and tedious progress, what value is there in participating other than to ensure an unfavourable agreement is not developed? Without a perspective change COPUOS is unlikely to adjust its processes necessary to adopt a more productive consensus style or expand the forum to improve compliance. Given the challenges the IMO, ICAO, and the internet community still face balancing sustainability with domain development, even as more agile and responsive organisations, the space governance regime will need to change to add even limited value.

Summarizing Lessons Learned

The case studies confirm the importance of governance adaptation for addressing sustainability challenges of a global commons, and specifically, space. In each case study, the organisation or multistakeholder group being examined routinely sought ways to adapt governance to meet ever changing governance needs. Recalling discussion from chapter 2, the need to adapt governance is identified by the research of Ostrom et. al., which finds that adapting governance is essential for keeping pace with ever changing technology and state interests. To this end, the IMO, ICAO, and the internet community changed their processes and outputs to ensure the organisation could continue to advance useful governance despite exogenous change. For governance focused on environmental sustainability, decision-making and compliance emerged as two important focus areas for adapting governance.

Based on the case studies, as each organisation began to struggle with environmental challenges, they had to adapt processes to ensure the forum could meet new governance needs. At the heart of adapting processes is how the forum makes decisions. In each case study, the forum either adjusted its decision-making approach or allowed for a more flexible selection of decision-making approaches to better balance transaction costs with compliance and/or member buying to the process. Similarly, as governance evolved, each case study organisation adapted its approach to compliance via various measures and tools. Adapting compliance measures is

important because governance addressing sustainability challenges can often increase costs to states and operators (e.g., requiring certain ships to have double hulls). For both decision making and compliance, the case study organisations clearly viewed governance as a process not an end state. In other words, adapting processes and outputs was a feature of governance, not a bug.

Conversely, the space governance regime, and COPUOS specifically, have remained largely stagnant for several decades. Processes and approaches to decision-making within COPUOS are today as they were when the forum was created. COPUOS' use of various governance tools has changed overtime but in ways that reflect less useful adaptation. For example, COPUOS has shifted from binding to non-binding measures because the forum struggles to reach consensus on more impactful measures. So, while there is some variation in agreement choice, the variation is not due to the forum's ability to adapt to changing technology and state interests, but rather the forum's inability to adapt to those things. For the same reason, the forum has been unable to address compliance.

To address the generally reactive nature of space governance to prevent and combat space debris and other space sustainability issues, the case studies make clear that COPUOS will need to adapt organisational processes, including its approach to consensus decision-making and its use of varied governance tools to assess and aid compliance of new measures.

6. SPACE TRAFFIC MANAGEMENT

If satellites are the workhorse that will deliver the next phase of space development, then it makes sense that there would need to be a way to manage the growing number of satellites and satellite activities orbiting the Earth. Not unlike in aviation, shipping, or the internet, space traffic will need to be managed. Managing traffic of all types provides the means to organize otherwise chaotic activities, offering safety, sustainability, efficiencies, and other benefits that serve governments and the public alike. Even in a place like near-Earth space, which may seem so vast that traffic management is unnecessary, managing the traffic of satellites is necessary. But traffic management regimes do not exist naturally; they must be created.

Developing a traffic management regime requires norms, laws, technology tools, and enforcement by proper authorities. In international domains like space, developing a traffic regime also requires international cooperation. In the air and maritime domains traffic regimes for aviation and shipping are well established, and importantly, continue to evolve with the changing character of aviation and shipping. Even in new domains, like the internet, traffic management is an important aspect of a functional and sustainable global common. ICAO, the IMO, and various internet technical and private governing groups are responsible for advising and maturing their respective traffic regimes. In doing so, they permit efficient and sustainable development of their industries.

In contrast, a STM regime does not exist. Many of the prerequisite features of a traffic management regime, like shared data, rules of the road, laws, and international cooperation, are underdeveloped or non-existent in the space domain. Moreover, international organisations, like COPUOS or the ITU, suited to help develop a STM regime have only recently begun taking the topic more seriously but have a long way to go before being able to encourage the development of—let alone govern—a STM system.

The consequences of not having a STM regime include a higher risk to space unsustainability from space debris, military miscalculation due to a lack of space norms, and greater financial cost to space operators faced with increasingly dynamic operational

requirements (e.g., having to respond more frequently to an unpredictable environment). There is even risk to life as crewed spacecraft, like the International Space Station, face threats from the poorly coordinated operational environment. In addition to the risk, uncoordinated space activities hamper development. The more congested space becomes the more coordination is required to efficiently use the limited orbital space available and sustain activities. Similar, too much chaos in orbit can be seen as risky and stunt investment in space activities.

As discussed in previous chapters, the space environment is rapidly changing, and increasing the need for a STM regime that offers coherence and efficiency for space operations while protecting the space domain and the people and property in it. Developing such a regime will require overcoming technical, legal, normative, and organisational barriers. Though developing an STM regime is no small task, the air, maritime, and internet domains offer decades of lessons learned as comparative case studies. The following chapter will first outline the requirements of a STM regime followed by an examination of the traffic management regimes supporting the air, maritime, and internet domains. Finally, the chapter will conclude with analysis and recommendations that could aid in the development of a system of STM.

Understanding Space Traffic Management

In orbit currently are thousands of satellites (and more being deployed almost every month) operated by dozens of independent actors whose incentives, risk thresholds, concern for space sustainability and other spacecraft or actors, and perspectives on good or bad behaviour all differ from one another. The divergent views complicate something at mutually advantageous as avoiding satellite collision.⁵⁵⁸ While satellite collisions are not yet a regular occurrence, the number of instances satellites must adjust course to avoid hitting is rapidly increasing.⁵⁵⁹

⁵⁵⁸ For example, see: Chelsea Ghold, “SpaceX and OneWeb satellites didn’t have a close call in space after all: report,” Space.com, November 2021, accessed November 2021, <https://www.airforcemag.com/u-s-officials-russian-anti-satellite-test-created-extensive-new-orbital-debris-field/>; and, David Goldman, “Re: IBFS File No. SAT-MOD-20200417-00037,” Email to Federal Communications Commission, April 20, 2021, accessed November 2021, <https://cdn.arstechnica.net/wp-content/uploads/2021/04/SpaceX-OW-Ex-Parte.pdf>.

⁵⁵⁹ For example, the SpaceX Starlink have experienced approximately one million close approaches with other objects with some 10,000 maneuverers. The number of collision avoidance manoeuvres by a single constellation is unprecedented. For more see: Hugh Lewis, Twitter post, April 28, 2022 (10:14 a.m.).

Moreover, each time a satellite manoeuvres it does so unilaterally, leaving other space operators unsure of how the manoeuvre will create new collision hazards.

Moreover, each space actor has different thresholds and procedures for conducting a collision avoidance manoeuvre. The lack of uniformity for an expected activity, like collision avoidance, is understandable because there are currently no rules, norms, laws, or other measures to inform what is correct or incorrect traffic management behaviour in space. STM would provide the metaphorical stoplights, road signs, laws, and enforcement necessary to be order to the chaos currently in orbit and enable a safer and more sustainable space environment.

The concept of STM first appeared in the 1980s and began evolving through American Institute of Aeronautics and Astronautics (AIAA) workshops until the early 2000s. The first in-depth study on STM was conducted between 2001-2006 by International Academy of Astronautics (IAA).⁵⁶⁰ The IAA study provided the first comprehensive assessment of what an STM regime would require. It defined STM as:

“Space traffic management means the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space, and return from outer space to Earth free from physical or radiofrequency interference.”⁵⁶¹

The study also detailed phases of an STM regime, including launch phase, in-orbit operation phase, and re-entry phase, and a framework.⁵⁶² The study’s STM framework detailed information needs (i.e., satellite or launch data), notification system needs, and the rules, norms, and other shared practices to manage traffic.⁵⁶³

⁵⁶⁰ Corinne Contant-Jorgenson, Petr Lala, Kai-Uwe Schrogl, “The IAA Cosmic Study on space traffic management,” *Space Policy* 22 no 4, (2006): 283-288, <https://doi.org/10.1016/j.spacepol.2006.08.004>.

⁵⁶¹ *Ibid.*, 284.

⁵⁶² *Ibid.*, 285-286.

⁵⁶³ *Ibid.*, 286.

Since the IAA study there has been more discussion of STM as a concept, but little consensus has emerged. Within and between countries definitions of STM vary.⁵⁶⁴ There are at least 19 descriptions of STM found in existing literature.⁵⁶⁵ The lack of shared understanding can muddle the purpose of STM and complicate the development of an STM regime. For example, according to one study, developing states found the idea of ‘management’ to mean larger space fairing nations would hold more influence over the administration of space traffic.⁵⁶⁶ Definitions also place different levels of emphasis on the purpose of an STM regime, whether it be safety, collision avoidance, operational efficiency, or space sustainability.

Though there are variations, definitions often touch on: the regulations of activities; the establishment of rules, guidelines, norms, and recommendations; the coordination of orbital and orbit-access activities; the promotion of safety; and, the assurance of a sustainable orbital environment.⁵⁶⁷ Definitions may vary, but generally STM requires shared knowledge of what is happening in space, to include what is entering and existing; the means to manage those activities through shared rules, laws, norms and other measures; and the means to administrate the shared STM regime, including updating practices, problem solving, and adjudicating disputes.

Space Situational Awareness

To manage space traffic, one must know what is happening in space; meaning one must know what is in space (i.e., spacecraft and debris), operations, future plans, and the actors involved. Indeed, the situational awareness necessary to manage space traffic is a foundational

⁵⁶⁴ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, “Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM),” 61.

⁵⁶⁵ Dan Oltrogge, Maruska Strah, Mark A. Skinner, Robert J Rovetto, Andre Lacroix, A. K. Anil Kumar, Kyran Grattan, Laurent Francillout, Ines Alonso, “Recommendations of the IAF Space Traffic Management Terminology Working Group,” International Astronautical Federation, 2021, 1, accessed November 2021, https://comspoc.com/Resources/Papers/20211019_Recommendations_of_IAF_STM_Terminology_WG_FINAL.pdf.

⁵⁶⁶ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, “Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM),” 62.

⁵⁶⁷ Dan Oltrogge, Maruska Strah, Mark A. Skinner, Robert J Rovetto, Andre Lacroix, A. K. Anil Kumar, Kyran Grattan, Laurent Francillout, Ines Alonso, “Recommendations of the IAF Space Traffic Management Terminology Working Group,” 2.

piece without which norms, laws, and other elements of a traffic regime offer little value. To put it simply, to manage space traffic requires space situational awareness (SSA).

A key element of SSA is data. Data must be collected, processed, turned into data products, shared, and all with oversight and coordination.⁵⁶⁸ When data is limited, poor quality, or siloed between countries or space operators, it complicates risk assessments and decision making. In 2021 two commercial satellites operated by SpaceX and OneWeb were shown to be at risk of collision but different data, risk tolerances, and company policies made coordination and risk mitigation difficult. The satellite close approach did not result in a collision, but the two companies argued after the fact about what was necessary and who was to blame for the consternation that arose from different data and approaches to collision avoidance.⁵⁶⁹

Indeed, the data needs to be systemic and trusted. According to one study, systemic information means all stakeholders have the same actionable information, while trusted data means it is attributed, available, and without concern for malicious tampering.⁵⁷⁰ Developing such a data system is easier said than done. Developing trust means overcoming political and other competitive factors (e.g., intellectual property concerns) while creating a systemic data set requires shared technical and procedural elements not to mention access to the data. Without trust and systemic data, a STM system offers little ability to organize disparate space actors and activities.

Data is collected through a suite of sensors, including optical, radar, and radio frequency, which are primarily ground based but can also be space based. Data can also be provided by the spacecraft. Once collected the data must be processed and turned into products to inform operators. Systemic and trusted data is what is needed, but it is not what is currently available.

⁵⁶⁸ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, “Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM),” iv.

⁵⁶⁹ Chelsea Ghold, “SpaceX and OneWeb satellites didn't have a close call in space after all: report,”; and, David Goldman, “Re: IBFS File No. SAT-MOD-20200417-00037.”

⁵⁷⁰ Harvey Reed, Nate Dailey, Ruth Stilwell, Brian Weeden, “Decentralized space information sharing as a key enabler of trust and the preservation of space,” Presentation at AMOS 2021, 1, accessed November 2021.

Contemporary data collection capabilities are common among major spacefaring nations and some commercial providers, but it is not systemic nor trusted. The United States has the largest data catalogue and provides data products to help operators of all types make informed traffic management decisions. Russia also has a develop data catalogue produced via a large network of sensors. The United States and Russia are not the only countries to collect data, but they have the most develop suite of sensors among states. On the commercial side, the Space Data Association, LeoLabs, and ExoAnalytics are a few examples of industry organisations and for-profit companies providing SSA data to operators.⁵⁷¹ Finally, satellite operators often have data on their own spacecraft, but whether they share it depends on the operator.

Collecting data and turning it into products is not new nor unique to the United States, Russia, and a few commercial companies, its relatively common among spacefaring nations and operators. But the data often provides an incomplete or less accurate picture of what is happening in space. Even the most advanced sensor network operated by the US Space Force has trouble tracking all debris with high degrees of precision.⁵⁷²

With poor data, satellite operators have reason not to trust the data. Manoeuvring a spacecraft can mean pausing services or using limited reserves of fuel, and when data accuracy is poor operators must decide whether pausing services and using fuel is wise. In the SpaceX and OneWeb example mentioned previously, the operators disagreed over appropriate action because the data offered different assessments. If the data is poor the work of managing satellite traffic increases. According to one study, a single satellite constellation could require examining millions of collision warnings per year only to avoid a few collisions.⁵⁷³ Conversely, the same

⁵⁷¹ For a more detailed list of SSA providers see: Stephen Garber and Marissa Herron, “How has traffic been managed in the sky, on waterways, and on the road? Comparisons for space situational awareness (part 1),” *The Space Review*, June 2020, accessed November 2020, <https://www.thespacereview.com/article/3961/1>.

⁵⁷² Theodore J Muelhaupt, Marlon E. Sorge, Jamie Morin, and Robert S. Wilson, “Space traffic management in the new space era,” *The Journal of Space Safety Engineering* 6 (2019), 82, accessed November 2021, <https://doi.org/10.1016/j.jsse.2019.05.007>; Daniel L. Oltrogge and Salvatore Alfano, “The technical challenges of better Space Situational Awareness and Space Traffic Management,” *Journal of Space safety and Engineering* 6 no 2 (2019), 75, accessed November 2021.

⁵⁷³ Theodore J Muelhaupt, Marlon E. Sorge, Jamie Morin, and Robert S. Wilson, “Space traffic management in the new space era,” 83.

study found that more accurate data reduced the number of false warnings to zero, improving operator confidence in warning assessments.⁵⁷⁴

More accurate data may be available soon. Over the last decade the number of sensors of all types has increased globally.⁵⁷⁵ Innovation in computing, cloud, and software necessary to turn raw data into products and share them is also occurring.⁵⁷⁶ These innovations are driven in part by the reduction in cost for technology that enables more data to be collected and synthesized into more accurate SSA products.⁵⁷⁷ Though more data is seemingly on the horizon there are still issues with making it systemic.

Until the last decade, most space operators relied on the US to provide SSA information. Recently, however, an increasing desire to become self-reliant and to protect space assets has spurred a growth in SSA capabilities among commercial companies and governments alike.⁵⁷⁸ SSA systems operate largely independently of one another. Agreements to share SSA data between countries are on the rise, though they are primarily bilateral. Agreements to share SSA data is an improvement in some respects. But given the relatively small number of countries (approximately 18⁵⁷⁹) that have or are pursuing independent SSA capabilities, bilateral agreements could lead to SSA ‘spheres of influence’ where large segments of the space community receive their SSA data from a few sources with little coordination occurring between spheres. It could also enable space operators to ‘shop around’ for the data that confirms their operational preferences.

While SSA is a critical component of an STM regime, it only adds value if the data is complemented by shared ‘rules of the road’ in space.

⁵⁷⁴ Ibid.

⁵⁷⁵ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, “Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM),” 27.

⁵⁷⁶ Ibid., vi, 43.

⁵⁷⁷ Ibid., vi, 31-33, 43.

⁵⁷⁸ Ibid., 20, 41.

⁵⁷⁹ Ibid. 20.

Traffic Management Rules, Norms, and Laws

While SSA can paint a picture of what is happening in space, it is not the rules or norms that provide guidance for what is or is not proper behaviour. To oversee, coordinate, and manage space activities requires laws, norms, guidelines, and other measures that provide space actors with known behavioural expectations. Like how speed limits and traffic signs inform motorists of expected vehicular behaviour. These ‘rules of the road’ for space activities must be shared and enforced.

An increasing number of space activities requires a diverse set of rules, norms, laws, etc. to oversee, coordinate, and manage them. Each of these measures must account for the qualities of the space operational environment. For example, the speed at which satellites travel around the Earth, and with little or no human control, means measures designed to help satellites avoid collisions will need to provide timely warnings so satellite operators on Earth have time to respond. It also means accounting for the different actors and types of activities. The rules applicable to military spacecraft may need to be different from those of commercial or civil spacecraft as they often are in the air and maritime domains. Similarly, the rules or norms informing human spaceflight could warrant special requirements compared to uncrewed satellites.

According to a report that surveyed satellite operators, many operators are supportive of measures that safeguard operations and preserve the development opportunity of space.⁵⁸⁰ The expectation is that the measure put in place provide transparency, predictability, and certainty in operations without becoming onerous or discourage broader adoption.⁵⁸¹ There is no predetermined guide for what these rules, norms, and other measures need to be, other than that they must be shared, enforced, evolve overtime and be capable of providing order in orbit.

The Registration Convention is one instance of an existing international law attempting to aide in STM, but as discussed earlier in this research, there are many problems with the convention, including limited data and poor compliance that limit the convention’s influence in

⁵⁸⁰ Ibid., 6-4.

⁵⁸¹ Ibid.

traffic management. The closest activity akin to shared space traffic management practices are conjunction assessments and collision avoidance manoeuvres. Conjunction assessments are used to determine when risk is high enough to warrant remediation (i.e., satellite manoeuvre). Conjunction assessments use SSA data to provide a probability of collision between objects. Though critical STM, conjunction assessment practices require refining.

Current conjunction assessment practices have important limitations often due to limited or poor data. For instance, common conjunction assessments are unable to determine object size, mass, passed manoeuvres or predict future manoeuvres.⁵⁸² They can also struggle with transparency and poor response time during evolving situations.⁵⁸³ As mentioned in the previous section there are also trust issues with conjunction assessments given limitation on SSA data. Finally, because there are no shared STM standards, governments and private companies use different metrics for calculating conjunction assessments and often have different risk tolerances for determining the actions following a warning.⁵⁸⁴

One emerging practice is to automate conjunction assessments and remediation actions. For example, SpaceX Starlink satellites are reported to manoeuvre autonomously based on SpaceX's collision avoidance policies.⁵⁸⁵ Automation is likely necessary given the speed at which satellites travel and the increasingly congested and dynamic orbital environment, but without shared rules, thousands of autonomous spacecraft manoeuvring without coordination can create a chaotic orbital environment and additional risk.

An STM regimes relies on rules, norms, laws, and other measures to define when and how spacecraft respond to various situations. Yet such rules do not currently exist beyond individual

⁵⁸² Daniel L. Oltrogge and Salvatore Alfano, "The technical challenges of better Space Situational Awareness and Space Traffic Management," 76.

⁵⁸³ For example, email exchanges are common tools used to coordinate response between satellite operators. For other limitations, see: Ibid.

⁵⁸⁴ Daniel L. Oltrogge and Salvatore Alfano, "The technical challenges of better Space Situational Awareness and Space Traffic Management," 1.

⁵⁸⁵ Federal Communications Commission, Memorandum Opinion and Order, in the Matter of Space Exploration Holdings, LLC, Request for Modification of the Authorization For the SpaceX NGSO Satellite System, Federal Communications Commission, DA-20-588, June 2020, accessed November 2021, "[https://ecfsapi.fcc.gov/file/1081071029897/SpaceX%20Orbital%20Debris%20Meeting%20Ex%20Parte%20\(8-10-21\).pdf](https://ecfsapi.fcc.gov/file/1081071029897/SpaceX%20Orbital%20Debris%20Meeting%20Ex%20Parte%20(8-10-21).pdf)."

country or company policies. Developing shared rules of the road for space will require international cooperation.

Administering an STM Regime

The international cooperation required to develop an effective STM regime suggests an IO would provide an ideal form of administration. As will be discussed later in the chapter, an international body is not the only way to manage a traffic regime, but they are common. The exact makeup of the IO, how it supports a traffic regime, and other important qualities can all vary and depend on the preferences and capabilities of stakeholders involved. While there is no one right way to use an IO as a governance body, an IO's ability to convene stakeholders and focus efforts proactively are hard to replicate through decentralized arrangements.

COPUOS, the ITU, and smaller organisations like, the Consultative Committee for Space Data Systems, are all capable of addressing various aspects of an STM regime, but none are suited to develop or administer the regime alone. The ITU and Consultative Committee for Space Data Systems are narrowly focused on select aspects of STM, while COPUOS has struggled with far less technical or administratively rigorous governance measures, like debris mitigation guidelines. The challenges for an institution attempting to develop an STM regime are captured in part by a study conducted on SSA by the US Institute for Defense Analysis, which found:

“There is growing agreement in the SSA community that data sharing alone across countries and organisations is not enough...At the same time, participants in international forums recognize that with increasing numbers of players, technologies, and activities in space, this will be complex. Issues related to lack of trust and transparency pose challenges to efforts to develop more binding and formal institutions for STM.”⁵⁸⁶

⁵⁸⁶ Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, Sara A. Carioscia, “Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM),” vii.

Once an IO develops new methods, tools, or regulations, national governments will need to integrate them into national regulatory structures and enforce adherence. The interplay between IOs, industry actors, and national governments will create the network of technical, legal, and regulatory element necessary to develop an STM regime. Given the advanced role commercial companies are playing in the development of space, and in some cases the increasing insecurity in space, industry participation is likely necessary as well to ensure adoption but also that best practices are informed by the latest developments in technology and space activities.

Conclusion

Understanding what an STM regime requires is relatively clear, yet current practices are far from what is needed. Currently, managing space traffic is conducted at the satellite operator or country level on a mostly ad hoc basis with very little data, nearly no regulatory guidance or shared rules, norms, or other measures, and poor communication between stakeholders. International organisations are conducting work related to STM but its exploratory at this point with no near-term prospect of creating a regime.

Informing the development of an STM regime can be aided by the decades of lessons learned through traffic management regimes found in other domains, specifically the maritime, air, and internet domains.

Maritime Case Study

Managing maritime traffic is far from a recent development. Maritime collision avoidance laws have existed in some fashion since at least A.D. 600-800.⁵⁸⁷ The first international conference focused on maritime traffic rules was held in 1889 in the US.⁵⁸⁸ Since, there has been a vibrant evolution of maritime traffic laws, norms, standards, and other measures addressing collision avoidance, safe navigation, marine security and more. Generally, maritime traffic management is a distributed system where the master of the ship is responsible for their own

⁵⁸⁷ John Kemp, "The Evolution of Navigation Lights for Ships," *Journal of Navigation* 48, no. 2 (1995), 256, doi:10.1017/S0373463300012728.

⁵⁸⁸ "Final Act of the International Marine Conference held at Washington, October 16 to December 31, 1889," *The American Journal of International Law* 5 no. 1 (1911): 42-73, <https://doi.org/10.2307/2212463>.

navigation, including collision avoidance as situations arise.⁵⁸⁹ In certain areas, like confined waters such as ports, vessel traffic services (VTS) are used to organize maritime traffic for safety, security, and efficiency of operations. VTS systems are regulated by the state. At an international level, the IMO considers a host of maritime traffic issues to inform states and operators, but it does not act as a regulator for shipping traffic. As shipping practices, technology, and environmental needs have changed, so too have shipping traffic management practices including the associated legal and normative regime.

Key Features of Maritime Traffic Management

At the heart of modern maritime traffic management are VTS practices. Ships are responsible for their navigation, including collision avoidance. As they enter national waters, and specifically, congested areas such as ports or channels, VTS services aid in ship navigation. VTS services are implemented by a “Competent Authority” defined by the IMO and supported by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA, a non-governmental and non-profit technical association). The competent authority is normally a national regulatory body which determines the need for VTS and implements the international guidelines and regulations related to VTS within its national waters. There are some 500 VTS services around the world, and while they follow international guidelines, they are implemented through national services, so some variations exist between services.⁵⁹⁰

Countries had developed systems to track and monitor maritime traffic in their waters, and VTS arose to standardise the practice.⁵⁹¹ In 1985 the IMO adopted resolution A.578(14), Guidelines for Vessel Traffic Services, which outlined the role of the VTS authority and listed elements of a VTS among other features.⁵⁹² VTS do not shift responsibility for navigation from

⁵⁸⁹ Faulko van Westrenen and Gesa Praetorius, “Maritime traffic management: a need for central coordination,” *Cogn Tech Work* 16, (2014): 59, accessed November 2021, DOI 10.1007/s10111-012-0244-5.

⁵⁹⁰ Ibid.

⁵⁹¹ “Vessel Traffic Services,” International Maritime Organization, accessed November 2021, <https://www.imo.org/en/OurWork/Safety/Pages/VesselTrafficServices.aspx>.

⁵⁹² International Maritime Organization, Guidelines for Vessel Traffic Services, Resolution A.578(14), January 20, 1986, accessed November 2021, [https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.578\(14\)](https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.578(14)).

the ship's master, but standardise practices which enable communication and information sharing necessary to safely navigate areas where maritime traffic or risk of collision is higher. VTS guidelines have since been updated to include guidelines on recruitment, qualification, and training of VTS operators.⁵⁹³

Three services typically fall within VTS, information service, traffic organisation service, and navigational advice and assistance. Legally, these are information sharing services. In other words, VTS provides a ship master with information to inform their decision making regarding safe navigation, to the extent that VTS dictate the actions ship masters much take depends on the requirements imposed by the national authority. For example, VTS information services provide operators with general information about the area (i.e., waterway conditions), traffic organisation services provide information to inform vessel movements (i.e., traffic clearances), and navigational advice and assistance provides information about obstacles, depths, and other navigational information the ship may not have.⁵⁹⁴ VTS services, as detailed in IMO guidelines, are intended to be results oriented and leave the execution and decision making related to VTS information to the master of the ship.⁵⁹⁵

VTS operators collect data across three areas to provide VTS services. Data on the fairway includes weather and navigational aide, data on traffic includes vessel positions, movements, and other information, and data on the vessel's accordance with the requirements of ship reporting.⁵⁹⁶ This information is collected by the VTS authority via VTS sensors, radars, and other sources and via vessel provided information like the automatic identification system (AIS) or the long-range identification and tracking system (LRIT) used to provide ship locations.

14).pdf#:~:text=RESOLUTION%20A.578%2814%29%20adopted%20on%2020%20November%201985%20GUIDELINES,operating%20the%20vessel%20traffic%20service%20and%20participating%20vessels%2C.

⁵⁹³ International Maritime Organization, Guidelines for Vessel Traffic Services, Resolution A.578(20), December 3, 1997, accessed November 2021, [https://www.wcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.857\(20\).pdf](https://www.wcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.857(20).pdf).

⁵⁹⁴ Ibid, 7.

⁵⁹⁵ Ibid.

⁵⁹⁶ Ibid. 8

VTs are a valuable practice to aid maritime traffic management as a decentralized traffic management scheme. As an information service, VTs do not impose requirements on vessels, though it is well within the right of a country to tie VTs information to legal measures that can influence vessel behaviour. As an information service, VTs are also reactive, rather than proactive, in their influence of maritime traffic. Other shortcomings include differences between VTs operations among countries or VTs operators within the same country, its limited ability to anticipate changes in the operating environment, and the quality of VTs services can depend on the human operators responsible for providing the service.⁵⁹⁷

Conventions and Agreements

Several existing international legal and other agreements cover various aspects of VTs, AIS, and other maritime navigation topics. The MSC is the main IMO organ responsible for addressing ship navigation and the prevention of collisions. Other international organisations, like IALA, play a part as well, and often in concert with the IMO. IMO agreements address navigation data, responsibility, technical standards, among other features required by a traffic management regime.

The MSC addresses ship navigation through an evolving body of work handled by its subsidiary bodies, including the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR). NCSR is focused on issues related to navigation and communication, requirements and performance standards for communication equipment, LRIT systems, and search and rescue matters.⁵⁹⁸ These IMO bodies have overseen the evolution of VTs, technical standards, and other facets of the maritime traffic management regime.

Several central IMO agreements, including conventions, codes, and resolutions, touch on the maritime traffic management regime. COLREGS details 41 rules spread across five sections

⁵⁹⁷ Gesa Praetorius, “Vessel Traffic Service (VTS): a maritime information service or traffic control system?” (PhD diss., Chalmers University of Technology, 2014), 50, accessed November 2021, <http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1084991&dswid=4028>.

⁵⁹⁸ “Sub-Committee on Navigation, Communication and Search and Rescue (NCSR),” International Maritime Organization, accessed November 2021, <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/NCSR-default.aspx>.

outlining technical navigation standards, like steering and sailing, lights and shapes, sounds and light signals, exemptions, and international distress signals.⁵⁹⁹ Each rule can vary in the detail but together offer foundational navigation standards to aide ships port to port. In 2013, COLREGS was amended (resolution A.1085(28)) to align with the Member State Audit Scheme.⁶⁰⁰

SOLAS is another cornerstone agreement with important maritime traffic management features. SOLAS Chapter V – Safety of navigation includes 35 regulations addressing certain navigation services contracting states are responsible for providing and sets operational requirements for all ships on all voyages with some exclusions.⁶⁰¹ Regulation 12, for example, covers VTS. Chapter V regulations cover the responsibilities of both states and ships.

STCW contains 15 Articles and an annex with technical regulations for the training and certification of crews. Articles cover regulations applicable to shipping generally, like the master and deck department, engine department, radiocommunication and radio operators, and watchkeeping.⁶⁰² In addition to improving the competency of crews, STCW also details standards related to fair labour practices. Crew training and certification standards help ensure more technical regulations necessary for a maritime traffic regime are understood and adhered to.

⁵⁹⁹ “COLREG – Preventing collisions at sea,” International Maritime Organization, accessed November 2021, <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/NCSR-default.aspx>.

⁶⁰⁰ International Maritime Organization, Amendments to the Convention on the International Regulations for Preventing Collisions at Sea, Resolution A.1085(28), December 4, 2013, accessed November 2021, [https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1085\(28\).pdf#:~:text=Resolution%20A.1085%2828%29%20%28adopted%20on%204%20December%202013%29%20AMENDMENTS,FOR%20PREVENTING%20COLLISIONS%20AT%20SEA%2C%201972%20THE%20ASSEMBLY%2C](https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1085(28).pdf#:~:text=Resolution%20A.1085%2828%29%20%28adopted%20on%204%20December%202013%29%20AMENDMENTS,FOR%20PREVENTING%20COLLISIONS%20AT%20SEA%2C%201972%20THE%20ASSEMBLY%2C).

⁶⁰¹ International Maritime Organization, *Amendments to the Convention on the International Regulations for Preventing Collisions at Sea, Resolution A.1085(28)*, December 4, 2013, accessed November 2021, [https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1085\(28\).pdf#:~:text=Resolution%20A.1085%2828%29%20%28adopted%20on%204%20December%202013%29%20AMENDMENTS,FOR%20PREVENTING%20COLLISIONS%20AT%20SEA%2C%201972%20THE%20ASSEMBLY%2C](https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.1085(28).pdf#:~:text=Resolution%20A.1085%2828%29%20%28adopted%20on%204%20December%202013%29%20AMENDMENTS,FOR%20PREVENTING%20COLLISIONS%20AT%20SEA%2C%201972%20THE%20ASSEMBLY%2C).

⁶⁰² “International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978,” International Maritime Organization, accessed November 2021, <https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-Convention.aspx>.

Finally, the Convention on Facilitation of International Maritime Traffic (FAL) is focused on creating an efficient maritime industry. It aims to prevent delays in maritime traffic, aid cooperation between governments, and secure uniformity in formalities and other procedures. The agreement is composed of 16 articles which detail “Standards” and “Recommended Practices” for activities related to the arrival, stay, and departure of ships, crews, passengers, baggage, and cargo.⁶⁰³ According to FAL, a standard is an international measure “necessary and practicable in order to facilitate international maritime traffic” while recommended practices are applicable as “desired”.⁶⁰⁴ Because standards are viewed by the convention as necessary, contracting parties who do not comply or follow different standards must inform the Secretary-General of the IMO of the differences. FAL was designed as a living agreement to the extent that it is expected to change as necessary to facilitate international maritime traffic. The Facilitation Committee (FAL-C) is responsible for updating FAL.⁶⁰⁵

The language used throughout these agreements suggests they are more strongly encouraged recommendations than firm requirements, allowing states to decide if and how they will implement and enforce them. For example, phrases like, “contracting governments undertake to arrange...” and “nothing in this regulation...shall prejudice the rights and duties of governments...” found in Chapter V of SOLAS are also found in other agreements. The phrasing is not uncommon to IMO agreements generally or agreements produced by other international regulatory organisations. The choice in language reflects the need to balance transaction costs with member state adoption for reasons discussed previously in this research.

Practices like VTS and regulations, standards, and recommended practices detailed in IMO agreements are not the end of the story. The international community and the IMO continue to mature the maritime traffic regime to facilitate the safe, prosperous, and sustainable development of international shipping.

⁶⁰³ “Convention on Facilitation of International Maritime Traffic (FAL),” International Maritime Organization, accessed November 2021, [https://www.imo.org/en/About/Conventions/Pages/Convention-on-Facilitation-of-International-Maritime-Traffic-\(FAL\).aspx](https://www.imo.org/en/About/Conventions/Pages/Convention-on-Facilitation-of-International-Maritime-Traffic-(FAL).aspx).

⁶⁰⁴ Ibid.

⁶⁰⁵ “Facilitation Committee,” International Maritime Organization, accessed November 2021, <https://www.imo.org/en/OurWork/Facilitation/Pages/FALCommittee-default.aspx>.

IMO's Approach to Changing Traffic Management Demands

The maritime traffic regime described above is a decentralized system. States develop their own VTS systems as they see fit while the IMO and other international organisations provide standards, recommended practices, and the legal support through conventions to encourage uniformity among state practices. The decentralized system has been a valuable aid to navigation and coordination of a shipping industry with relatively low density. Growth in the shipping industry has started to expose weaknesses in the decentralized system, however.

Some 90% of global trade is transported by sea, most of which is shipped in containers.⁶⁰⁶ The containerization of shipping has seen incredible growth in recent decades both in terms of volume of goods and size of ships.⁶⁰⁷ The increase in volume and changes to the ships themselves has begun to stress the current maritime traffic management regime. The current system of global trade is a highly efficient one, developed based on just in time delivery and made to order operations. But the decentralized and responsive, rather than proactive, nature of the current shipping traffic management regime offers little complement to a highly digital and connected global trade ecosystem.⁶⁰⁸

In response to the changing character of international shipping, the IMO introduced the idea of E-navigation during the eighty-first session of the MSC in 2006. According to the IMO,

“E-navigation is intended to meet present and future user needs of shipping through harmonization of marine navigation systems and supporting shore services. It is expected to provide digital information and infrastructure for the benefit of maritime safety, security and protection of the marine environment,

⁶⁰⁶ Anna Nagurney, “Our economy relies on shipping containers. This is what happens when they're 'stuck in the mud',” World Economic Forum, October 2021, accessed November 2021, <https://www.weforum.org/agenda/2021/10/global-shortagof-shipping-containers/>.

⁶⁰⁷ The average container ship has doubled in size in the last 20 years. See: Ibid.

⁶⁰⁸ For discussion on this point see: Maritime Safety Committee, *Strategy for the Development and Implementation of E-Navigation MSC 85/26/Add.*, December 4, 2013, 1-2, accessed November 2021, <https://wwwcdn.imo.org/localresources/en/OurWork/Safety/Documents/enavigation/MSC%2085%20-%20annex%2020%20-%20Strategy%20for%20the%20development%20and%20implementation%20of%20e-nav.pdf>.

reducing the administrative burden and increasing the efficiency of maritime trade and transport.”⁶⁰⁹

The central feature of the E-navigation concept, detailed in MSC 85/26/Add.1, annex 20, is the harmonization of information aboard ships and ashore. The concept’s information sharing is built around three expectations:⁶¹⁰

1. Integrating ships sensors, supporting information, a standard user interface, and comprehensive system for managing alerts to develop an intuitive navigation process.
2. A coordinated and uniform data exchange and management system to aid shore-based navigation and safety operations and improve efficiency.
3. Communications infrastructure offering seamless information sharing between all relevant actors, including ship crews, ships, shore authorities and other parties necessary for navigation.

The E-navigation concept outlines eleven goals that can be summed up as core elements of maritime traffic management (data, communication, standards) to improve the safety and efficiency of shipping and the security of the marine environment while leaving room to evolve E-navigation in the future.⁶¹¹ The concept also details expected requirements. They include:

- Implementation should be measured, based on user needs rather than being technology driven, and not necessarily hasty,
- Creating an evolving system of procedures,
- Leaving primary decision making with the mariner,
- Human centered design of systems and interfaces to avoid overloading operators complemented by proper training,
- Providing adequate resources for e-navigation itself, training, and radio-spectrum,

⁶⁰⁹ “E-navigation,” International Maritime Organization, accessed November 2021, <https://www.imo.org/en/OurWork/Safety/Pages/eNavigation.aspx>.

⁶¹⁰ Maritime Safety Committee, *Strategy for the Development and Implementation of E-Navigation MSC 85/26/Add.*, 3.

⁶¹¹ *Ibid.*, 3.

- Implementation should be measured, and
- Cost should not be excessive.⁶¹²

The IMO's plan also recommends that governance of the program should reside within a single institution with the requisite knowledge, experience, and capabilities to “define and enforce the overarching framework with implementation, operation, and enforcement taking place at the appropriate level—global, regional, national, or local—within that framework.”⁶¹³ The IMO concept also notes that the governing organisation can delegate responsibilities and does not need to conduct them all internally.⁶¹⁴ Despite working on the program since 2006, E-navigation is still largely just a concept but with some advances.

In addition to the IMO's E-navigation concept, the European Union (EU) is also trying to develop a more centralized and proactive maritime traffic management system. Developed in 2010 by the Swedish Maritime Administration the Motorways and Electronic Navigation by Intelligence at Sea (MONALISA) project sought to combine dynamic and proactive route planning, electronic certificate verification, ensure quality of hydrographic data on shipping routes and areas, and global sharing of maritime data to improve the shipping safety, efficiency, and environmental protection.⁶¹⁵

MONALISA evolved into MONALISA 2.0 in 2015 at which time other European countries joined Sweden on the project. In 2018 with support from the EU the project evolved again and was renamed Sea Traffic Management. Sea Traffic Management held many of the same core goals of MONALISA with a few changes, including the creation of an organized traffic management entity that tracks all ships at sea to manage shipping routes port to port. Sea Traffic management is inspired by European air traffic management.⁶¹⁶ Sea Traffic Management is still in development with EU support until 2030.

⁶¹² Ibid., 5.

⁶¹³ Ibid., 9.

⁶¹⁴ Ibid., 9.

⁶¹⁵ “Monalisa,” International Association of Marine Aids to Navigation and Lighthouse Authorities, accessed November 2021, <https://academy.iala-aism.org/technical/e-nav-testbeds/monalisa-1/>.

⁶¹⁶ “About Sea Traffic Management,” Sea Traffic Management, accessed November 2021, <https://www.seatraficmanagement.info/about-stm/>.

Both the E-navigation and Sea Traffic Management systems share common goals for maritime traffic management. They are designed to leverage modern data-driven technologies and system to create a maritime traffic management system that offers a clearer picture of shipping to enable improved decision making.

Conclusion

Assessing buy in of a decentralized traffic management system is not straightforward. While VTS services are a primary means of managing traffic, only approximately 50 countries employ VTS systems. However, the top 50 ports for global trade operated by 22 countries, and representing most of global trade by ships, use VTS. So, while buy in of VTS is limited as far a country participation, it does support some of the most congested water ways and important shipping trade hubs around the globe. Moreover, inclusion of VTS into SOLAS, COLREGS, FAL, and other measures covers most of shipping by tonnage. In sum, member buy in is not a comprehensive as it could be, but because VTS services support most of global trade by shipping it does appear that there is important IMO member buy as it relates to the use of VTS.

The IMO continues to mature its approach to supporting maritime traffic management, showing some agility. Incorporation of VTS into major maritime agreements, formalizing the member state audit scheme so it covers VTS, and attempting to guide the development of the next generation of maritime traffic management through E-navigation are all evidence of how the IMO continues to evolve governance tools as maritime traffic management needs change. These changes reflect an agile organisation attempting to stay current.

In terms of effectiveness, the IMO's approach has been to provide guidance to create uniformity in traffic management and codify certain elements into formal treaties and agreements. Traffic management will likely stay decentralized, so the extent to which the IMO can affect how each member manages traffic is limited to providing standards and recommended practices, educational tools, and legal support through inclusion of traffic management tenant into agreements. While VTS and other shipping traffic management practices vary around the global, there is also some uniformity in the use of VTS broadly. E-navigation could aid in greater

efficiencies, but the concept is dependent upon advanced technologies, which may be difficult for developing countries to adopt. In all, the effectiveness of the IMO's work related to traffic management is limited to a standards setting organisations with some legal support through treaties.

Finally, because most shipping trade passes through VTS services of some form suggests the shipping industry has benefitted from the IMO's work. Again, differences in VTS services do leave some areas for improvement, but the IMO has been able to encourage the adoption and support for more uniform VTS services than would otherwise be possible if the IMO had not taken up the issue. The advancement of E-navigation also promises to benefit shipping in new ways.

Shipping traffic management, like STM, requires organizing disparate actors who rarely give up their regulatory authority. As a result, the IMO has provided useful standards and recommended practices and legal measures to help organize shipping traffic management despite having little authority to dictate how states must act. As we shall see, the situation is not all that different for civil aviation.

Civil Aviation Case Study

The Chicago Convention laid the groundwork for modern air traffic management (ATM). Article 28, 'Air navigation facilities and standard systems' requires that each contracting state shall provide in its territory the "services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time" and adopt "the appropriate standard systems...and other operational practices."⁶¹⁷ As a result, ICAO Annex 15 describes ATM as "the dynamic, integrated management of air traffic and airspace — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions."⁶¹⁸ ICAO further defines an ATM *system* as, "A

⁶¹⁷ Convention on International Civil Aviation, 13.

⁶¹⁸ International Civil Aviation Organization, *Annex 15 to the Convention on International Aviation, Aeronautical Information Services*, (Montreal: International Civil Aviation Organization, 2010), 1-2.

system that provides ATM through the collaborative integration of humans, information, technology, facilities and services, supported by air and ground- and/or space-based communications, navigation and surveillance.”⁶¹⁹ States are principally responsible for ATM systems and services while ICAO aids in the standardization of practices through SARPs, SUPPS, PANS and the facilitation of regional agreements.

Key Features of Air Traffic Management

As sovereignty extends into the airspace above a country’s territory, states are responsible for ATM within their borders. Annex 11 establishes that air traffic services in airspace over the high seas or of undetermined sovereignty will be provided by a state based on regional air navigation agreements.⁶²⁰ ICAO created ten air navigation regions (later adjusted to nine) to divide airspace and facilitate the coordination of aviation practices where regional needs were unique from global needs. Navigation regions are organized based on geography. For example, the North American Region includes the US and Canada while the Caribbean Region includes Mexico, Central America, and the Northern most South American countries.

Each region is supported by an ICAO Regional Office, which facilitate cooperation and the development of agreements applicable to each region. Navigation regions are subdivided into Flight Information Regions (FIR). Each FIR is managed by an established control authority (e.g., UK Civil Aviation Authority) which is responsible for providing air traffic services within the FIR. FIRs can vary in size and larger countries may have more than smaller countries. Areas over the high seas are typically divided into two or more FIRs and controlled by boarding countries.

Regional Offices assist Planning and Implementation Regional Groups (PIRGs) on ATM topics.⁶²¹ PIRGs detail the facilities, services, and procedures required for international air

⁶¹⁹ International Civil Aviation Organization, *Doc 4444 Procedures for Air Navigation Services, Air Traffic Management, 16th Ed*, (Montreal: International Civil Aviation Organization, 2016), 1-4.

⁶²⁰ International Civil Aviation Organization, *Annex 11 to the Convention on International Civil Aviation, Air Traffic Services, 13th Ed*, (Montreal: International Civil Aviation Organization, 2001), 2-1.

⁶²¹ “RASGs and PIRGs,” International Civil Aviation Organization, accessed November 2021, <https://www.icao.int/safety/implementation/lists/rasgspirgs/allitems.aspx>.

navigation within a geographic area through regional Air Navigation Plans (ANPs). ANPs take regional air navigation needs into consideration and apply only to the region in question. While the Chicago Convention has helped to organize the ATM responsibilities of states, states are still the principal responsible for executing ATM within their borders and assigned areas. ICAO facilitates uniform ATM practices among various national ATM systems through SARPs, SUPPS, and PANS.

SARPs, SUPPS, and PANS for Air Traffic Management

ICAO through the cooperation of its members has developed a complementary set of standards and recommended practices that support regional and global ATM coordination. At a global level SARPs and PANS offer standards and recommended practices for ATM services while SUPPS offer acute regional guidance based on the unique qualities and needs of geographic areas. These agreements are developed through various ICAO bodies. The central role of ATM in civil aviation is such that most of ICAO's work relates to ATM to some degree. The discussion below will focus on the central features of ICAO's ATM work.

The heart of ICAO's ATM work resides in the annexes to the convention. Annex 2 contains SARPs for general rules of the air including protection of people and property, flight plans, avoidance of collisions, time, signals, and more.⁶²² Annex 4 provides SARPs that cover aeronautical charts, including production and the obligation of states to provide certain charts and related information to ensure uniformity and quality of information.⁶²³ Annex 10 details SARPs and PANS on aeronautical communications related to navigation and surveillance systems, essential aids (e.g., GNSS and VHF radios), voice and data communication categories, radar and collision avoidance systems, and relevant radio spectrum utilization.⁶²⁴ Annex 11 provides SARPs on air traffic services, and more specifically, how to prevent collisions between aircraft throughout the entire operational period. Annex 15 includes SARPs for aeronautical

⁶²² International Civil Aviation Organization, Annex 2 to the Convention on International Civil Aviation, Rules of the Air, 10th Ed, (Montreal: International Civil Aviation Organization, 2006), 2-1.

⁶²³ International Civil Aviation Organization, *Annexes 1 to 18* (Montreal: International Civil Aviation Organization).

⁶²⁴ International Civil Aviation Organization, *Annex 10 to the Convention on International Civil Aviation, Aeronautical Telecommunications – Volume 1, Radio Navigational Aids, 7th Ed*, (Montreal: International Civil Aviation Organization, 2018).

information services (AIS).⁶²⁵ According to Annex 15, States are responsible for ensuring that “aeronautical data and aeronautical information necessary for the safety, regularity and efficiency of air navigation are made available in a form suitable for the operational requirements of the air traffic management (ATM) community”.⁶²⁶ Annex 15 also details a range of aeronautical information products and services and the mechanisms to keep aeronautical data and aeronautical information up to date.⁶²⁷

Specific ICAO PANS complement annexes. PANS-AIM (Doc 10066) complements annexes 4 and 15 with detailed requirements for the collection and management of aeronautical information and data products and services specifications.⁶²⁸ PANS-ATM (Doc 4444) complements annexes 2 and 11 by providing greater detail on air traffic service unit procedures for air traffic services.⁶²⁹

At a regional level, ICAO Doc 7030 is a 300-page document detailing the Regional Supplementary Procedures (SUPPS) that form the procedural part of ANPs. Doc 7030 is organized by FIR. Topics include flight rules, flight plans, communications, navigation, surveillance, air traffic services, safety monitoring, air traffic management, special procedures, phraseology, search and rescue, meteorology, and aeronautical information services.⁶³⁰ Each SUPP can vary in detail, but must include a mode for implementing procedural provision in Annexes and PANS, must not come in conflict with the provisions contained in the Annexes or PANS, and they must avoid variations in the text of procedures with similar intent applicable to more than one area.⁶³¹ The number of SUPPS found in each FIR section depends on the region. For example, the North American Region, which includes the US and Canada has relatively few

⁶²⁵ “Aeronautical Information Management,” International Civil Aviation Organization, accessed November 2021, <https://www.icao.int/airnavigation/information-management/Pages/default.aspx>.

⁶²⁶ Ibid.

⁶²⁷ Ibid.

⁶²⁸ International Civil Aviation Organization, Doc 10066 Procedures for Air Navigation Services, Aeronautical Information Management, 1st Ed (Montreal: International Civil Aviation Organization, 2018), vii.

⁶²⁹ International Civil Aviation Organization, Doc 4444 Procedures for Air Navigation Services, Air Traffic Management, 16th Ed, X.

⁶³⁰ Secretary General, Doc 7030 Regional Supplementary Procedures, 5th edition, (Montreal: International Civil Aviation Organization, 2018).

⁶³¹ Ibid. v.

SUPPs compared to the European Region.⁶³² SUPPS are developed at Regional Air Navigation meetings and implemented following review by ANC and approval by the ICAO Council.⁶³³

These agreements are developed through a series of ICAO bodies tuned to technical or regional aspects of ATM services. The ANC is responsible for overseeing ATM related SARPS and other agreements and delegates responsibilities according to the topic or agreement in question. For example, the Air Traffic Management Operations Panel develops strategy and coordination for air traffic services, air traffic flow management, procedures and phraseology for air traffic control, airspace management, and civil military coordination.⁶³⁴ While the ATM Requirements and Performance Panel is focused on the next stage of ATM modernization through work supporting ICAO's Global Air Traffic Management Operational Concept (GATMOC).⁶³⁵ Other panels include the Communications Panel, the Navigation Systems Panel, the Information Management Panel, Separation and Airspace Safety Panel, and the Surveillance Panel.⁶³⁶ The panels conduct studies, develop SARPs, and otherwise inform the agreements used to align and organize ATM practices.

The GATMOC (Doc 9854) is ICAO's vision for an "integrated, harmonized and globally interoperable ATM system."⁶³⁷ The GATMOC is the latest evolution in ICAO's ATM work. The Manual on Air Traffic Management Systems Requirements (Doc 9882) and the Manual on Global Performance of the Air Navigation System (Doc 9883) are companion manuals of the GATMOC. The GATMOC is not a technical manual. Instead, it's a document that outlines what is required for the ATM system of the future. More technical guidance resides in Annexes, SUPPS, PANS, and other measures developed through various ICAO bodies.

⁶³² Ibid., NAM (i), EUR (i).

⁶³³ Ibid. 7030, vii.

⁶³⁴ "ANC Technical Panels," International Civil Aviation Organization, accessed November 2021, <https://www.icao.int/about-icao/AirNavigationCommission/Pages/anc-technical-panels.aspx>.

⁶³⁵ Ibid.; and, International Civil Aviation Organization, *Doc 9854, Global Air Traffic Management Operational Concept, 1st ed*, (Montreal: International Civil Aviation Organization, 2005).

⁶³⁶ "ANC Technical Panels," International Civil Aviation Organization.

⁶³⁷ International Civil Aviation Organization, *Doc 9854, Global Air Traffic Management Operational Concept, 1st ed*, 1-1.

ICAO's Approach to Changing Traffic Management Demands

ATM has no doubt aided the safety and efficiency of civil aviation. Shared standards and procedures combined with a complement of ground-based and aircraft-based ATM systems has created a suite of ATM solutions that are accessible and relatively easy to follow. The result has been improvements in the capacity and safety of civil aviation. ATM systems, like Automatic Dependent Surveillance Broadcast (ADS-B), have been shown to reduce the likelihood of certain aviation accidents by 53% and fatalities by 89%.⁶³⁸

Still, the current ATM system is not without limitations. According to ICAO, ATM limitations include inefficient routes, indirect departure and arrival procedures, use of inefficient altitudes, speeds, and poor management of weather-related disruptions.⁶³⁹ These limitations create inefficiencies, additional CO2 emissions, and leave ATM poorly suited to accommodate new forms of aviation mobility (e.g. autonomous aerial vehicles).⁶⁴⁰ Many ATM systems are not digitalized, which makes sharing information, updating systems, and other key features of an improved ATM system difficult or impossible to do.⁶⁴¹ The ATM procedures are also reliant on ground based-sensors, which can mean flights are restricted to where those sensors can provide services.⁶⁴²

To remedy the shortcomings of current the ATM system, ICAO as well as governments have begun exploring performance-based navigation (PBN). Rather than relying on ground-based sensor specific routes, PBN provides flexible routes and non-sensor specific navigation.⁶⁴³ PBN has the potential to be more environmentally friendly, improve safety, enhance operational

⁶³⁸ Daniel Howell and Jennifer King, "Measured Impact of ADS-B In Applications on General Aviation and Air Taxi Accident Rates," Regulux Group, 2019, 7.

⁶³⁹ International Civil Aviation Organization, *Doc 9854, Global Air Traffic Management Operational Concept, 1st ed*, C-1.

⁶⁴⁰ Digital European Sky, "Draft proposal for a European Partnership under Horizon Europe, Integrated Air Traffic Management," European Union, 2020, accessed November 2021.

⁶⁴¹ *Ibid.*, 12.

⁶⁴² "Overview," International Civil Aviation Organization, accessed November 2021, <https://www.icao.int/safety/pbn/Pages/Overview.aspx>.

⁶⁴³ *Ibid.*

returns, and increase air capacity.⁶⁴⁴ For these reasons, there are several exploratory programs underway around the world.⁶⁴⁵

ICAO has developed the Global Air Navigation Plan (GNAP) to drive the evolution of air navigation systems for 2040 and beyond.⁶⁴⁶ GNAP is an implementation planning tool aligned to the GATMOC. As not all regions or states have the same needs, the GNAP serves as a tool by outlining a performance-based evolution of the air navigation system so that “no country is left behind”.⁶⁴⁷ The GNAP employs a multilayer structure composed of two global levels, a regional level, and a national level. The global strategic level is designed to aid decision makers through a common vision, performance ambitions, and a conceptual roadmap. The Global Technical level is designed for technical managers and helps with planning implementation of basic services and new operational improvements. The Regional level addresses regional and sub-regional needs. Finally, the National level informs States on national planning. Various ICAO bodies, like Regional Offices and PIRGs, help to employ GNAP at their respective levels. The GNAP is reviewed prior to each session of the ICAO Assembly and updated, as necessary. GNAP plays an important role facilitating the evolution of ATM, which must account for national, regional, and global needs of an ever-changing aviation sector.

ATM plays an integral role in the advancement of civil aviation. It enhances safety, efficiency of operations, and impacts environmental sustainability. The need for international cooperation combined with the sovereignty of airspace require patching together national practices to create a process for managing air traffic. Mixing various national practices with an ever-changing aviation sector poses challenges for efficiency and safety, however. ICAO has responded by developing a system that encourages uniformity while accounting for the unique needs and qualities of individual states or regions.

⁶⁴⁴ Ibid.

⁶⁴⁵ Some PBN examples include, the US NextGen program, SESAR in Europe, and CARATS in Japan.

⁶⁴⁶ International Civil Aviation Organization, “Welcome to the Global Air Navigation Plan (GNAP) Strategy,” International Civil Aviation Organization, 2020, 2, accessed November 2021, https://www4.icao.int/ganportal/GanpDocument#/lessons/Uk5BykeNFeA4P01MGxec7WevUtylNlpR?_k=obxx5p.

⁶⁴⁷ Ibid., 5.

Conclusion

ICAO's management of ATM requires considerable member state buy in. Producing SARPs, PANs, SUPPs, regional, international, and future focused measures all require ICAO members to participate in sessions, adopt measures, and institutionalize them domestically. Like with many international governance agreements, not all states adopt or abide by ICAO measures uniformly. Still, the scope of ICAO's work, which touches nearly every feature of ATM, speaks to the work of its members, their commitment, and support. This is in part because ATM offers value because it is uniformly adopted by countries. The financial costs of equipping aircraft with different systems and training pilots and ATM professionals to accommodate very different ATM schemes encourages uniformity. While there are some differences, like those for specific regions, the ATM system organized through ICAO offers a level of uniformity that benefits civil aviation broadly.

Through SARPs, SUPPs, PANs, supplemental materials, like manuals, and GNAP, ICAO has demonstrated agility by changing ATM practices with the aviation industry. ICAO offers several pathways to develop new standards and recommended practices. Whether through ANPs or SARPs, ICAO members have more than one way to address changing ATM needs. GNAP is another example of an agile organisation attempting to lead its members into the future. These measures cover a range of topics, from technical to training, compliance, and performance. Regardless of how civil aviation traffic management needs might change, ICAO is capable of changing with them.

International aviation has such importance today because it operates through shared standards and practices. ATM is one of those practices that helps streamline aviation operations and improve safety, like the reduction of aircraft fatalities by 89% by using ADS-B.⁶⁴⁸ Still, there are areas for improvement, like with route performance and accommodating new forms of aviation. ICAO is attempting to address these shortcomings through GNAP. In all, the effectiveness of ICAO's work is demonstrated in part by the volume and scope, which exists because ICAO members find reason and value to produce it. While ICAO is not able to enforce

⁶⁴⁸ See page 186.

ATM practices, the spectrum of governance tools the organisation has adopted empowers national regulators to adopt and enforce safe and efficient ATM practices more easily.

Traffic management is a foundational piece for organizing activities in a global common, and it is unlikely that the prosperous civil aviation industry that exists today would offer the same value without ICAO's work. For this reason, it would appear unpersuasive to suggest ICAO has not had a positive impact of ATM practices and aviation broadly. Though the work is never done for international governance, ICAO has helped to create a system of ATM that improves aviation around the globe.

In sum, ICAO has cultivated member buy in to support a large scope of work focused on ATM. ICAO's work has improved ATM practices around the global, representing an effective system of ATM governance. Without ICAO's work it stands to reason that international civil aviation would face great complexity and cost to organize air traffic through a more decentralized alternative approach.

Internet Case Study

When an internet user wants to send an email, watch a video, or access a social media page, several steps must occur to allow the right information to move between networks from origin to destination. Everything that occurs over the internet is predicated on the managed flow of information.⁶⁴⁹ In other words, using the internet requires managing internet traffic.

When information is sent over the internet that information is deconstructed into what is known as a packet. Packets are a central feature of internet traffic management. Deconstructing pieces of information, like an email or video, into packets facilitates efficient traffic flows across networks. Once those packets have arrived at their destination, they are reassembled to present the original message or information.

⁶⁴⁹ For a detailed account of this process see: Office of the Chief Technology Officer, "Technical Analysis of the EDPB Letter to BEREC," Internet Corporation for Assigned Names and Numbers, April 2020, accessed November 2021.

For the internet to function in a timely manner, packets must arrive at their destination in rapid succession. For example, if the packets containing information for a video call arrived too far apart in time, the call would be interrupted by latency. As internet traffic increases, the volume can challenge the capacity of the network to deliver packets in a timely manner. When internet traffic is disrupted or delayed, it affects internet users and services. To ensure internet traffic is delivered seamlessly, network operators, the internet technical community, and governments work to manage internet traffic.

Managing internet traffic requires working across a diverse ecosystem of internet actors. From private internet service providers (ISPs) and internet exchange points (IXPs), NGO protocol developers, content creators, end users, government regulations, and many more. Managing internet traffic requires accounting for the commercial business factors and government interests. In some instances, like network neutrality, there can be conflict between what businesses believe is important and what government or citizens believes is important. Internet traffic management also requires working across national jurisdictions given internet traffic routinely flows across borders. A breakdown at any point in the management of internet traffic for technical, legal, security, or economic reasons can prevent access to the internet or degrade services.

How internet traffic is managed holds important implications for users, commercial companies, and governments. Managing internet traffic requires finding a balance between the technical needs of network operators, like ISPs, and the needs of end users and content creators. For this reason, major internet governance topics, like network neutrality, cyber security, and protocol development, are central to the internet traffic management debate. The internet is increasingly a requirement for modern education and business, making it more difficult to refute the idea that access to the internet is a human right. As the internet becomes (if it is not already) indispensable for modern life, the need to effectively manage internet traffic for all users becomes paramount.

Key Features of Internet Traffic Management

In the early days of the internet, a simple design, a relatively small number of users, and shared hardware required little traffic management. In the mid-1980s the internet grew in users and interconnections, which began to expose limitations—principally congestion issues—in the existing protocols.⁶⁵⁰ New protocols were developed among other changes, which allowed traffic to be managed by what were considered user neutral schemes. Considered neutral because they affected all users equally. For instance, if a network was experiencing congestion, all traffic was slowed equally to reduce congestion and ensure bandwidth was shared evenly.

As internet traffic began to include new content, like videos and voice calls, it became necessary to prioritize certain data (rather than treat it all the same) based on the needs of the content. Because information is deconstructed at the source and sent as packets before being reconstructed at the destination, voice calls, videos, and similar content are more sensitive to bandwidth delays. When a video is not assembled in a timely manner at the destination it can affect the quality of the video. Conversely, if an email takes extra time to reach its destination the receiver may not notice given it may only appear in an inbox once fully assembled. As a result, network service providers may choose to prioritize or shape certain content to protect network capacity and quality of service.⁶⁵¹

Avoiding latency is a key challenge for internet traffic management. In the same way sending a large container requires more resources of the mail carrier than a letter, certain internet traffic can require more resources (i.e., bandwidth) of the ISP. Determining what internet traffic receives what network resources is often referred to as prioritization. But the prioritization of certain internet traffic over other traffic is in many ways counter to the internet's original design. Decentralization and interoperability were key features of the internet's architecture.⁶⁵² The use of packets facilitated both decentralization and interoperability but only if packets were handled

⁶⁵⁰ John Harris Stevenson and Andrew Clement, "Regulatory Lessons for Internet Traffic Management from Japan, the European Union, and the United States: Toward Equity, Neutrality, and Transparency," *Global Media Journal* 3 no. 1 (2010), 13.

⁶⁵¹ Ibid.

⁶⁵² Luca Belli and Primavera De Filippi eds, *Net Neutrality Compendium: Net Neutrality Compendium* (Switzerland: Springer, 2016), 288.

in a neutral way. Until the early 2000s the type and volume of internet traffic combined with many local networks encourage indiscriminate handling of packets, keeping internet traffic management neutral.

At the same time, spam, malware, and other cyber security challenges increased so network operators began scrutinizing internet traffic to keep users and the network secure. New tools, like deep packet inspection, which allows network operators to ‘inspect’ the contents of a packet, were adopted to aid cyber security practices. But inspecting packets can also be used to filter and regulate benign internet traffic.

Network operators and content and application providers have also grown in influence and in some cases merged. At its origin, network operators often had little to do with the creation of internet data (i.e., emails, files, games, etc.) consumed by users. With network operators and content and application providers separate, networks were neutral conduits for internet traffic. Now, network operators are also commonly producers of internet content, which can challenge the neutrality of a network as a traffic manager. As this change occurs, the internet traffic management can become more centralized.

The evolution has enabled fundamental changes to the way internet traffic is managed. The centralization of internet traffic management responsibilities between network operators and content and application providers has altered the incentives to discriminately manage internet traffic while tools, like deep packet inspection, make it possible to do so. While the evolution has in many ways aided the management of internet traffic, it has also created the opportunity to treat internet traffic selectively which can limit the openness of the internet threatening the rights of end users.⁶⁵³ Whether or not internet traffic is managed with fairness and neutrality or with discrimination depends largely on the actors managing internet traffic, like ISPs, and national laws.

⁶⁵³ Ibid., 289.

Internet Traffic Management Actors

All information accessed on the internet is stored in one or more places. Accessing information requires navigating the pathways that connect individual networks. Connecting individual networks occurs via ISPs. Because there are several ISPs, IXPs are required to allow traffic to flow between ISPs. Finally, internet protocols, like TCP/IP and the DNS, provide the uniform instructions for how to route data over interconnected networks. Organizing these various connections occurs through a decentralized actor-based approach.

Each of these individual pieces, including the data, the networks, network exchanges, content and applications, and the protocols are managed or led by different actors. ISPs, like Sky in the UK, are commercial companies responsible for managing networks, including monitoring internet traffic. Some of the most accessed data is produced by content creators, like social media companies or news organisations, who care about the quality of network connections and data latency. And as we know from chapter 3, protocols are developed by nongovernment organisations like the IETF to allow networks and content to be interoperable. Each as a key role in internet traffic management.

As users connect to the internet and access webpages or content that internet traffic traverses IPS's networks. As commercial companies, ISPs can be in competition for customers. At the same time, to connect ISPs to other ISPs and create the global internet we rely on today, ISPs also have to work together. How ISPs work together can affect how internet traffic is managed, access to content, and associated services.⁶⁵⁴

The interconnection of private networks is achieved through privately negotiated contracts between private companies, rather than through centralized government regulation. According to Mueller, privately negotiated contracts replaced public regulations, limiting government's ability to influence certain aspects of internet access, like price.⁶⁵⁵ The role ISPs play granting access to

⁶⁵⁴ P. Faratin, D. Clark, P. Gilmore, S. Bauer, A. Berger, and W. Lehr, "Complexity of Internet Interconnections: Technology, Incentives and Implications for Policy," Research Gate, August 2007, 22, accessed November 2021, https://www.researchgate.net/publication/242769120_Complexity_of_Internet_Interconnections_Technology_Incentives_and_Implications_for_Policy_1.

⁶⁵⁵ Milton Mueller, *Networks and States*, 57.

the internet to user and controlling the flow of data makes them a central figure in internet traffic management.

Network operators, like ISPs, and content and application providers make internet traffic management decisions based on business, customer, or technical needs, which can be optimized for profit.⁶⁵⁶ Governments do regulate ISPs to some extent (e.g., net neutrality legislation), but generally network operators and content and application providers are free to decide interconnection arrangements.

While there are not uniform categorizations of networks, they typically fall within a tier system.⁶⁵⁷ Tier 1 networks are typically the largest networks in a region or country and can reach all other networks within that region and may also have global access. Given their size and reach, Tier 1 networks are somewhat dependent on other Tier 1 networks for global access. As a result, Tier 1 networks negotiate interconnection agreements via peering (settlement free), rather than via traffic exchange fees.⁶⁵⁸ Tier 1 networks often hold considerable influence over internet traffic management given their size and systemic incentive to connect via peering.

Tier 2 networks may pay tier 1 networks traffic exchange fees to connect, while tier 3 almost always pay larger networks for connection. Size of the networks influences the market incentive driving the need to pay or not. Tier 2 are generally smaller and thus offer little value to the Tier 1 network, creating the incentive for Tier 1 networks to charge a traffic exchange fee to smaller networks. The same situation occurs for Tier 3 networks but difference in size is greater than between Tier 1 and 2. When smaller ISPs pay larger ISPs to connect, they are for all intents and purposes paying the larger ISP to deliver its traffic. Agreements can take many forms though peering, paid-peering, and partial transit are examples of common agreement structures.

Though there are common agreement practices, recent developments in content and application providers are creating incentives to adjust practices. As content and application

⁶⁵⁶ Laura DeNardis, *The Global War for Internet Governance*, 123

⁶⁵⁷ P. Faratin, D. Clark, P. Gilmore, S. Bauer, A. Berger, and W. Lehr, "Complexity of Internet Interconnections: Technology, Incentives and Implications for Policy," 6-7.

⁶⁵⁸ Ibid.

providers, like social media websites or games, drive internet usage, ISPs must consider how access to popular content could affect customer's desire to do business with that ISP. The ability of content and application providers to drive interconnection terms is a relatively recent development as far as internet traffic management is concerned.

Given that ISPs are often national or regional companies, they require a connection to outside networks. IXPs solve this problem. IXPs are commonly independent, not for profit associations of their constituent networks (i.e., ISPs). IXPs act as a hub for ISPs and are especially important for interconnection between countries and regions by acting as a bridge between them.

The role IXPs play has important implications for internet traffic. IXPs can affect political, technical, and economic aspects of accessing the internet. For example, one study by the Internet Society found that countries that possess a local IXP have less latency.⁶⁵⁹ For users in a country without an IXP, sending traffic can require routing it through a foreign IXP only to have the traffic return to local user, which adds costs and latency.⁶⁶⁰ Moreover, when an IXP goes down it can have sweeping negative consequences on internet access for the area it serves.⁶⁶¹ Having more than one IXP in an area can, therefore, also add resiliency by offering alternative pathways for internet traffic.⁶⁶² In all, IXPs are an indispensable feature of internet traffic, and as independent actors, can affect how internet traffic is managed. Though they play an irreplaceable role in internet traffic management, IXPs often do not receive the attention that ISPs do.⁶⁶³

In addition to network operators there are also numerous organisations, like the IETF, IEEE, and ISOC, responsible for developing internet protocols for managing internet traffic.

⁶⁵⁹ Terry Sweetser, "Measuring the Impact of Local IXPs: Understanding Hosting Trends in the Asia-Pacific Region From the Regional Domain Perspective," Internet Society, 2021, accessed November 2021, <https://www.internetsociety.org/wp-content/uploads/2021/10/Measuring-the-Impact-of-Local-IXPs-EN.pdf>.

⁶⁶⁰ Laura DeNardis, *The Global War for Internet Governance*, 127.

⁶⁶¹ For example, see: Alan Burkitt-Gray, "DE-CIX down at Frankfurt after power failure at Interxion," Capacity, April 2018, accessed November 2021, <https://www.capacitymedia.com/article/29ota593u7c7lkmjbg7b4/news/de-cix-down-at-frankfurt-after-power-failure-at-interxion>.

⁶⁶² Growing the Internet, "Explainer: What is an Internet Exchange Point (IXP)?" Internet Society, June 2020, accessed November 2021, <https://www.internetsociety.org/resources/doc/2020/explainer-what-is-an-internet-exchange-point-ixp/>.

⁶⁶³ Laura DeNardis, *The Global War for Internet Governance*, 125.

These protocols are development to balance the needs of internet actors (from network owners to content providers and users) against the technical requirements of a changing internet. It is an evolutionary process balancing technical and community needs, though for reason discussed in chapter 4, many of the organisations that produce protocols do not engage in the politics or commercial business of internet traffic management.

There is a long list of individual protocols designed to affect various aspects of internet traffic management. Some include HTTP/2, QUIC, TLS 1.3, and DOH.⁶⁶⁴ The technical details of these protocols are not the focus of this discussion, but the organisations that produce them are. As discussed in chapter three, there are many technical bodies, like the IETF, that produce protocols through networks of experts and various consensus-based procedures. Commercial companies, like Google, can also produce protocols, though their widespread adoption can still be dependent on the support of the IETF or similar bodies. These protocols seek to improve the technical layer of internet traffic management to address security, economic, and user interests.

These organisations can also produce norms to address internet traffic management topics. For example, ISOC developed the Mutually Agreed Norms for Routing Security (MANRS) initiative to encourage the implementation of best practices and technology solutions to address security concerns among network operators.⁶⁶⁵ The IEEE has also conducted numerous studies and provide recommendations around internet traffic management.⁶⁶⁶ There are numerous other examples of norms and best practices being produced to positively affect internet traffic.

Finally, governments also play an important role typically as a regulator. National regulations are common, though not uniform. While some governments use their role to regulate access to content, others use it to protect the rights of internet users. For example, countries ruled by

⁶⁶⁴ Mark Nottingham, "Internet Protocols are changing," APNIC, December 2017, accessed November 2021, <https://blog.apnic.net/2017/12/12/internet-protocols-changing/>.

⁶⁶⁵ Securing Global Routing, "The world needs a secure and resilient Internet," Internet Society, updated 2022, accessed January 2022, <https://www.internetsociety.org/action-plan/2022/securing-global-routing/>.

⁶⁶⁶ Mohammed Aledhari, Sukanya Mandal, Nagender Aneja, et al, "White Paper: Protecting Internet Traffic: Security Challenges and Solutions," Institute of Electrical and Electronics Engineers, May 2017, 20, accessed November 2021, <https://standards.ieee.org/wp-content/uploads/import/documents/other/whitepaper-protecting-internet-traffic-dh-v1.pdf>.

autocratic regimes often regulate or censor access to content, while in the EU government has taken regulatory steps to ensure users rights and privacy is protected.⁶⁶⁷ The role governments play can be as unique as governments are generally.

As the internet is governed through a multistakeholder approach so too is internet traffic managed. Various technical organisations like, ISCO, IETF, and IEEE, provide standards and protocols to improve aspects of internet traffic management related to security, latency, and cost. Commercial and not for profit organisations, like ISPs and IXPs, operate networks while balancing consumer, business, and government interests. Government impose regulation on internet traffic in a manner fitting the country's broader political philosophy. Together this decentralized group address complex issues, like network neutrality, access, privacy, and security. Moreover, the process is an evolutionary one with each actor changing their approach as internet traffic evolves.

Conclusion

In the case of the internet, member state buy in does not apply in the same way as it does in the air and maritime domains. For the internet, stakeholders are bought in because it is their business to be engaged in internet traffic management. ISPs, IXPs, the protocol community, and to some extent government regulators responsible for balancing privacy, security, and neutrality, have professional responsibility to be engaged. In the case of ISPs there is economic incentive to manage traffic. For the protocol community it is their job to produce useful protocols. And for government, it is governments responsibility to ensure internet traffic is managed in accordance with laws and values of the state. Though engaged, the multistakeholder ecosystem predicated on mixed motivations, like business, do undermine trust and legitimacy of the traffic management regime. This is evidenced by the tension over net neutrality, security, and privacy.

⁶⁶⁷ Eda Keremoglu, Nils B. Weidmann, "How Dictators Control the Internet: A Review Essay," *Comparative Political Studies* 53, no. 10-11 (2020): and, "Internet Traffic Management and Net Neutrality – Everything You Need to Know," PureComms, March 2020, accessed December 2021, <https://www.purecomms.co.uk/internet-traffic-management-and-net-neutrality-everything-you-need-to-know/>.

Business and professional responsibility also drive agility for internet traffic management. An ISP's bottom line can be a strong incentive to modernize or adjust internet traffic management practices. Similarly, for the protocol community, account for an ever-changing internet landscape, whether through IoT, new content, or other changes, requires constantly changing. Where agility may be lacking is in the community's ability to develop access and necessary government regulations. Broadband in rural locations continues to be an issue that ISPs can be reluctant to fix because it can cost more to provide services to a rural area than the users will produce in revenue. For governments, regulating complex issues like net neutrality has proved a laborious task with many viewpoints. Still, the internet actors most invested in managing internet traffic do routinely make changes to practices, business models, and standards.

The growth of the internet may be the best evidence that internet traffic management is generally effective. More occurs over the internet than ever before, including working from home, IoT devices, and the generation of incredible volumes of content. Despite incredible shifts—some of which, like working remotely in response to COVID-19, happened very quickly—the internet community has managed to keep pace.

When drawing insights as to whether the internet is better because of the traffic management regime, it is harder to assess because the regime is almost all the internet has known. Early days of the internet saw less commercial control, but those days also saw less content, use cases, and general need for the internet as a human right. Moreover, given the multistakeholder origins and technical design, it is hard to envision a more centralized approach like those found in aviation and shipping. That said, access, privacy, and security issues are an important limitation that a multistakeholder traffic management regime appears poorly suited to address.

In sum, the internet's unique governance approach offers some valuable qualities for managing traffic, like stakeholder buy in and agility. It also appears poorly suited to address certain negative qualities, however. Both can prove valuable for drawing lessons for STM.

Analysis and Conclusion

STM requires understanding what is happening in space, norms, laws, and regulations to influence space activities toward sustainable, efficient, and safe practices, and the means to administer the STM regime via an IO or multistakeholder network. None of what an STM regime requires is entirely novel to the space community, though none of the three requirements are sufficiently developed. For example, the rise in SSA systems around the globe is a promising development. Conversely, while COPUOS is the central international space governance forum and it has addressed the topic of STM, the forum is not currently suited to administer an STM regime, nor has it produced any meaningful outputs that would influence STM activities. To progress an STM regime will take developments in each of the three key areas.

The goal of this analysis is not to prescribe exact technical qualities of an STM regime, like navigation or communication practices. The focus of this discussion will be SSA, developing the necessary rules, laws, and other measures, and what is necessary to administrate a STM regime with particular focus for how to coordinate STM activities, because without coordination STM cannot provide value across the space enterprise.

Governance Challenge and the Need to Adapt: A Lack of Space Situational Awareness

In simple terms, SSA is about knowing what is happening in space. Data collection, analysis, product development, and dissemination inform space actors about what is happening in space so they can make educated decisions about their space activities. Unfortunately, SSA is underdeveloped, leaving space operators uninformed or untrusting of the data. Data needed to understand what is happening in a domain to inform traffic management is important to all three case studies. No traffic management data collection system is the same, but there are commonalities in how data is collected and shared and shortcomings with current practices.

In all three case studies individual operators or regulators managed their own data, though trends for more centralized control or sharing of data were present in aviation and maritime case studies. These practices were major factors limiting the regimes to reactive rather than proactive management systems. For example, in aviation and maritime domains, data is provided to flight control authorities or VTS authorities as planes or ships enter their area of control. This data is

often provided by the aircraft or ship, though some passive collection, like ground radar, is used to inform authorities. Similarly, internet traffic data is managed by individual ISPs as the data flows across their networks. The responsive nature is a consequence of the decentralized way traffic data is collected and shared.

The decentralized approach creates inefficiencies. As seen in aviation and maritime case studies, reliance on operator provided data at the time of need means delays in service, wasted fuel, and backlogs at airports and ports. The inefficiency is driving efforts at the national and international level (e.g., E-Navigation and GNAP) to leverage data more effectively to create a more proactive and centralized traffic management system that prevents wastefulness and improves operating environments. The evolution toward more efficient use of traffic data is not unique. In fact, how each regime uses data has evolved over time as technology has matured and traffic has increased.

Governance Solution via Adaptation: Better SSA Coordination

Key limitations with current SSA included limited quality and being siloed between operators or governments, with a few exceptions. Managing space traffic will require better data available to all space operators.

Unlike other domains, there are no clear borders or sovereign areas in space to inform STM authority. All space operators will need to know what is happening in space, but not all will have the means to develop their own SSA capabilities. First, SSA is a costly and technical endeavour. Suites of sensors are required around the global and in space to accurately understand what is happening in space. Second, not all satellites, and debris, can transmit their location to operators. Of the commercial satellites that can, and based on practices in other domains, it is unlikely they will be required by law to share their data globally. Should the case studies inform expectations for SSA, then a centralized SSA system is unlikely, though limited international or bilateral arrangements are.

This suggests SSA or STM operators at national or international levels will need to be in close coordination. Aviation relies on similar coordination scheme through FIR, Regional

Offices, and PIRGs. But aviation schemes are still based on sovereignty allowing for clear demarcations of responsibility. Limited international SSA coordination will have to rely on a shared desire to avoid incidents in space and for the efficient management of space traffic. According to the case studies, SSA coordination will also require recognized authorities, and the military is not likely an appropriate authority given the concerns other states or commercial operators may have over a military, rather than civilian organisation, handling SSA.

Internet IXPs could offer useful insights for coordinating national or regional SSA data. As not-for-profit organisations composed of their constituency (e.g., ISPs), IXPs for SSA data could offer a useful model for collecting and distributing uniform and trusted SSA data. An IO could help inform best practices and audit for quality.

One could also envision an operator-based approach to SSA coordination like the multistakeholder scheme used to manage internet traffic. In such a scenario there would need to be impartial ways of sharing data to ensure it is trusted. As is the case with internet neutrality, decentralized schemes can require government regulation, and differences in government regulation of commercial actors can complicate the management of traffic.

Even with close coordination, this could resign STM to a reactive, rather than proactive regime. What little STM occurs, like collision avoidance, is reactive. While satellites move at incredible speeds their orbits are often known providing operators days or more to adjust and avoid incidents. But time is not always available, as is the case with unexpected collisions. As space traffic increases, a reactive regime could reduce efficiency, increase risk to the environment, and impose costs on operators, all of which has occurred in each case study domain. This again suggests SSA coordination is key to the success of STM. Close coordination of data can underwrite the means to manage traffic proactively.

The method for sharing trusted data is undetermined, but COPUOS could codify rules for sharing and creating trusted data. In the IMO and ICAO case studies, standards and recommended practices influenced how states constructed their traffic management schemes. Based on how the IMO and ICAO are moving toward performance-based systems, COPUOS

could guide states through a similar scheme that does not dictate specifics but details ideal outcomes for data sharing.

Governance Challenge and the Need to Adapt: Need for Norms, Standards, and Regulations

All traffic management regimes require norms, standards, laws, and other regulations to guide actor behaviour. There are few measures to guide space activities as they related to STM. There are guidelines that inform debris mitigation practices related to STM, like deorbiting, and its common to deconflict space traffic to avoid collisions, but when, how, and by whom these activities are conducted is not uniform. Nor is there an agile process for developing new measures.

In all three case studies, norms, laws, standards, and other measures were used to influence behaviour with some similarities and some differences. For example, the IMO and ICAO take a similar approach through standards and recommended practices while the internet shares technical standards, via protocols. In all case studies, these measures are not static but evolve overtime. Their enforcement falls largely to national regulators or operators.

The measures used to guide aviation and maritime traffic management take a few forms, but standards and recommended practices play a central role. In both case studies the coordination of traffic rules are largely suggestions with national regulators deciding what and how to enforce them. There are numerous standards and recommended practices addressing international and regional concerns across the spectrum of traffic management needs. Collective standards and recommended practices provide aviation and shipping operators with the means to adopt uniform traffic management practices. Though compliance of standards and recommend practices is generally expected—save exceptions voiced through appropriate organisation processes—the spectrum of standards and recommended practices and the system of adoption provides some flexibility. The flexibility enables adoption of standards and recommend practices by lowering the transaction costs necessary to move them through organisational processes. Given the lack of consequences for noncompliance and the value uniform practices provide the ecosystem of operators, there is generally support for standards and recommended practices. Typically, the

measures ICAO, IMO, and internet standards community adopt along these lines also provide sufficient detail to make their adoption easier.

Standards and recommended practices are routinely incorporated into or complemented by major international conventions that complement key themes related to domain governance. For example, SOLAS and COLREG conventions include several measures to inform maritime traffic management. Similarly, ICAO SARPs are included in Chicago Convention Annexes. Such inclusions are important for adherence. Including them in core features of domain governance also means standards and recommended practices are supported by existing organisational remits, bodies, and processes. The IMO applying its member state audit scheme to maritime traffic management is one example of cohesion among IMO traffic management measures and other IMO governance tools.

Internet traffic management is driven more by technical and business requirements than by norms or regulations, with some exceptions, like net neutrality or measures related to privacy. Still, the internet requires shared practices for interconnection. Protocols must be developed and adopted at scale for them to influence the internet's functionality. While technical in nature they are standards that require stakeholder input to develop and adopt. Business considerations also require shared practices. ISP peering and IXP cooperation are two examples. Internet practices are, in some ways, like the standards and recommended practices adopted by the IMO and ICAO in that they organize disparate actors towards a common goal of managing traffic.

Common to all standards and recommended practices found across the three case studies was a focus on accessibility of measures for all actors. ICAO, the IMO, and the internet protocol community take steps to ensure the measures developed are not prohibitive based on differences in operator sophistication or technology requirements. While not perfectly effective, this is important for adoption and coherence because the more traffic management activities are shared across states and actors, the better and more beneficial it will be. The practices found in the air, maritime, and internet domains are far more developed than anything that exists for STM.

Governance Solution via Adaptation: Advancing STM Norms, Laws, Standards, and Measures

Using the case studies to inform the advancement of STM norms, laws, and other measures suggest standards and recommended practices should play a central role in STM.

Not unlike civil aviation or shipping, different countries have different capabilities, resources, and aptitudes when it comes to space activities, like satellites, launch, etc. Developing measures to provide STM needs to account for the variation in international participation and ability of countries to adopt and enforce the laws, norms, standards, and other tools. As we learned in the previous chapter, balancing transaction costs and adherence are two important factors that can influence the ease at which agreements are developed.

If designed with diversity of actors in mind, like GNAP, standards and recommended practices offer a helpful way of aligning STM practices while reducing transaction costs. As the IMO and ICAO have both done, the menu of standards and recommended practices account for a variety of users and applications and regional and international needs. So, while the greater the adoption the better, the utility of the aviation and IMO traffic management systems does not depend on total adherence to a select few agreements. Moreover, many of the standards and recommended practices are designed around shared outcomes rather than strict technology or procedure requirements.

For STM this could mean developing standards that outlines the goals for STM behaviours, rather than requiring operators adopt specific technologies. This offers different actors flexibility in how they reach the desired outcome, which is important for managing compliance costs. To be sure, some standards and recommended practices will require adopting common technologies or meeting detail performance metrics, but many will not.

While standards and recommend practices are likely to make up the bulk of STM governing tools, STM will also require additional treaties, norms, codes, and other measures. In large part, the regulatory weight of a standard or recommended practice is its connection to a more legally binding treaty, like the Chicago Convention or SOLAS. For existing space treaties to accommodate STM standards and recommended practices would require amending the treaties,

which would not be easy in COPUOS' current state. Creating new treaties is also possible but not without reform to COPUOS as discussed in Chapter 3.

Finally, the case studies clearly show the need for the suite of regulatory tools to evolve with domain needs. The IMO, ICAO, and the internet governance community routinely modernize the system of rules, norms, standards, technology, and other measures necessary to manage traffic. The same will be necessary for STM, and perhaps even more so given the nascent development of STM currently combined with the rapidly advance nature of space activities. Developing and evolving any sort of traffic management measures requires an organisations or network of stakeholders capable of advancing domain governance.

Governance Challenge and the Need to Adapt: STM Administration

When examining the case studies, it is clear traffic management is a cornerstone responsibility for the safe, sustainable development of a domain. Maritime traffic has existed for hundreds of years, and the IMO has incorporated various aspects of traffic management into major conventions because of traffic management's central role. Likewise, the Chicago convention includes provisions on aviation traffic management while several convention annexes include SARPs and other features that make up the aviation traffic management regime. While the internet does not have hundreds of years of traffic management experience or international conventions outlining traffic management needs, the very existence of the global internet, let alone its advancement, requires managing how information flows over and between networks.

Examining how each governance organisation or network manages traffic illuminates the need for diverse expertise, agile processes, and stakeholder support to properly administrate the regime. In each case study the administration of a traffic regime leverages several technical bodies focused on specific aspects of traffic management. The IMO uses the MSC and subsidiary bodies, like the NCSR, to manage standards for communication and the evolution of VTS. ICAO relies on regional offices, PIRG, and various panels that report to the ANC to address a spectrum of air traffic management needs. Internet traffic management does not fall to one group, but each piece, whether network management, protocol development, or government regulation is interwoven and cooperation between groups is required.

In aviation and shipping case studies, the IO or multistakeholder group provided administrative function because the need to manage traffic did not trump national sovereignty. Instead, the importance of sovereignty influenced the design and function of the administrative organ. The desire of states to control what happens within and near their borders shaped the traffic management regimes into a decentralized system where pilots, captains, and national authorities are ultimately responsible for managing traffic. This has resigned IOs to a facilitation role where the IO uses its convening ability to develop standards and agreements necessary to cohere activities but does not enforce them. The IOs play an essential role administering traffic regimes by advancing new agreements, providing administrative support to processes and products, and by acting as an advisor to states.

Internet traffic management does not fall to a single administrative organ, like the IMO or ICAO. Instead, the market and governments act as an administrator. The large influence of commercial business on the internet drives both technical and regulatory traffic management change. For example, as network traffic began to include videos and other data heavy content, the market incentivized treating some traffic differently than other traffic. Which motivated governments to advance net neutrality measures. As change is required, the multistakeholder group that governs the internet will undergo incremental alterations as new technical and policies solutions become available.

In each case study traffic management was central focus for the IO or group of actors responsible for governing the domain. COPUOS does not play a meaningful role in the development or administration of a STM regime. National efforts provide SSA and some STM functions, like conjunction assessments, but national activities are mostly ad hoc and there is little coordination between them. Without a more central IO or network of space actors to advance and administer an STM regime, one may not materialize.

Governance Solution via Adaptation: Reforming COPUOS

COPUOS is not suited to administer a STM regime. The committee lacks the forum capacity and administrative support through the Office of Outer Space Affairs to operate on a more agile and technical basis required to develop and oversee traffic management. Because developing an

entirely new international organisation and gaining international membership would be a major political challenge, reforming COPUOS is the most pragmatic option, though not without its own political obstacles.

Based on the administration of traffic in the case study domains, COPUOS reforms that address its decision-making style, add technical committees, and develop procedures and agreements built around standards and recommended practices are capable of improving the forum's ability to govern. A goal could be to develop COPUOS such that it can play the same facilitation role as the IMO and ICAO to cohere and advance STM, while states adopt and enforce necessary practices.

The Analysis and Conclusion section of the previous chapter addressed the need for a new decision-making style in detail. Many of the reforms discussed in the previous chapter would also apply to the reforms necessary to develop and administer an STM regime. Principally, reaching consensus through a pragmatic approach that balances transaction costs and adherence are shown by the case studies to be beneficial. The type of agreement in question should influence how that balance is struck as is the case in the IMO, ICAO, and internet technical organisations.

The technical and continuous nature of administering a traffic management regime requires the organisational capacity to address multiple diverse topics regularly. COPUOS is limited to a full committee and two subcommittees with the occasional temporary working group. In its current form, COPUOS does not have the organisational capacity to oversee STM and will require more focused support through new COPUOS subcommittees or groups. The exact configuration of new COPUOS subsidiary bodies is less important than their features. When looking at the IMO, ICAO, and the internet community, expertise influences the work various groups perform. And based on the group in question, each group can have different permission to begin or adjudicate work and outputs. What seems consistent among the case studies is that various subsidiary bodies are designed around the work they are expected to do and not designed uniformly. This suggests they were developed to prioritize necessary outputs rather than to carry on with what may be considered idyllic procedures, like strict consensus decision-making styles.

This adjustment should be made to account for the nature of agreements COPUOS will likely need to advance for STM. Currently, COPUOS, in part because it does not have the forum capacity, does not produce standards and recommended practices. Based on lesson from the case studies, adjusting processes and the forum composition of COPUOS could offer the means to produce standards and recommended practices as a central output for STM. This is not to say new binding treaties or other agreements would not also be important, they would be. But because states are unlikely to cede their rights to manage traffic to an IO, offering standards and recommended practices through COPUOS has the potential to facilitate uniform STM processes while new treaties and binding measures provide incentives to adhere to COPUOS STM outputs.

Summarizing Lessons Learned

As predicted by Ostrom et al, the technical nature of traffic management requires traffic management governance to routinely evolve. When considering the three elements of managing international traffic (traffic data, traffic rules, and international administrative support), technological evolution influences each. The evolution in digital connectivity means more technology today produces or relies on data. When it comes to tracking planes, ships, or an internet packet more connectivity and data sharing can mean new operational efficiencies. These efficiencies are driving change in traffic management practices, as indicated by the shifts from reactive to proactive regimes found in the case studies. But technology alone cannot guarantee efficiencies and new benefits from international traffic management governance, it requires an IO to help cohere activities, share lessons and tools, and otherwise ensure traffic management practices remain inclusive, otherwise technological disparities could lead to fractured or incoherent international traffic management. To this end, each case study provides evidence that for international governance of traffic to remain effective, it must adapt.

Evolving international traffic management governance relies heavily on changing standards and recommended practices and updating other agreements to ensure they remain current with technology. Indeed, each case study IO regularly worked on new governance measures to ensure traffic could be managed effectively. The rate at which technology is changing traffic management practices also encouraged IOs to emphasis agreements and tools that are inclusive despite technology and other differences between IO members. This is important because

technology disparities can make it difficult to develop an international traffic management system. To this end, a key example of governance evolution found in the case studies is the shift from more technically prescriptive governance measures to performance-based measures to improve inclusivity and allow for a range of technical approaches. Performance-based measures can better accommodate rapidly changing technology because they are outcome oriented, and therefore, tend to be technology agnostic. Performance based measures can also improve compliance by lowering barriers to entry because members can choose how to reach performance goals vs being asked to adopt specific technologies and practices.

The last lesson emphasizing the importance of governance evolution is how each case study organisation or multistakeholder group adjusted internal roles, responsibilities, and processes to keep pace with traffic governance needs. As technology changes, so too do the IO's needs for technical expertise, research, and working groups among others to effectively administer traffic governance. In each case study, evolution of the organisation was once again expected as part of the organisations responsibility to govern effectively. While debate and disagreement were present, change persisted.

Reforming the currently limited SSA practices, COPUOS, and developing standards and recommended practices, laws, norms, and other measures to develop an STM regime is a considerable undertaking. However, as the case studies illuminate, what is discussed in this section as necessary for STM is common practice in other domains. Managing traffic is a central feature of domain governance, in fact. As a result, the changes necessary for STM while difficult, are also realistic. More importantly, change is a feature of governing STM. To be sure, without proper STM, it will be exceedingly difficult to ensure space is developed sustainably.

7. ON-ORBIT RENDEVOUS, PROXIMITY, SERVICING, & ASSEMBLY OPERATIONS

To this point in the research the activities and governance challenges discussed are familiar activities in that they have been addressed in other domains for decades. Sustainability challenges and traffic management regimes are activities governments have been regulating through international fora like the IMO and ICAO for years. The history of governing such activities can make them familiar and offers applicable lessons for governing similar activities in space. In this chapter the research will diverge from the familiar to explore how governance accommodates entirely new activities with less historical precedent. The lessons gleaned from the governance of emerging activities will help inform the development of necessary space governance for similarly novel space activities known as on-orbit satellite or spacecraft rendezvous, proximity, servicing, and assembly operations (ORPSAO).

Unlike in the previous chapters which focused on the same activity (e.g., traffic management) across each domain, this chapter will explore how the maritime domain governs autonomous shipping, the air domain governs unmanned aircraft vehicles (UAS), and the internet regime governs the expanding IoT ecosystem. While these activities are very different in application, they are similar in that they are novel to each domain, requiring new governance of unfamiliar activities. The challenge of governing new emerging activities is that while governance is required for necessary environmental protections and safety, it must be balanced so to not stymie the development of beneficial innovation. Finding such a balance requires advancing governance at a pace relative to new technological innovations. For example, in governing UAS, civil aviation governance must account for the rapid development of new UAS use cases, types of UAS, and markets without hindering their development.

The lessons gleaned from the case studies will help inform new governance for commercial ORPSAO. ORPSAO is a set of activities expected to advance space development by unlocking new space activities necessary for the next stage in space development. ORPSAO are not new to space development—they are routinely conducted to resupply, services, or deliver astronauts to

the international space station—however, ORPSAO are not routine in commercial space practices. It is expected that ORPSAO will see growing commercial interest and market share in the coming years, but a lack of shared technical and safety standards poses challenges for growing the commercial application of ORPSAO.⁶⁶⁸ New governance to ensure commercial ORPSAO are conducted safely and in a manner that facilitates sustainable space development will be necessary.

The chapter will begin with an overview of ORPSAO and governance needs, followed by three sections discussing how the maritime, air, and internet regimes govern emerging activities. The final section will highlight insights from the case studies to inform new ORPSAO governance.

Understanding ORPSAO

ORPSAO describes activities during which two or more satellites will operate within relative distance, rendezvous with one another, service one another, or where something is assembled in space. For example, when supplies are delivered to the International Space Station, the resupply spacecraft must operate within proximity to the station before rendezvousing and docking. Similarly, when US astronauts needed to service the Hubble space telescope, they had to position the Space Shuttle within proximity of the telescope before docking and conducting servicing operations.

ORPSAO activities have occurred since the dawn of the space age, for example when US astronauts rendezvoused and docked the lunar lander with the command module during the moon landings. While not entirely new, except for a few recent commercial activities, ORPSAO do not routinely occur routinely outside of International Space Station activities.⁶⁶⁹ It is anticipated that

⁶⁶⁸ Benjamin A. Corbin, Amana Abdurrezak, Luke P. Newell, Gordon M. Roesler, Bhavya Lal, “Global Trends in On Orbit Servicing, Assembly, and Manufacturing (OSAM),” iii, March 2020, accessed January 2022, <https://www.ida.org/-/media/feature/publications/g/gl/global-trends-in-on-orbit-servicing-assembly-and-manufacturing-osam/d-13161.ashx>.

⁶⁶⁹ For an example of recent commercial ORPSAO see: “Mission Extension Vehicle,” Northrop Grumman, 2020, <https://www.northropgrumman.com/space/space-logistics-services/mission-extension-vehicle/>.

the frequency and use case of ORPSAO will increase and unlock new activities necessary to advance space development.

Breaking down each facet of ORPSAO can help illuminate the complexity and the benefits of the activities. Proximity and rendezvous operations are necessary for all in space servicing and assembly operations. In space, such operations can be complex activities requiring corresponding speed and position of spacecraft using onboard sensors, complex computations, and guidance, navigation, and control systems. Proximity and rendezvous operations are a first step in servicing and assembly, they also pose risks. Poorly coordinated proximity and rendezvous operations can lead to collision causing space debris and subsequent problems, like the loss of a satellite.

Servicing includes altering or inspecting one satellite with another (an exception would be astronaut alterations of the space station; however human servicing is expected to be rare.). Expected servicing activities include refuelling, repairing, and relocation, among others. The ability to service a satellite to extend its life with new fuel, a new part, upgrades, or new position would radically change how many space operators think about designing and producing satellites. For example, without the ability to repair a satellite once in orbit, satellite manufacturers often rigorously test satellites and include system redundancies, which can increase manufacturing time and costs. Through servicing, operators would be protected from some malfunctions once in orbit while also able to deorbit defunct satellites to avoid new space debris. In all, servicing has the potential to radically change how satellites are designed, produced, and used while reducing debris.

Assembly refers to the construction of a larger system through the marriage of subcomponents in space. The opportunity to assemble satellites or spacecraft in orbit overcomes limitations imposed by launch. Currently, satellite designs are influenced in large part by requirements necessary for getting a satellite into space. The satellite must fit into the launch vehicle's payload fairing and meet the vehicle's mass restrictions. The satellite must also be designed to withstand the force of launching atop a rocket. These factors influence how satellites are designed, which can limit the type or viability of some space activities. For example, space-based astronomy would benefit from larger mirrors than can be launched into orbit today by even

the largest available launch vehicle. If it were possible to launch several small mirrors and assembling them in space, one could offer more advance astronomy services. Like servicing, assembly is expected to create entirely new opportunities for commercial, civil, and national security space activities while improving sustainability.

The benefits of technologies and services that enable satellites to “approach, inspect, grasp, manipulate, modify, repair, refuel, integrate, and build completely new platforms and spacecraft on orbit”⁶⁷⁰ (activities inherent in ORPSAO) can spur new business models, services, and opportunities in space for both development and sustainability. Indeed, ORPSAO has the potential to radically change how space is developed, explored, and sustained. However, as with most radical changes there are also risks.

The Need for Safety and Transparency

The frequency and commercial application of ORPSAO are major changes from what has been occurring to date. Like other activities discussed in this research, the expected increase in frequency and number of actors conducting ORPSAO poses risks to the space environment and space development if not conducted safely and transparently.

Given the speed at which satellites orbit the Earth, even minor miscalculations that result in collision could ruin the satellites involved and generate new debris. The potential consequences justify coordination for both business and sustainability reasons. ORPSAO also pose concerns for national security. The same operations that permit the inspection or servicing of a satellite could also be used to collect intelligence on military satellites or interfere with them. The difference between safe commercial operations and understanding what constitutes benign vs malign ORPSAO are rules, norms, and other measures that enable coordination and transparency.

⁶⁷⁰ David A. Barnhart, Rahul Rughani, Jeremy J. Allam, Brian C. Weeden, Frederick A. Slane, and Ian Christensen, “Using Historical Practices to Develop Safety Standards for Cooperative On-Orbit Rendezvous and Proximity Operations,” 1.

Coordination to date has not been significant, though there are signs that that could change. According to one study released in 2020 there are more than 100 organisations across 17 countries engaged in ORPSAO related activities.⁶⁷¹ The same study found that two broad trends categorize these activities. The first is that while some countries like the US and UK are fostering private sector ORPSAO activities, others, like China and Russia, are driving largely government efforts.⁶⁷² The second trend identified that no country had developed related policies though several had plans to do so.⁶⁷³

In April of 2022, the US released an in-space servicing, assembly, and manufacturing national strategy.⁶⁷⁴ The ESA has also produced close proximity operations guidelines and NASA has long used rules for approaching and docking with the International Space station.⁶⁷⁵ International agreement to organize or govern ORPSAO have not been developed, though some tenants of existing treaties and guidelines could be applicable in a limited sense. There are some standards developed by standard setting bodies, like the ISO, that could be applicable to ORPSAO as well, but they are not unique to ORPSAO nor is there consensus on how such standards apply to ORPSAO.⁶⁷⁶

Concerning the development of standards and best practices, industry has made notable progress. One of the most prominent industry efforts is the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS). Created in 2018 through industry and US government funding, CONFERS is an industry-led initiative “that aims to leverage best practices from government and industry to research, develop, and publish non-binding, consensus-derived

⁶⁷¹ Benjamin A. Corbin, Amana Abdurrezak, Luke P. Newell, Gordon M. Roesler, Bhavya Lal, “Global Trends in On Orbit Servicing, Assembly, and Manufacturing (OSAM),” IV.

⁶⁷² Ibid.

⁶⁷³ Ibid.

⁶⁷⁴ In-Space Servicing, Assembly, and Manufacturing Interagency Working Group, In-Space Servicing, Assembly, and Manufacturing National Strategy, National Science & Technology Council, Office of the President of the United States, April 2022.

⁶⁷⁵ Jessica, “ESA Published Guidelines for Safe Close-Proximity Operations,” European Space Agency, November 2021, accessed January 2022; and, Rebecca Reesman and Andrew Rogers, “Getting in Your Space: Learning from Past Rendezvous and Proximity Operations,” Center For Space Policy and Strategy, Aerospace Corporation, May 2018, 7, accessed January 2022.

⁶⁷⁶ David A. Barnhart, Rahul Rughani, Jeremy J. Allam, Brian C. Weeden, Frederick A. Slane, and Ian Christensen, “Using Historical Practices to Develop Safety Standards for Cooperative On-Orbit Rendezvous and Proximity Operations,” 85-86.

technical and operations standards for on orbit servicing (OOS) and remote proximity operations (RPO) (OOS and RPO represent same activities as ORPSAO except assembly).⁶⁷⁷ CONFERS is composed of an executive committee that approves new members, removes members, forms and manages consortium committees, and is responsible for dispute resolution.⁶⁷⁸

CONFERS membership is open to industry, academia, government, and other organisations “having direct and material interest in participating in the standards development process.”⁶⁷⁹ Membership is organized by tier, with the top tier requiring contracts to provide products or services related to OOS/RPO. The next tier must have relevant technical, financial, or policy experience.⁶⁸⁰ The final two tiers are observer for non-government entities and government agencies involved in relevant activities.⁶⁸¹ Annual dues and benefits are influenced by the member tier.⁶⁸² According to the CONFERS website as of June 2022, CONFERS has 15 sustaining members (tier 1), 22 Contributing members (tier 2), 13 Observer members, and 1 Government Observer.

CONFERS has produced four guiding documents for servicing and proximity operations. The first is Guiding Principles for Commercial Rendezvous and Proximity Operations and On-Orbit Servicing.⁶⁸³ The principles are intended to “help establish responsible norms of behaviour for RPO and OOS.”⁶⁸⁴ They include consensual operation, compliance with relevant laws and regulations, responsible operations, and transparent operations.⁶⁸⁵

⁶⁷⁷ “About,” The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), accessed January 2022, <https://www.satelliteconfers.org/about-us/>.

⁶⁷⁸ “Executive Committee,” The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), accessed January 2022, <https://www.satelliteconfers.org/executive-committee/>.

⁶⁷⁹ “Articles of Collaboration,” The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), October 2021, 4, accessed January 2022, <https://www.satelliteconfers.org/executive-committee/>.

⁶⁸⁰ Ibid., 5.

⁶⁸¹ Ibid.

⁶⁸² Ibid. 4.

⁶⁸³ “Guiding Principles for Commercial Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS),” The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), October 2021, accessed January 2022, https://www.satelliteconfers.org/wp-content/uploads/2021/11/CONFERS-Guiding-Principles_Revised-Oct-21.pdf.

⁶⁸⁴ Ibid.

⁶⁸⁵ Ibid.

The second document is CONFERS' Recommended Design and Operational Practices scheme produced from lessons learned from prior servicing and RPO operations.⁶⁸⁶ The recommended design and operational practices are intended to support the guiding principles and are viewed as “an effective way to enhance operational safety and mission success.”⁶⁸⁷ The guiding practices include four major categories of recommended practices with several sub and sub-sub recommendations. They are:⁶⁸⁸

1. Design servicer vehicles and operations for mission success by taking into account a layered risk mitigation and operational safety approach touching on hardware, software, ground segment, mission operations, and security.
2. Design future satellites, both servicer and potential client vehicles, to facilitate safe and effective servicing.
3. Share information, to the extent permissible, on resolution of spacecraft anomalies.
4. Promote the long-term sustainability of space.

The third document is CONFERS On-Orbit Servicing Mission Phases. The document describes the phases of OOS missions.⁶⁸⁹ The document details 12 phases including, pre-mission, launch and prepare servicer spacecraft, client operations pre-mission, rendezvous, proximity operations, contact approach and capture, service, release and departure, return to quiescent operations, and disposal, each with several subsequent steps.⁶⁹⁰

A fourth guiding document, Satellite Servicing Safety Framework – Technical and Operational Guidance Document, serves “as a point of departure for guidance for the conduct of

⁶⁸⁶ Ibid.

⁶⁸⁷ “CONFERS Recommended Design and Operational Practices,” The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), October 2021, 1, accessed January 2022, https://www.satelliteconfers.org/wp-content/uploads/2021/11/CONFERS_Operating_Practices_Revised-Oct-21.pdf.

⁶⁸⁸ Ibid.

⁶⁸⁹ “CONFERS On-Orbit Servicing (OOS) Mission Phases,” The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), October 2019, 1, accessed January 2022, https://www.satelliteconfers.org/wp-content/uploads/2019/10/OOS_Mission_Phases.pdf.

⁶⁹⁰ Ibid., 2-7.

commercial on-orbit RPO, capture, and robotic servicing operations.”⁶⁹¹ It introduces a common lexicon and structure and provides initial conditions to develop and evolve best practices, guidelines, and standards.⁶⁹² The document provides detailed guidance on numerous features of satellite servicing, from satellite design and mission assurance and satellite servicing operations to servicing mission safety.⁶⁹³

CONFERS has also produced several research studies, presentations, and briefings all of which are publicly available. CONFERS’ work has also informed an ISO standard on principles and practices for RPO/OOS service providers to ensure safe operations and a healthy RPO/OOS industry.⁶⁹⁴ The standard is intended to be the “highest level standard” and is therefore intentionally broad in scope and expected to precede more detailed standards.⁶⁹⁵

A team at the University of Southern California (USC) broke down CONFERS On-Orbit Servicing Mission Phases to quantify and compare each step based on mission. The USC team detailed functions and attributes for each of the 12 CONFERS mission phases, where functions are required activities for a specific mission phase and attributes are quantifiable metrics or characteristics used to determine when a function is complete.⁶⁹⁶ Whereas CONFERS outlined the mission phases at a high level, USC’s work provided quantifiable metrics for assessing each phase.

Informed by CONFERS Safety Framework, Sandia National Laboratories created a framework for RPO/OOS. Sandia’s framework is based on the Always/Never Surety framework

⁶⁹¹ “CONFERS Satellite Servicing Safety Framework Technical and Operational Guidance Document, Draft,” The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), April 2018, 4, accessed January 2022, <https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.satelliteconfers.org%2Fwp-content%2Fuploads%2F2018%2F07%2F2018-04-05CONFERSSatelliteServicingSafetyFramework.docx&wdOrigin=BROWSELINK>.

⁶⁹² Ibid.

⁶⁹³ Ibid., 9-26.

⁶⁹⁴ “ISO/DIS 24330(en) Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic principles and practices,” International Standards Organization, updated 2021, accessed January 2021, <https://www.iso.org/obp/ui/#iso:std:iso:24330:dis:ed-1:v1:en>.

⁶⁹⁵ Ibid.

⁶⁹⁶ David A. Barnhart, Rahul Rughani, Jeremy J. Allam, Brian C. Weeden, Frederick A. Slane, and Ian Christensen, “Using Historical Practices to Develop Safety Standards for Cooperative On-Orbit Rendezvous and Proximity Operations,” 91-92.

used for safety, security, and control of nuclear weapons. As originally designed, the always/never framework outlines plans so that nuclear weapons are *always* available but *never* unsafe.⁶⁹⁷ Applied to RPO/OOS, the framework identifies operational environments (normal, abnormal, hostile, and tactical) and subsequent reliability requirements and safety assessments. The operating environment influences the reliability and safety requirements. For example, in a normal environment the reliability requirement is to “remain reliable” while the safety requirement is to “remain safe”. Conversely, in an abnormal environment the reliability requirement is to “treat as unreliable” and the safety requirement is to “remain safety”.⁶⁹⁸ Sandia’s framework is applied to each mission phase for both client and servicer satellites or spacecraft to provide a set of expectations and common safety requirements and language.⁶⁹⁹

The work of CONFERS, USC, and Sandia National Laboratories offer some utility. The frameworks and guiding documents could help coordinate and provide transparency for ORPSAO activities. Though as industry led initiatives it will likely take government adoption and enforcement before they offer full value.

To date, there is a clear need for international coordination of ORPSAO, but the industry and limited government efforts and policies fall short. The topic has not been seriously considered at COPUOS nor has the forum developed any influential measures on the topic. While there is still time given ORPSAO developments are still nascent, more is needed to organize the international community around this topic and develop the necessary governance. The consequences of not doing so could exacerbate existing space sustainability and development issues.

Conclusion

ORPSAO activities are on the horizon. Commercial actors and governments are investing in ORPSAO activities and the benefits of routine ORPSAO are clear. Yet, while ORPSAO

⁶⁹⁷ Celeste A. Drewien, Roger C. Byrd, Scott E. Slezak, and Mark R. Ackermann, “The Always/Never Safety Framework for Satellite Rendezvous and Proximity Operations and On-Orbit Servicing,” Sandia National Laboratories, April 2020, 13, accessed January 2022.

⁶⁹⁸ Ibid., 15.

⁶⁹⁹ Ibid., 31.

activities seem to be fast approaching, governance does not. The risks posed to the space environment and further space development from uncoordinated ORPSAO are easy to identify.

Industry led standards initiatives, like CONFERS, are promising steps but government will ultimately need to adopt governance tools and then enforce them. One gap within the frameworks discussed above is the lack of detail on assembly. Certain features of existing guidance will apply, but other features of assembly are left undiscussed. For example, the frameworks often discuss OOS/RPO based on two spacecraft, a client and a servicer. But how might three or four servicing spacecraft operate in close proximity during assembly? Moreover, the products produced by industry and government to date are simply suggestions at this point. While well researched and no doubt useful, until they become widely adopted and supported by governments, they offer little more than passive guidance. Herein is the need for new ORPSAO governance.

Formal adoption by governments and international space governance bodies of standards and best practices for ORPSAO is necessary to ensure those activities contribute to the development and sustainability of space. Once adopted new governance measures must be enforced. The novel nature of ORPSAO outside of limited government activities also suggests rules and governance will need to be agile and evolve with the state of ORPSAO activities. New governance will also need to balance necessary space domain protections, like debris mitigation, without imposing regulatory requirements that stunt ORPSAO innovations. Exactly how to strike such a balance is challenging to predict given much of ORPSAO is just beginning to emerge for commercial and other use cases. It seems unlikely that a balance can be struck without close industry and government cooperation.

The necessity and challenge of governing emerging activities is not unique to space nor a single point in history. Governing new activities is quite normal and occurs routinely. For this reason, looking to the maritime, air, and internet domains for useful lessons learned can be informative for governing ORPSAO.

Maritime Case Study

Autonomy is a driving factor in innovation across industries. The utility of smart technologies enabled by artificial intelligence (AI) that remove the need for humans partially or entirely holds the potential to reduce costs, increase safety, and change business models among many other benefits. There are also risks. Malfunctions in systems, whether cars, planes, or factory equipment, can come with serious financial and safety consequences, and culturally it can be difficult to envision removing the humans who have always controlled such systems. Nevertheless, autonomy is being advanced and expected to augment and replace humans across industries, including shipping.⁷⁰⁰

Governments were some of the first to explore autonomous ships. In 2000, the US military released a Master Plan disclosing its investment and interest in unmanned underwater vehicles.⁷⁰¹ In 2012, the EU funded the Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) program to “develop and verify a concept for an autonomous ship.”⁷⁰² The interest is steadily advancing as is the technology. Rolls-Royce and Finnish state-owned ferry operator Finferries successfully navigated the Ferry Falco under fully autonomous control in 2018,⁷⁰³ and Rolls-Royce hopes to have a remote controlled unmanned coastal vessel by 2025, a remotely operated unmanned ocean-going ship by 2030, and an autonomous unmanned ocean-going ship by 2035.⁷⁰⁴ Though autonomous shipping is advancing it is still nascent with technology demonstrations or limited applications making up the most recent activities. It is also expected that the technology will progress in stages where crew are slowly replaced by autonomy and ships are approved to sail farther from shore.

⁷⁰⁰ “The Future of Jobs Report 2020,” World Economic Forum, October 2022, 29-34, accessed January 2022, https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf.

⁷⁰¹ Ibid.

⁷⁰² Maritime Unmanned Navigation through Intelligence in Networks, “Final Report Summary – MUNIN,” European Commission, last updated April 2016, accessed January 2022, <https://cordis.europa.eu/project/id/314286/reporting>.

⁷⁰³ “Rolls-Royce and Finferries demonstrate world’s first Fully Autonomous Ferry,” December 3, 2018, accessed January 2022, <https://www.rolls-royce.com/media/press-releases/2018/03-12-2018-rr-and-finferries-demonstrate-worlds-first-fully-autonomous-ferry.aspx>.

⁷⁰⁴ Marine, “Autonomous ships The next step,” Rolls-Royce, 2016, 7, accessed January 2022, <https://www.rolls-royce.com/~media/Files/R/Rolls-Royce/documents/%20customers/marine/ship-intel/rr-ship-intel-aawa-8pg.pdf>.

There are numerous reasons governments and industry are investing in autonomous shipping. Current ship designs must account for the crew and their needs, from sleep quarters, to eating facilities and water, all of which are important design considerations. Without a crew a ship's design can be streamlined to carry more cargo while lowering building costs.⁷⁰⁵ Another benefit is reduced fuel consumption from reduction or elimination of life support systems and more efficient routes and schedules, which would benefit the environment.⁷⁰⁶ Safety could also be improved. Human errors contribute to 60-90% of maritime accidents according to recent studies.⁷⁰⁷ The expected advantages of automating shipping are an important driver for advancing the technology.

As with any innovation, there are also risks and important governance considerations. How does liability change if there are no crew on board? Can autonomous ships be pirated through cyber-attacks? How should training and education change for remote operation? How will routes change if crew do not need to be considered in planning? Many other questions exist and as the technology advances more questions will be uncovered. Answering new questions and governing the activity must provide necessary safeguards but also help advance the technology so that new governance does not undermine the benefits autonomous shipping is expected to bring.

Developing governance that balances the need for safe and environmentally sustainable practices without stunting important innovation is a task for governments, industry, and the IMO together. Unlike the other activities discussed in this research, governing autonomous shipping has little direct precedent for states, industry, or the IMO to draw from. For example, there had

⁷⁰⁵ Jiri de Vos, Robert G. Hekkenberg, Osiris A. Valdez Banda, "The Impact of Autonomous Ships on Safety at Sea – A Statical Analysis," *Reliability Engineering and System Safety* 210 (2021), 1.

⁷⁰⁶ One study found automation could save between 6-15% of fuel consumption. See: Lutz Kretschmann, Hans-Christoph Burmeister, and Carlos Jahn, "Analyzing the economic benefit of unmanned autonomous ships: An exploratory cost-comparison between an autonomous and a conventional bulk carrier," *Research in Transportation Business & Management* 25 (2017), 75.

⁷⁰⁷ For more on improved safety see: Jiri de Vos, Robert G. Hekkenberg, Osiris A. Valdez Banda, "The Impact of Autonomous Ships on Safety at Sea – A Statical Analysis," 1; Beatriz Navas de Maya, Rafet Emek Kurt, and Osman Turan, "Application of fuzzy cognitive maps to investigate the contributors of maritime collision accidents," (presented at Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria) accessed January 2022, 1; and, for more on the risks of autonomy in other industries see: Mikael Wahlstrom, Jaakko Hakulinen, Hannu Karvonen, and Iiro Lindborg, "Human factors challenges in unmanned ship operations – insights from other domains," *Procedia Manufacturing* 3 (2015).

been hundreds of years of shipping traffic rules before the IMO began to shape modern shipping traffic management governance, but the same does not exist for autonomous ships. In addition to the lack of precedent, the very technology used to make ships autonomous is novel as well. AI, secure networks, advanced user displays, and remote-control systems are important components of autonomous shipping that sit at the cutting edge of technology development. Their novel nature comes with many unknowns related to safety, security, and sustainability. To be sure, governing emerging activities requires wadding into uncharted territory.

Governments, industry, and the IMO are all active in developing standards and other governance measures for autonomous shipping. While each is important, the need for international coordination of autonomous shipping and the IMO's central role in shipping governance warrants the focus in this analysis.

IMO Activities for Autonomous shipping

The IMO decided to take up the topic of autonomous shipping during MSC 98 in June 2017 after recognizing there was an increase in activity in commercial applications of autonomous ships.⁷⁰⁸ Until the topic was introduced, the most relevant experience the IMO had with autonomous shipping were automation tools, like autopilot and dynamic positioning systems, which were governed through provisions in SOLAS and non-binding guidelines, respectively.⁷⁰⁹ Though autopilot and dynamic position systems do involve some level of automation they require onboard oversight by crew, and therefore, differ considerably from autonomous ships.

In 2017 at MSC 98, Denmark, Estonia, Finland, Japan, the Netherlands, Norway, the Republic of Korea, the UK, and the US proposed (via MSC 98/20/2) that the IMO undertake a scoping exercise to “ensure that maritime autonomous surface ships (MASS) designers, builders,

⁷⁰⁸ Maritime Safety Committee, “98th Session, 17-16 June 2017, meeting summary” International Maritime Organization, accessed January 2022, <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MSC-98th-session.aspx>.

⁷⁰⁹ For SOLAS regulations of autopilot see: SOLAS Chapter V, Safety of Navigation, January 7, 2002, accessed January 2022, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/343175/solas_v_o_n_safety_of_navigation.pdf; and for guidelines on dynamic positioning, see: Guidelines for Vessels and Units Dynamic Positioning (DP) System, MSC.1/Circ. 1580, International Maritime Organization, June 16, 2017, accessed January 2022, <https://www.register-iri.com/wp-content/uploads/MSC.1-Circ.1580.pdf>.

owners, and operators have access to a clear and consistent regulatory framework in order to be able to demonstrate compliance with IMO instruments.”⁷¹⁰ The scoping exercise sought to identify IMO regulations that preclude autonomous/unmanned operations, IMO regulations that would not apply to autonomous/unmanned operations because the regulations are specific to onboard crew, and IMO regulations which may need to be amended to ensure the “construction and operation of MASS are carried out safely, securely, and in an environmentally sound manner.”⁷¹¹ The exercise also sought to explore different levels of autonomy and related technologies and legal aspects.⁷¹² During MSC 98 it was agreed that the exercise would be included in the 2018-2019 biennial agenda with the goal of completing it in 2020.

While developing the scoping exercise, the MSC during its 101st session in June 2019, approved interim guidelines for MASS trials.⁷¹³ The guidelines were intended to inform costal states, flag states, port states, and relevant stakeholders (e.g., shipowners) as they evaluated MASS systems.⁷¹⁴ According to the interim guidelines, trials were to be conducted safely, securely, and with due regard for the environment and existing IMO agreements.⁷¹⁵ The interim guidelines provided a very high level set of objectives covering risk management, compliance with mandatory instruments, manning and qualifications of personnel, human elements, infrastructure for safe conduct, trial awareness, communications and data exchange, reporting requirement and information sharing, scope and objective for each trial, and cyber risk management.⁷¹⁶

A few years later, during MSC 103 in May 2021, the scoping exercise was completed.⁷¹⁷ The exercise assessed several treaties and related codes, including SOLAS, COLREG, CSC, Load Lines Convention and 1988 Protocol, STCW Convention, STCW-F Convention, SAR

⁷¹⁰ Maritime Safety Committee, “Maritime Autonomous Surface Ships Proposal for a Regulatory Scoping Exercise, MSC 98/20/2,” International Maritime Organization, February 2017, accessed February 2022, 2.

⁷¹¹ Ibid.

⁷¹² Maritime Safety Committee, “98th Session, 17-16 June 2017, meeting summary”.

⁷¹³ Maritime Safety Committee, “Interim Guidelines for MASS Trials, MSC.1/Circ. 1604,” International Maritime Organization, June 2019, Accessed February 2022.

⁷¹⁴ Ibid., 1.

⁷¹⁵ Ibid.

⁷¹⁶ Ibid., 2-3.

⁷¹⁷ Consideration of the effort was delayed by a session due to COVID-19.

Convention, Tonnage 1969.⁷¹⁸ The exercise identified eleven issues and gaps related to MASS terminology and definitions, functional and operations requirements of remote-controlled ships and operators, safety provisions related to manual operations and alarms and actions by personnel, search and rescue, watchkeeping, cybersecurity and connectivity, and information required on board for safe operations.⁷¹⁹

Several recommendations from the MSC's scoping exercise were offered. A new MASS code was seen as the "most appropriate way" to address MASS operations compared to amending each instrument separately, which could lead to "inconsistencies, confusion and raise potential barriers for the application of existing regulations to conventional ships."⁷²⁰ Recommendations also covered guidance in the event a holistic approach (e.g., MASS Code) was not preferred.⁷²¹

During MSC 105 in January 2022, the committee began working on draft MASS codes to ensure MASS regulations provide the same level of safety as SOLAS.⁷²² At MSC 105 in April of 2022, the MSC began work on a goal-based instrument to regulate MASS by approving a road map and work plan. The goal-based instrument is planned to take the form of a non-mandatory Code adopted in 2024 followed by a mandatory Code adopted in 2028.⁷²³ The Code will address the gaps identified during the scoping exercise and be limited to cargo ships with passenger ships to be considered in the future.⁷²⁴

At LEG 105 (Legal Committee session) in April 2018, the LEG also agreed to include a similar scoping exercise on the 2018-2019 biennial agenda to be completed by 2022. A year later at LEG 106, the LEG approved the method of work which borrowed the methodology adopted

⁷¹⁸ Maritime Safety Committee, "Outcome of the Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships (MASS)," International Maritime Organization, MSC.1Circ. 1638," June 2021, Accessed February 2022, 7.

⁷¹⁹ Ibid.

⁷²⁰ Ibid., 9.

⁷²¹ Ibid., 9.

⁷²² Maritime Safety Committee, "MSC 105," International Maritime Organization, 20-29 April 2022, accessed February 2022, <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MSC-105th-session.aspx>.

⁷²³ Ibid.

⁷²⁴ Ibid.

for the MSC's scoping exercise.⁷²⁵ The LEG scoping exercise reviewed 23 instruments and concluded that the existing regulatory framework would accommodate MASS without major adjustments.⁷²⁶ Though a new instrument was not found to be necessary, the exercise did expose some potential gaps related to the role and responsibility of the master and remote operator, questions of liability, definitions of MASS, and certificates.⁷²⁷ It was recommended that the LEG invite proposals for new outputs on MASS for the issues identified.⁷²⁸

During the same period, the FAL-C also undertook a scoping exercise following the same methodology as the MSC and LEG. The LEG's scoping exercise was approved during FAL-C 46 in May of 2022, and found similar gaps in terminology, the role and responsibility of the master and crew and remote operators.⁷²⁹ It also found that obligations on the FAL convention to stowaways, refugees, and person rescued at sea would be challenged given MASS ships may not be designed to include systems required for human crew, like accommodations.⁷³⁰ During the session the FAL-C included an output on "measures to address MASS in the instruments under the purview of the FAL" in its 2022-2023 biennial agenda.⁷³¹

The scoping exercises highlighted gaps in maritime governance exposed by novel technologies and applications associated with autonomous shipping. Understanding such gaps is a useful first step to ensuring autonomous shipping contributes to the sustainable development of the maritime domain. Useful as the exercise maybe it does have limitations. According to one study, the scoping exercises are limited in utility because the technology and uses cases for autonomous shipping is still very nascent.⁷³² In other words, the IMO does not know what it does

⁷²⁵ Legal Committee, "Outcome of the Regulatory Scoping Exercise and Gap Analysis of Conventions emanating from the legal committee with Respect to Maritime Autonomous Surface Ships (MASS), LEG. 1/Circ.11," International Maritime Organization, December 2021, 2, accessed February 2022.

⁷²⁶ *Ibid.*, 5.

⁷²⁷ *Ibid.*, 6.

⁷²⁸ *Ibid.*, 10.

⁷²⁹ Facilitation Committee, "FAL 46," International Maritime Organization, 9-13 May, accessed February 2022, <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/FAL-46th-Session.aspx>.

⁷³⁰ *Ibid.*

⁷³¹ *Ibid.*

⁷³² Henrik Ringbom, "Regulating Autonomous Ships—Concepts, Challenges and Precedents," *Ocean Development & International Law* 50 no. 2-3 (2019), 162, <https://doi.org/10.1080/00908320.2019.1582593>.

not know about autonomous shipping, therefore the scoping exercises could only expose gaps based on current knowledge or assumptions about MASS technology and practices.

Resulting from the scoping exercises the MSC, LEG, and FAL created a Joint Working Group on MASS to “provide advice on and consider ways to address common issues identified by the three committees.”⁷³³ Pending endorsement from the IMO Council, the group has planned to meet in September of 2022.

Conclusion

A key challenge in governing new activities is the need to balance the advancement of new innovations with the preservation of the environment and human lives. The IMO has been proactive in addressing autonomous shipping to do just that for MASS. Importantly, as is evident from the IMO’s cadence of work related to MASS, the balancing of priorities to advance novel technologies and maritime applications requires routine calibration and adjustment. Much of this work reflects the buy in of members states, like those who initiated the work and scoping exercise. The cadence of work also shows member buy in. Between 2015 and 2022 the IMO conducted three scoping exercises, produced MASS guidelines, began work on goal-based measures, evaluated proposed MASS codes, and formed a new working group to cohere activities. The cadence of work would be hard to produce without some eagerness from IMO members.

Despite some limitations, the scoping exercise is an example of agile, proactive governance. In chapter five, a key governance challenge identified was the often-reactive nature of governance, and often after a major disaster.⁷³⁴ The IMO taking several proactive steps to ensure autonomous shipping is advanced without unacceptable risk to life or the marine environment is progress, even with some limitations in the work. Moreover, the rate at which the IMO routinely updates or creates new agreements to address maritime safety and environmental concerns suggests that despite some limitations with current IMO MASS governance the forum has the ability to modify measures as autonomous shipping is advanced.

⁷³³ Facilitation Committee, “FAL 46”.

⁷³⁴ See Chapter 5, Small Satellites for Sustainable Development, 112-114.

Regarding the effectiveness of the IMO's approach, the use of guidelines, goal-based measures and a code enable the IMO to quickly begin shaping state behaviour around MASS before MASS becomes routine. Guidelines to help stakeholders evaluate MASS systems provide the means to coordinate development of MASS. Meanwhile, a goal-based measure outlines the desired objectives but is not prescriptive in how those objectives are met. For example, in the IMO's interim guidance for MASS trials one objective calls for redundant communications but does not prescribe how that objective should be achieved.⁷³⁵ The value of goal-based standards is that they introduce flexibility for stakeholders as they pursue innovation activities without sacrificing the necessary safeguards. Finally, the use of a code helps the IMO avoid additional work necessary to amend all relevant treaties. As is often the case in international governance, the time and resources required to develop a new governance measure can be burdensome and hinder effectiveness (e.g., by allowing development of new technology to progress without IMO guidance). By reducing the need for several new agreements with a Code, the IMO can more quickly produce necessary governance for a rapidly emerging activity. In all, each example reflects attempts to develop effective tools in a proactive manner.

The IMO has leverage proactive scoping exercises, goal-based measures, and Codes to keep pace with the rapid evolution of autonomous shipping. There are weaknesses in the approach as discussed, however governance is never perfect and the ability to evolve with activities is arguably more important than trying to produce perfect governance measures, if such a measure is even possible. The IMO's approach appears to balance the need for innovation with the need to safeguard the marine environment thus far. Based on the scope and pace of work, the shipping community appears better for the work the IMO is doing to govern autonomous shipping.

Civil Aviation Case Study

Technology innovation is impacting aviation in very similar ways to that of shipping and space. One such area is unmanned aircraft systems (UAS), like remotely piloted drones or fully autonomous systems, which serve everything from commercial and recreational uses to military capabilities and eventually human transport. Like autonomous shipping and new space activities,

⁷³⁵ Maritime Safety Committee, "Interim Guidelines for MASS Trials, MSC.1/Circ. 1604," 4.

the challenge imposed by UAS is the need to balance how these new systems are regulated for safety and environmental protection without stunting the progress these innovations promise.

One aspect of this challenge that is different from shipping or new space activities, is how quickly recreational activities are coming online and the need to organize them against existing civil aviation governance. ICAO found that UAS operations are quickly expected to surpass manned aircraft operations, which is exposing new regulatory needs.⁷³⁶ For example, how does air traffic control work when the skies are full of off the shelf drones used by average people for recreational or other purposes, like farming? What training does a person need to operate UAS? How can federal regulators keep recreational users accountable? Given many unmanned arial systems have cameras, is personal privacy an issue ICAO or federal aviation regulators are responsible for addressing?

Additionally, aviation governance bodies must also deal with new forms of more traditional issues related to unmanned systems.⁷³⁷ For example, what are the rules for unmanned systems delivering packages across borders? What about the rules for carrying hazardous materials, like medical supplies? What does an international air traffic management system look like with UAS? What about cyber security and terrorism? These questions represent just a fraction of the changes posed by UAS.

The rate at which unmanned aircraft technology and use cases are advancing is much faster than rules can be developed.⁷³⁸ Whereas the development of autonomous shipping involves longer research and development periods as well as higher financial costs—which can afford governments and the IMO more time to develop new governance measures—UAS are cheaper to produce, purchase, and use, speeding up the rate at which innovations occur. The speed at which unmanned aircraft systems are being advanced suggest that however governance bodies, whether

⁷³⁶ “Unnamed Aircraft Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization, Edition 3,” International Civil Aviation Organization, accessed February 2022, <https://www.icao.int/safety/UA/Documents/UTM-Framework.en.alltext.pdf>, 5.

⁷³⁷ <https://www.icao.int/safety/UA/UASToolkit/Pages/Narrative-Regulation.aspx>

⁷³⁸ For example, ICAO has found the speed of UAS evolution challenges everything from standards development to methods of certification. See: “Unnamed Aircraft Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization, Edition 3,” 5.

ICAO or a federal agency, choose to balance regulation with the need to encourage innovation, it must be done more quickly than has traditionally been required.

National regulations of UAS are an important part of the broader UAS governance conversation. And national regulators all over the world have been developing domestic regulations for several years. However, given that the focus of this chapter is the international governance of emerging technologies, ICAO will be the focus of this analysis. Though, the discussion will touch on domestic regulations.

ICAO's Approach to UAS

Unmanned aircraft are not entirely new to ICAO. Article 8 of the Chicago convention addresses pilotless aircraft, which includes fully automatic and autonomous aircraft, free balloons, and drones.⁷³⁹ The inclusion of unmanned aircraft in Article 8 is useful, but alone the reference is not enough to sufficiently govern rapidly expanding UAS operations. In April 2005, during the first meeting of the 165th session, the ANC requested that the Secretary General of ICAO consult with states and international organisations to understand the unmanned aerial vehicles (UAV) activities in civil airspace.⁷⁴⁰ A year later ICAO held its first exploratory meeting on UAVs to determine the organisation's role in UAV regulation. The session determined that UAV regulations were increasingly needed, but ICAO was not the most suited organisations to lead that effort.⁷⁴¹ Instead, ICAO would act as a focal point to harmonize terms, strategies, and principles with respect to the regulatory framework.⁷⁴²

A second meeting was held in January 2007 and found technical specifications for UAV operations were being sufficiently advanced by aviation standards organisations in the US and Europe, though SARPs would eventually be necessary.⁷⁴³ The meeting also determined that there

⁷³⁹ Elie El Khoury, "Remotely Piloted Aircraft Systems (RPAS)," International Civil Aviation Organization, 2016, accessed February 2022, <https://www.icao.int/MID/Documents/2016/RASG-MID5/PPT3%20-%20RPAS%20Elie.pdf>.

⁷⁴⁰ Secretary General, "Unmanned Aircraft Systems (UAS), Circ 328," International Civil Aviation Organization, 2011, accessed February 2022, 1.

⁷⁴¹ Ibid.

⁷⁴² Ibid.

⁷⁴³ Ibid.

was a unique opportunity to seek harmonization and uniformity of regulations given nascent stage of UAV development and that ICAO was suited to do that work.⁷⁴⁴ Therefore, ICAO would develop a strategic guidance document to guide the regulatory evolution.⁷⁴⁵ The guidance document would be non-binding, but represent the basis for regulatory progress by states and organisations and facilitate consensus in the eventual development of SARPs.⁷⁴⁶ At the same session it was also agreed that ICAO would discuss the topic using “unmanned aircraft system” to align with other international aviation organisations.⁷⁴⁷

In support of the agreed course of action, the ANC established the Unmanned Aircraft Systems Study Group (UASSG) in April of 2007 to facilitate the coordination and development of ICAO SARPs, produce guidance materials for UAS, and support the integration of UAS into non-segregated airspace.⁷⁴⁸ The UASSG became the focal point for ICAO’s UAS work, though it was agreed that the UASSG would eventually be superseded by the creation of a Remotely Piloted Aircraft Systems Panel (RPASP).⁷⁴⁹

The UASSG’s first output was UAS Circular 328, which was published in March 2011, and highlighted the issues and gaps between necessary UAS regulation and what existed in current Annexes. The work, much like the IMO’s scoping exercise, was intended to highlight where new regulations were required to ensure that UAS operations were safe, routine, and harmonized with manned aviation.⁷⁵⁰ Circ 328 also detailed global UAS developments, legal matters, specific UAS operations, aircraft systems, personnel licensing, and examples of regional and state UAS initiatives.⁷⁵¹ In all, Circ 328 covers some 40 UAS topics.⁷⁵²

⁷⁴⁴ RPAS manual, 2015, 1-2

⁷⁴⁵ Secretary General, “Unmanned Aircraft Systems (UAS), Circ 328,” 1.

⁷⁴⁶ Ibid.

⁷⁴⁷ Ibid.

⁷⁴⁸ Secretary General, “Manual on Remotely Piloted Aircraft Systems (RPAS), 1st ed., Doc10019,” International Civil Aviation Organization, 2015, accessed February 2022, 1-3.

⁷⁴⁹ Elie El Khoury, “Remotely Piloted Aircraft Systems (RPAS)”.

⁷⁵⁰ Secretary General, “Unmanned Aircraft Systems (UAS), Circ 328,” III.

⁷⁵¹ Ibid.

⁷⁵² Ibid.

In 2012, ICAO began producing SARPs for remotely piloted aircraft systems (RPAS). The shift in terminology from UAS to RPAS was due to the determination that RPAS, which were controlled remotely vs being full autonomous, were the only UAS that could be safely integrated into non-segregated airspace and at aerodromes alongside manned aviation.⁷⁵³ The first packages of RPAS SARPs were adopted for Annex 2, Rules of the Air, and Annex 7, Aircraft Nationality and Registration Marks.⁷⁵⁴

In May 2014, the ANC agreed it was time to establish the RPASP to progress the work started by the UASSG and develop SARPs, procedures, and guidance to facilitate the safe and secure integrations of remotely piloted aircraft into nonsegregated airspace and aerodromes.⁷⁵⁵ The panel, which is supported by ICAO's voluntary workforce, is composed of experts nominated by States and international organisations. RPASP works across ICAO to develop studies and provisions related to air traffic management, airworthiness, technical safety systems, human performance, licensing, RPAS operations, and telecommunications for C2 links and air traffic control.⁷⁵⁶ The scope of RPASP covers all 19 Annexes.⁷⁵⁷

The bulk of the SARPs and other guidance produced by RPASP comes in the form of the RPAS Manual. The first edition of the RPAS manual was produced from 2012-2015 through the input of numerous experts familiar with the various aspects of RPAS and related activities.⁷⁵⁸ The RPAS Manual is intended to be iterative with the next edition expected in 2022. Each evolution of the manual will contain updated SARPs and other RPAS guidance material. RPAS does not cover state aircraft, autonomous UAS, operations in which more than one remotely piloted aircraft is being managed by a remote pilot station at a time, and model aircraft.⁷⁵⁹ The current RPAS Manual covers some 15 subjects related to the RPASP focus areas listed above via as many chapters and provides related document templates.

⁷⁵³ Secretary General, "Manual on Remotely Piloted Aircraft Systems (RPAS), 1st ed., Doc10019," 1-3.

⁷⁵⁴ Ibid.

⁷⁵⁵ Safety, "Remotely Piloted Aircraft Systems Panel," International Civil Aviation Organization, accessed February 2022, [https://www.icao.int/safety/UA/Pages/Remotely-Piloted-Aircraft-Systems-Panel-\(RPASP\).aspx](https://www.icao.int/safety/UA/Pages/Remotely-Piloted-Aircraft-Systems-Panel-(RPASP).aspx).

⁷⁵⁶ Ibid.

⁷⁵⁷ Safety, "ICAO RPAS SARPS," International Civil Aviation Organization, November 2020, accessed February 2022, <https://www.icao.int/NACC/Documents/Meetings/2020/UAS/UASWeb-P05EN.pdf>, 12.

⁷⁵⁸ Secretary General, "Manual on Remotely Piloted Aircraft Systems (RPAS), 1st ed., Doc10019," V.

⁷⁵⁹ Ibid., 1-8.

RPASP also produced a RPAS Concept of Operations for international instrument flight rules (IFR) Operations, which acts as a general framework representing stakeholder perspectives, and “describes the operational environment of manned and unmanned aircraft...including the challenges...to provide a common view from which ICAO and States can prioritize and address needs associated with the introduction of remotely piloted aircraft into their respective airspace.”⁷⁶⁰ The Concept of Operations covers systems overview, airworthiness, RPAS operations, personnel licensing, and operating environments for certified RPAS operating internationally within controlled airspace.⁷⁶¹ The goal of the Concept of Operations is to facilitate the amendment of SARPs and PANs related to RPAS integration into international IFR operations.⁷⁶²

Whereas RPASP is composed of a voluntary workforce and focused on coordination and development of SARPs and other guidance materials for international UAS operations, ICAO saw a need for a technical body at the Secretariat level to develop guidance and other provisions to advise states on the regulation of UAS that remain outside the international IFR framework (e.g., national UAS regulations). In 2015, the Unmanned Aircraft Systems Advisory Group (UAS-AG) was established to do just that.⁷⁶³

The UAS-AG is responsible for developing ICAO’s Unmanned Traffic Management (UTM) framework to organize and coordinate the near-real-time and real-time management of unmanned aircraft operations.⁷⁶⁴ The framework offers a common foundation from which ICAO, through its members and UAS industry, can develop rules and regulations, facilitate consensus

⁷⁶⁰ “Remotely Piloted Aircraft System (RPAS) Concept of Operations (CONOPS) for International IFR Operation,” International Civil Aviation Organization, 1, accessed February 2022, <https://www.icao.int/safety/UA/Documents/ICAO%20RPAS%20CONOPS.pdf>.

⁷⁶¹ Ibid., 3.

⁷⁶² Ibid., 1.

⁷⁶³ “Unmanned Aircraft Systems Advisory Group (UAS-AG),” International Civil Aviation Organization, accessed February 2022, [https://www.icao.int/safety/UA/Pages/Unmanned-Aircraft-Systems-Advisory-Group-\(UAS-AG\).aspx](https://www.icao.int/safety/UA/Pages/Unmanned-Aircraft-Systems-Advisory-Group-(UAS-AG).aspx).

⁷⁶⁴ “Unmanned Aircraft Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization, Edition 3,” 5.

on UTM governance measures, and develop guidance material for a harmonized global UTM system.⁷⁶⁵

The UTM framework has gone through three iterations with a fourth edition being drafted at the time of writing. Each edition is complementary by addressing new areas relevant to UTM. For example, edition one covered registration, identification, tracking, communications systems, geofencing systems, and related architectures. Edition four will address UAS performance requirements in UTM environments, UTM system certification requirements, UTM in aerodrome environment and activities.⁷⁶⁶

The framework does not provide technical solutions or encourage specific UTM system designs, instead it provides common guiding principles and enabling actions states can take to harmonize their UTM approaches.⁷⁶⁷ As of Edition three, common principles included oversight, prioritization of aircraft (e.g., public safety operations), equitable access to airspace, pilot qualifications, state access to information on UAS pilots and related operations, safety culture, and reporting of accidents.⁷⁶⁸ UTM frameworks also provides insight and considerations for technical areas related to UTM, like communications systems or information exchange systems between UTM and ATM systems.

The UAS-AG also developed, at the request of member States, model UAS regulations. While national UAS regulations are being developed by some States, not all states have begun to regulate UAS operations. The model regulations are intended to guide states as they develop UAS regulations and consist of commonalities and best practices observed throughout the international community that are consistent with the ICAO aviation framework.⁷⁶⁹ Rather than being prescriptive or mandatory, the model regulations simply offer model language to states to

⁷⁶⁵ Ibid.

⁷⁶⁶ ICAO UAS Advisory Group, “ICAO UAS Related Activities,” International Civil Aviation Organization, September 2021, 5, <https://www.icao.int/NACC/Documents/Meetings/2021/UASRPAS/P05-UASRPASW2-Update-ICAO-UAS-Advisory-Group-Wuennenberg.pdf>.

⁷⁶⁷ “Unnamed Aircraft Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization, Edition 3,” 7.

⁷⁶⁸ Ibid., 8.

⁷⁶⁹ “Model UAS Regulations, Part 101 and 102,” International Civil Aviation Organization, June 23, 2020, 1, accessed March 2022.

enable the creation of national UAS regulations.⁷⁷⁰ The model regulations and related Advisory Circulars are intended to evolve with UAS practices to ensure regulations are harmonized.⁷⁷¹

Currently there are three model UAS regulations, Part 101, Part 102, and Part 149, and four Advisory Circulars, AC 101-1, AC 102-1, AC 102-37, and AC 922-001. Part 101 and Part 102 were released via a joint document in June 2020. The former addresses UAS general provisions and operations, while the latter addresses UAS pilot certification and requirements for UAS manufacturers.⁷⁷² Part 149 details the use of Approved Aviation Organizations to support civil aviation authorities in the regulations of UAS.⁷⁷³ Advisory Circulars provide additional insight into model regulations through guidance on standards, practices, and procedures from national civil aviation authorities.⁷⁷⁴ They are not mandatory nor do they constitute a regulation, they simply offer examples of methods used by states to comply with regulations and standards.⁷⁷⁵

ICAO has also produced guidance for UAS use in humanitarian aid and emergency response. The guidance document provides information on UAS operations related to aid and emergency response and document templates to expedite review by civil aviation authorities.⁷⁷⁶ The guidance covers operational overview (e.g., airspace rules and personnel training), transport of dangerous good, safety risk management, and appendices with supplemental information.⁷⁷⁷ The guidance was produced by the Task Force on UAS Humanitarian Aid and Development, which was established to support the Secretariat in the development of related UAS regulations.⁷⁷⁸

⁷⁷⁰ Ibid.

⁷⁷¹ Safety, "ICAO Model UAS Regulation," International Civil Aviation Organization, accessed February 2022, <https://www.icao.int/safety/UA/Pages/ICAO-Model-UAS-Regulations.aspx>.

⁷⁷² "Model UAS Regulations, Part 101 and 102" International Civil Aviation Organization.

⁷⁷³ "Model UAS Regulations, Part 149," International Civil Aviation Organization, June 23, 2020, 3, accessed March 2022.

⁷⁷⁴ "Advisory Circular (AC) 101-1," International Civil Aviation Organization, June 23, 2020, 2, accessed March 2022.

⁷⁷⁵ Ibid., 1-2.

⁷⁷⁶ "Unmanned Aircraft Systems (UAS) for Humanitarian Aid and Emergency Response Guidance," International Civil Aviation Organization, 4, accessed March 2022.

⁷⁷⁷ Ibid., 4-19.

⁷⁷⁸ Safety, "Task Force Unmanned Aircraft Systems for Humanitarian Aid and Development (TF-UHAD)," International Civil Aviation Organization, accessed February 2022, [https://www.icao.int/safety/UA/Pages/Task-Force-on--Unmanned-Aircraft-Systems-for-Humanitarian-Aid-and-Development-\(TF-UHAD\).aspx](https://www.icao.int/safety/UA/Pages/Task-Force-on--Unmanned-Aircraft-Systems-for-Humanitarian-Aid-and-Development-(TF-UHAD).aspx).

Finally, ICAO offers a UAS Toolkit. The Toolkit is designed to provide member states with additional resources to advance UAS operational guidance and safe national operations. The Tool Kit includes discussion of key considerations for States developing UAS regulations, training and educational aids, and an index of UAS regulations from around the world, among others.⁷⁷⁹ ICAO also provides online training for a fee that offer UAS fundamentals, UAS regulations, UAS system operations, and UAS safety management systems.⁷⁸⁰

Conclusion

The evolution of ICAO's work on UAS over 17 years speaks to member state buy in of the scope of work and products. ICAO has produced several measures related to international and national UAS regulations, SARPs, educational resources, and frameworks to empower states to adopt harmonized UAS regulations. ICAO has also established and formalized different groups to continue work around UAS. While a large portion of ICAO's work relates to helping states develop necessary regulations, ICAO's input will likely help create more uniform national regulations than if ICAO had not taken up the issue. Moreover, through its work around national regulations ICAO has laid the groundwork to encourage member buy in for future work because uniform national regulations can facilitate the development of international governance.

Many of ICAO's governance measures are expressly designed to evolve with the UAS industry and many have undergone several iterations in just a few years, representing agility and an eye toward the future. A key challenge identified in the beginning of this case study was the rapid pace at which the UAS industry was evolving and the challenge that posed for ICAO. While the UAS industry continues to evolve much more quickly than ICAO can create new governance measures, the approach ICAO has adopted empowers states to make informed decision more quickly through easy to adopt frameworks and other resources that proliferate best practices. While there is no finish line for UAS regulations, ICAO has developed several complementary tools to ensure the international community can advance UAS regulations together.

⁷⁷⁹ "UAS Toolkit Home," International Civil Aviation Organization, accessed February 2022, <https://www.icao.int/safety/UA/UASToolkit/Pages/default.aspx>.

⁷⁸⁰ Safety, "Unmanned Aviation," International Civil Aviation Organization, accessed February 2022, <https://www.icao.int/safety/UA/pages/default.aspx>.

As a governance organisation focused on standards and recommended practices, there are a few examples of effective outputs. The development of tools, educational resources, and model UAS regulations offer states ready-made resources to more quickly adopt governance measures for UAS. Guiding states through national regulations can facilitate the enforcement of international SARPs, which can improve the effectiveness of them. Moreover, ICAO has formalized working groups so it can continue its work around UAS governance as the industry evolves.

Finally, it is important to consider ICAO's impact governing UAS. While specific metrics are difficult to evaluate, the roles ICAO has played in governing UAS has not slowed the development of UAS but has offered means to coordinate and improve governance for the developing industry across a number of UAS topics, issues, and at national and international levels. The scope and volume of ICAO's UAS work suggests it is generally effective at shaping UAS behaviour despite some limitations, like when states are slow to leverage ICAO tools or fail to adhere to SARPs. As the UAS industry grows states will likely find ICAO's work more useful as they have in other areas of civil aviation.

Internet Case Study

Until recently the internet and web's growth consisted mostly of *users* and *content*. Improved access, social media, and e-commerce incentivized greater use by more people. Within the last few years, however, the IoT revolution has produced incredible growth in the number of things *connecting* to the internet. According to the IETF, "the Internet of Things refers to a system with devices that are often constrained in communication and computation capabilities, now becoming more commonly connected to the Internet or at least to an IP network, and to various services that are built on top of the capabilities these devices jointly provide."⁷⁸¹ IoT devices are typically referred to as "smart" versions of commonly used technology. They are "smart" because they are connected to the internet which allows users greater utility (e.g., control) from those devices. They include, smart thermostats, watches, cars, appliances, factory equipment and more. Importantly, IoT devices infuse physical properties into the internet by

⁷⁸¹ "Internet in Everything at the IETF," Internet Engineering Task Force, accessed March 2022, <https://www.ietf.org/topics/iot/>.

connecting everyday appliances or equipment. As one internet expert describes, in many ways the development of IoT has transformed the internet “from a communication network between people to a control network embedded directly into the physical world.”⁷⁸²

The growth in IoT devices is occurring at incredible pace. In fact, many more objects are now connected to the internet than people – some 28.5 billion networked devices.⁷⁸³ The rapid growth is due in part to the convince and efficiencies afforded by IoT devices across use cases. Commonly, a person is likely to carry a computer, smartphone, and a smart watch daily. That’s three internet devices used by a single person. Now consider that person may live in a home with others who also have those devices and where their kitchen appliances, thermostat, and TV are also connected. A family of four could have dozens of connected devices alone. Individual users are not the only ones that find IoT helpful. Factories, critical infrastructure, and many other industrial and government uses cases also leverage IoT devices.

The growth of IoT devices is generally positive, affording people and businesses efficiency, connection, and new ways of doing things.⁷⁸⁴ The challenge IoT poses for internet governance is balancing interoperability in a world where more and more things are connected and cyber security risks are on the rise. Indeed, interoperability—the ability of two systems to communicate and share services⁷⁸⁵—has been at the heart of internet governance since its creation, but IoT devices are challenging that principle.

As IoT devices become essential to business, governments, and individuals, the financial value of IoT grows. The increasing financial value incentivizes businesses to develop proprietary IoT systems and compete for market dominance. For example, a suite of smart home devices produced by one company is currently unlikely to work with another companies’ smart home

⁷⁸² Laura DeNardis, *The Internet in Everything* (New Haven, CT: Yale University Press, 2020), 3.

⁷⁸³ Cisco Public, “Cisco Visual Networking Index: Forecast and Trends, 2017-2022,” Cisco, 2019, accessed March 2022, <https://twiki.cern.ch/twiki/pub/HEPIX/TechwatchNetwork/HtwNetworkDocuments/white-paper-c11-741490.pdf>.

⁷⁸⁴ Laura DeNardis, *The Internet in Everything* (New Haven, CT: Yale University Press, 2020), 8.

⁷⁸⁵ Jussi Kiljander, Alfredo D’elia, Francesco Morandi, Pasi Hyttinen, et. al., “Semantic Interoperability Architecture for Pervasive Computing and Internet of Things,” *Institute of Electrical and Electronics Engineers* vol 2 (2014): 856-873, doi: 10.1109/ACCESS.2014.2347992.

devices. This encourages consumers to buy into a “family” of IoT products while imposing barriers, like cost, on switching product lines.⁷⁸⁶ It also incentivizes the creation of new standards setting organisations that attempt to meet the needs of an increasingly fragmented IoT technical community, and in doing so, contribute to the dilution of influence of the standard setting community through the paradox of plenty: where a multitude of like organisations compete for finite audience attention.

Finally, as more things become connected through the IoT revolution it raises new and more urgent cyber security concerns. Cyber security challenges are not new, but when considering that everything from critical infrastructure, healthcare devices, cars, the lock on a home’s front door, and countless other things are becoming connected to the internet, it exposes a daunting number of new devices that must be protected from malicious cyber activities. The risks are already present in even some of the most unassuming IoT devices. For example, the US Federal Drug Administration has issued multiple warnings about the cybersecurity risks in radio-frequency-enabled devices, like pacemakers and defibrillators, and other medical devices.⁷⁸⁷

For internet governance organisations, addressing interoperability and cyber security in a world quickly becoming more connected is an urgent challenge, yet the pace at which new IoT devices are brought online or evolved can make governing through standards, norms, and other measures an almost Sisyphean task. Still, the continued success of IoT devices depends on being secure and relatively interoperable. The key to IoT governance thus becomes keeping pace with technological change and balancing new innovations with measures that provide the right amount of security and interoperability.

Internet Governance and IoT Interoperability

For the internet technical community interoperability is part of its ethos. Early internet equipment vendors called their workshops “interops”, and interoperability is a cornerstone in the

⁷⁸⁶ Karen Rose, Scott Eldridge, Lyman Chapin, “The Internet of Things: An Overview,” Internet Society, October 2015, 47, accessed March 2022, <https://www.internetsociety.org/wp-content/uploads/2017/08/ISOC-IoT-Overview-20151221-en.pdf>.

⁷⁸⁷ “Cyber Security,” U.S. Food & Drug Administration, June 2022, accessed June 2022, <https://www.fda.gov/medical-devices/digital-health-center-excellence/cybersecurity#safety>.

IETF community of affiliated standards work.⁷⁸⁸ Indeed, interoperability is such a fundamental feature of the internet that internet governance expert Milton L. Mueller describes interoperability as “an almost religious principle of the internet technical community, built into its DNA.”⁷⁸⁹

Interoperability is fundamental because it is what has allowed the internet to grow and become the essential feature of daily life today. Much of the internet’s value—connecting, sharing, innovating—is a product of interoperability, and barriers intended to obstruct interoperability can undermine that value. What is changing today is the value IoT devices have for the user relative to the rest of the internet community. Before IoT devices, one must adopt shared protocols and other standards to be online to view content, send an email, or otherwise benefit from the internet. With IoT devices the value to users is more acute and thus does not require the same scale of interoperability that internet use does. IoT devices must share a connection via shared standards, like Wi-Fi or Bluetooth, but aside from the standards that provide connection, the requirements for interoperability can vary for IoT devices.

Whereas the internet community benefits from greater inclusivity, IoT devices, like smart watches, do not necessarily benefit from the same inclusivity. For instance, a person wearing a smart watch benefits from its functionality, but for other internet users not wearing the smart watch, there are almost no benefit. Interoperability in personal IoT devices is thus limited to the user or a family of users versus the larger internet community. Similar reasons can affect the interoperability of industrial or other IoT uses cases as well, though different applications can have different impacts on interoperability. For example, controlling an actuator that moves a piece of machinery can require different standards than the standards necessary for interoperability of home appliances.

The shift from inclusive interoperability to narrow interoperability creates new business cases for IoT devices. Where internet software and hardware manufactures were once incentivized to create widely interoperable products so users could connect through the internet,

⁷⁸⁸ “1988,” A History of the Internet, accessed February 2022, <http://inthishistory4u.blogspot.com/2010/08/1988.html>.

⁷⁸⁹ Milton Mueller, *Will the Internet Fragment?* (Malden, MA: Polity Press, 2017), 8.

in many IoT devices the goal is to limit interoperability to a proprietary ecosystem of relevant IoT products and services. By creating IoT products with limited interoperability businesses can differentiate their products and chase market share. For the consumer, having to buy into a family of IoT products often affords more features and conveniences, but it also makes it more difficult to switch between product brands.⁷⁹⁰ Because IoT products often exist within a proprietary ecosystem, switching between ecosystems can require replacing each IoT device; a smart watch from one manufacture may not be interoperable with the smart phone of another manufacture or the smart home door lock may not connect with another manufactures smart home security system.

IoT interoperability also affects cyber security. At the heart of limited interoperability are proprietary or new standards. Developing new, proprietary standards can expose users to unknown security risks that may be less common in proven and widely utilized security standards. Conversely, internet interoperability is one reason some cyber security attacks proliferate so quickly. So, to some extent, siloed IoT ecosystems offer a way to limit the reach of some cyber security threats. Still, it can be a guessing game as to whether it is safer to go with less proven but siloed IoT systems or more interoperable IoT systems with tested security standards. Balancing the cyber security risks is a key consideration affecting interoperability, and preferences often differ between use cases and users based on their needs and risk tolerance.

Internet and IoT interoperability can occur at various technical layers, from the application layer to the device layer.⁷⁹¹ In a review of interoperability proposals one study found proposed solutions are on the rise but tend to focus on device or network levels.⁷⁹² Where in the technical architecture interoperability standards are required is at the centre of the interoperability discussion, in part, because of the novel nature of IoT and its rapid growth across industries and uses cases. The importance of interoperability at different technical layers is captured by the fact that interoperability at various layers can reverberate across the internet rather than staying isolated to single devices or user. A lack of interoperability at the network layer would mean the

⁷⁹⁰ Karen Rose, Scott Eldridge, and Lyman Chapin, "The Internet of Things: An Overview," 47.

⁷⁹¹ Laura DeNardis, *The Internet in Everything*, 140.

⁷⁹² Mahda Noura, Mohammed Atiquzzaman, and Martin Daedke, "Interoperability in Internet of Things: Taxonomies and Open Challenges," *Mobile Networks and Applications* 24 (2019): 796-809.

network remains isolated, for example. Conversely, a lack of interoperability at the security layer could mean cyber-attacks are more easily isolated. There is currently no consensus as to what variety of interoperability is best for the users, the IoT sector, or the internet.

Addressing IoT interoperability is happening across the internet multistakeholder ecosystem. As standards will continue to play a central role in the internet and IoT sector, how standards are developed will have a major impact on the evolution of the internet, IoT business competition, and users in the decades to come.⁷⁹³

IoT Interoperability Standards

A key difference between the standards that gave rise to a globally interoperable internet and siloed IoT standards are the ways that IoT standards affect the physical world through control of physical devices. The rise in IoT devices has allowed the internet to affect the physical world like never before. A smart home thermostat can allow a user to adjust the temperature in a home from anywhere, while a smart home door lock can be unlocked by a smart phone. Indeed, standards now must address control of objects rather than simply controlling communication between people.⁷⁹⁴ On a small scale the interaction between physical and digital worlds may seem rather insignificant, but the same physical control via IoT devices applies to factory equipment, critical infrastructure, healthcare devices, and much more. While malicious use of someone's home thermostat may only produce an unpleasant utility bill, the malicious use of IoT connected critical infrastructure or factory equipment could become a national security concern.

The evolution changes the significance of standards in important ways. First, the cost of insecure standards rises. An IoT enabled pacemaker or autonomous vehicle that can be easily hacked could cost lives. Standards capable of interacting in the physical world can also require completely different technical considerations than those restricted to the digital space; control of an actuator, for example.⁷⁹⁵ Finally, because there is considerable business opportunity in IoT devices, companies must decide what makes the most business sense and whether or not their

⁷⁹³ Laura DeNardis, *The Internet in Everything*, 159.

⁷⁹⁴ *Ibid.*, 135.

⁷⁹⁵ *Ibid.*, 136.

suite of products will be interoperable with another company's products.⁷⁹⁶ Choosing to coordinate or not can both make business sense depending on the IoT device and the business model of a particular company and product.

Changing incentives around IoT standards and interoperability is creating a more diverse and fractured internet governance ecosystem.⁷⁹⁷ While familiar standards setting organisations, like the IETF and ISOC, are active in pursuing IoT interoperability, other internet governance organisations like, ICANN, are having to explore how IoT relates to their remit and responsibilities as an internet governance body.⁷⁹⁸ Moreover, national regulations are increasingly stretched to account for the new ways IoT devices affect data, privacy, security and more. Outside of traditional internet governance stakeholders, many new IoT businesses are likely unfamiliar with digital standards setting organisations and may not be involved in the cooperative standards process. Finally, the speed at which IoT is evolving is challenging the capacity of standard setting organisations and leading to entirely new ones.⁷⁹⁹ One study found some 83 standard setting organisations and alliance initiatives related to IoT.⁸⁰⁰

In all, the IoT standards community is becoming a divergent and crowded place. Given the number of IoT standards organisations, it is not helpful to discuss all of them. Rather, detailing the complexity of the IoT standards ecosystem only requires discussing a few.

The IETF routinely has over 100 active working groups at any given time, several are focused on IoT standards across numerous areas. These groups are developing protocols and best

⁷⁹⁶ For example, it can be more expensive to design interoperability into new products compared to using existing proprietary standards but using proprietary standards may impact the lifecycle of a product because it may not be interoperable. For more, see: Karen Rose, Scott Eldridge, and Lyman Chapin, "The Internet of Things: An Overview," 48.

⁷⁹⁷ Laura DeNardis, *The Internet in Everything*, 136.

⁷⁹⁸ Security and Stability Advisory Committee, "SAC105 The DNS and the Internet of Things: Opportunities, Risks, and Challenges," ICANN, May 2019, 2, accessed March 2022, <https://www.icann.org/en/system/files/files/sac-105-en.pdf>.

⁷⁹⁹ Karen Rose, Scott Eldridge, and Lyman Chapin, "The Internet of Things: An Overview," 49.

⁸⁰⁰ WG03, "IoT LSP Standard Framework Concepts," AIOTI, 2017, accessed March 2022, https://aioti.eu/wp-content/uploads/2017/06/AIOTI-WG3_sdos_alliances_landscape_-_iot_lsp_standard_framework_concepts_-_release_2_v8.pdf.

practices for IoT communication and security.⁸⁰¹ The goal of the IETF's IoT work is to improve interoperability by providing standards and best practices to companies and other standards development organisations.⁸⁰² IETF working groups have identified a need to coordinate across working groups, however coordination does not always occur.⁸⁰³ The IETF IoT Directorate was established as an advisory group of experts to facilitate coordination among IETF IoT-related work and increase awareness and cooperation with outside organisations and companies.⁸⁰⁴ Despite the IoT Directorates work, external awareness of the IETF's efforts can be poor.⁸⁰⁵

The IEEE established an IoT Initiative in 2014 to provide a platform for learning, knowledge sharing, collaboration, and technology convergence.⁸⁰⁶ The IEEE Standards Association, which also work on standards unrelated to IoT, uses IoT working groups, like IEEE P2413, to develop required IoT standards. The Association has produced some 80 standards with another 46 in development as of 2021.⁸⁰⁷

The ISO and International Electrotechnical Commission have established a joint technical committee. The committee was the first joint project for IoT between the two organisations. As of 2021, it has developed 21 standards with 19 work programs in progress.⁸⁰⁸ Both organisations are developing IoT standards in addition to their joint work.

The ITU groups IoT standards in with other information and communication technologies. The ITU boasts activities across all domains of IoT.⁸⁰⁹ Nine standards initiatives and working groups are listed on the ITU's website with 41 active or retired work programs.⁸¹⁰

⁸⁰¹ "Internet in Everything at the IETF," Internet Engineering Task Force.

⁸⁰² Ibid.

⁸⁰³ "Internet of Things Directorate (iotdir)," IETF, accessed March 2022, <https://datatracker.ietf.org/group/iotdir/about/>.

⁸⁰⁴ "Internet in Everything at the IETF," Internet Engineering Task Force.

⁸⁰⁵ "Internet of Things Directorate (iotdir)," IETF.

⁸⁰⁶ "About the IEEE Internet of Things (IoT) Initiative," IEEE Internet of Things, accessed April 2022, <https://iot.ieee.org/about.html>.

⁸⁰⁷ Euijong Lee, Young-Duk Seo, Se-Ra Oh, and Young-Gab Kim, "A Survey on Standards for Interoperability and Security in the Internet of Things," IEEE Communications Surveys and Tutorials, 23 no. 2 (2021), 1028.

⁸⁰⁸ Ibid.

⁸⁰⁹ Internet of Things, "ITU: Global Standards for the Internet of Things," International Telecommunications Union, accessed April 2022, <https://www.itu.int/en/ITU-T/techwatch/Pages/internetofthings.aspx>.

There are also a host of other standards organisations that have emerged with the growth of IoT. OneM2M was created in 2012 as a global partnership for machine-to-machine and IoT standardization. It has nearly 200 participating partners and members who address several topics from market requirements to interoperability and security. The Alliance for IoT Innovation was founded in 2015 by the European Commission to support the convergence of IoT standards. A snapshot of the numerous other IoT standards organisations include, IoTivity, IPSO Alliance, Object Management Group, Open Connectivity Foundation, Open API Initiative, OpenFog Consortium, and the Organization for the Advancement of Structure Information Standards. As mentioned previously there are more than 83 catalogued IoT standards organisations which do not account for the standards advanced by individual companies.⁸¹¹

While just a glimpse into the world of IoT standards, it should be clear that governance coordination is being diluted at best, and at worst, is absent. While many of the IoT standards organisations listed previously advertise a focus on interoperability, the ecosystem is growing too large and IoT standards are being developed too quickly to coordinate and advance IoT interoperability. The multistakeholder nature of internet governance is struggling to reconcile with the growth of actors, activities, and concerns rising from IoT devices. Market incentives are stressing the balance between consumer demands and security. The novel nature of the IoT industry and the lack of coordination within the internet governance community makes it difficult to predict what the future holds for internet and IoT governance. Given current trends, the multistakeholder model used to produce interoperable and secure internet devices seems to be under strain.

Conclusion

The rapid growth and importance of IoT technologies is a significant evolution for internet governance. Not unlike the other domains discussed in this research, accommodating new

⁸¹⁰ Ibid.; and for the ITU's catalogue of work programs see: "ITU-T work program," International Telecommunications Union, accessed April 2022, https://www.itu.int/ITU-T/workprog/wp_search.aspx?isn_sp=8265&isn_status=-1,1,3,7&acronym=IoT&details=0&field=acdefghijo.

⁸¹¹ WG03, "IoT LSP Standard Framework Concepts".

technologies can be challenging for governance regimes. For internet governance, the multistakeholder model appears less well suited to manage such change.

Prominent internet governance organisations, like the IETF, are still important, but the growth in other standards setting organisations dilutes influence across the standards community. While there is still considerable buy in from the community broadly, trust and joint engagement appears to be suffering. The growth in standards setting organisations also suggest that buy in is down in some respects. For example, rather than engaging through the IETF or other more traditional standard setting groups, companies are active in creating their own standards and creating new organisations better suited to their IoT needs. While stakeholder support for IoT standards is not waning, the use of long-standing internet governance fora appears to be.

The incentives for being organized and interoperable are changing in this new digital-physical internet era. As the need for interoperability changes, a shift away from working together may be occurring. While less coordination may prove troubling for interoperability, it does seem to create greater agility across the community. Various business and technical motivations have encouraged more rapid production of standards, and without the burden of coordination they are able to do just that. Generally, this reflects improve stakeholder agility, though it does not say anything about the effectiveness of the outputs.

The incredible growth of IoT devices has placed strain on the internet standards community challenging its ability to offer effective governance solutions. The multistakeholder model by its nature lacks centralized authority. Where organisations like the IMO or ICAO are designated by states to provide centralized coordination to advance governance across the community, the internet's multistakeholder model lacks the centralized coordination to ensure new governance measures, like standards, are advanced collectively. While the internet has evolved since its creation and required new standards along the way, the change from digital only to digital-physical seems to be more than what the core of the internet standards community can handle. These tensions affect the development, adoption, and effectiveness of internet standards in ways that are seemingly counterproductive for the internet.

Not everything the internet protocol community is doing to support IoT is bad or counterproductive. New standards permit new IoT devices and technologies, which offer a host of benefits, and it can encourage interoperability at some technical levels. This suggests that IoT may be exposing new weaknesses in the multistakeholder model that governs the internet, calling into question the benefit the model offers when confronting emerging internet technologies.

Analysis and Conclusion

As discussed early in this chapter, governing ORPSAO requires ensuring related activities are safe and transparent despite how they may evolve overtime. Safety is necessary to avoid creating new debris, harming functional satellites, and protecting lives, like those aboard the International Space Station. Safety is what allows ORPSAO to become a critical feature in the sustainable development of space. Transparency is required to ensure actors, government, and industry, are clear about expectations, roles, and responsibilities as they explore new rules, norms, standards, and other governance measures. Transparency is how ORPSAO is matured without excessive oversight that may stunt related innovation. For instance, with poor transparency governance might be driven by national security concerns that could limit commercial ORPSAO innovation. Together safety and transparency are what enable a healthy balance of regulation and ORPSAO advancement.

Achieving safety and transparency requires close collaboration between industry and government. Industry and government cooperation are normal across the international governance ecosystem, to include space governance, but the lack of existing government standards and recommend practices or other regulatory measures for ORPSAO does seem to place greater emphasis on industry's role in creating governance for ORPSAO than is the case for small satellite development or STM. Related to small satellite development there exist several national and international regulatory measures to guide the design, build, operation, and disposal of satellites. Similarly, in space traffic management, governments offer some of the most advanced SSA capabilities. With ORPSAO, however, government currently has less to offer than industry across new use cases or regulatory tools. Given industries work on ORPSAO standards, cooperation could expedite the production of measures.

The cases studies offer insight into various methods for protecting safety, creating transparency, and pursuing coordination through governance.

Governance Challenge and the Need to Adapt: Safety and Transparency

Despite having unique governance needs for different emerging technologies, the IMO, ICAO, and the internet governance community did share a focus on safety and transparency, though there were unique approaches and features to each.

Safety and transparency were core considerations motivating the IMO's work. The IMO's approach could be distilled down into two phases. The first was to learn. Scoping exercises provided key insight into what governance needs exist and how they might be filled. The second phase was to create a progressive system of measures that encourage the development of MASS while still protecting important governance benefits, like safety and transparency. The IMO's interim guidelines were intended to inform states as they began evaluating MASS technologies and use cases with specific mention of safety and transparency. The interim guidelines were also a way for the IMO to guide member states more quickly (developing a more formal measure would have taken more time). The creation of the MASS working group served to encourage cooperation and transparency on MASS work streams across the IMO. Developing goal-based measures reflect a proactive approach to governing an emerging field where the future is hard to predict but where safety and transparency must accompany developing MASS. In sum, learning provided the foundation while a progressive system of MASS governance allows it to evolve as the industry does. Safety and transparency underwrote both phases.

The IMO's pursuit of goal-based measures in the form of a Code, versus other measures, may be one choice where safety and transparency were not the priority. As discussed earlier in the chapter, the IMO decided a Code was the best governance tool because filling governance gaps via Codes would require fewer new agreements than if other measures were used. While pursuing Codes is not necessarily in contrast with safety or transparency, selecting Codes over other measures because it would require producing fewer new agreements seems to suggest the choice served more pragmatic ends than safety or transparency. It may be worth noting, however, that the need for a larger number of new agreements could threaten safety as it would

almost certainly take more time to produce more agreements. It may also affect transparency because member states would have to familiarize themselves with more workstreams and new governance measures which, as discussed in chapter four, can be challenging for developing states.⁸¹² In either case, how a Code improves safety and transparency depends more on contents of the agreement than the type of agreement.

ICAO followed a similar path to that of the IMO, but with some unique features. ICAO's first step was to understand what UAS governance needs were and whether ICAO was best suited to fill governance gaps. ICAO's two primary workstreams for UAS regulation are SARPs and guidance and supporting materials for national UAS regulations. These two work streams seek to create uniformity and coherence among UAS regulations to support safety and transparency as UAS develops.

Much of ICAO's work is focused on helping national regulators develop constructive regulations because most UAS activates are domestic. While some do cross international borders, UAS is not yet operating at the same geographic scale as manned aviation. Therefore, ICAO has focused many of its efforts on developing tools and measures to build a productive foundation of UAS governance at the state level knowing that state regulations can affect international governance; when adherence to an international governance measure requires major changes at the domestic level it can prevent states from complying.⁸¹³ ICAO has also instituted new bodies, like the UAS-AG, within the organisation to ensure it continues work on UAS governance as the industry and technology evolves.

For IoT, safety and transparency are important but the multistakeholder model proves less suited to prioritize them. Whereas the IMO and ICAO have centralized methods for governing their respective emerging activities, internet governance has addressed IoT governance from a far more decentralized position driven by the multistakeholder model. Thus, companies and standards organisations are free to adopt or develop standards as they see fit, but poor coordinatization between them has resulted in competing or conflicting standards. Ultimately,

⁸¹² Chapter 4, the IMO, ICAO, and Internet Governance Organizations, 74.

⁸¹³ See Chapter 4, the IMO, ICAO, and Internet Governance Organizations, 90.

the multistakeholder model complicates coordination across the internet governance ecosystem while also lacking the ability to control how the ecosystems approaches the need for new governance. As the IoT case study shows, the decentralized approach can make it more challenging to ensure IoT is developed safely and transparently. Given the multistakeholder model, whether a company pursues interoperability or established cyber security standards can depend on what makes business sense for that company at the time.

The multistakeholder approach does yield more standards than might be possible to produce through a more centralized governance model, and many of the standards could improve safety, but there is no way to encourage adoption across the community. For transparency, there appear to be few upsides to a decentralized approach. Transparency and IoT interoperability are interrelated and when dozens of standards organisations and companies are operating independently with little communication between them, transparency and interoperability tend to suffer. If coordination of IoT standards is difficult within the IoT standards community, it is likely difficult to organize around the impacts of IoT elsewhere in the multistakeholder ecosystem as well. For example, with so much diverse and uncoordinated activity occurring around standards, it may prove difficult for governments, network operators, or other internet stakeholders within the multistakeholder community to contribute to IoT governance without causing additional disruption.

Finally, it is unclear how the multistakeholder model is prepared for the future of IoT. The internet governance community will continue to have an impact on IoT governance, but because decisions made for safety and transparency are so closely linked to the market it is likely that perceptions and needs related to IoT safety and transparency could change as the market does. Whether the IoT market favours short-term profits over long-term safety and transparency is unclear because there are incentives for both. The influence of the market relative to the internet governance community renders the future of IoT governance unpredictable.

Important differences exist between case studies. What works to govern one emerging technology may not work to govern another. Similarly, centralized vs decentralized governance

models impose additional barriers and opportunities. Applied to ORPSAO, each offers useful insight.

Governance Solution via Adaptation: Safety and Transparency for ORPSAO

For the space governance community there are features of each case study that could aid in the development of safe and transparent ORPSAO activities. The scoping exercise conducted by the IMO used to understand governance needs would be a useful step in providing direction for COPUOS or a national regulatory body. ICAO's approach of focusing on domestic regulations could also guide states toward more uniform standards as states begin participating in ORPSAO activities. Finally, equitable inclusion of industry as found in IoT governance would also be helpful given the role industry has played thus far in developing governance tools, like CONFER's guiding documents.

Undertaking a scoping exercise may not prove very contentious for COPUOS, and thus is possible compared to producing a more substantial governance measure, like a treaty. This is because for the last several years COPUOS has undertaken several activities designed to catalogue how states are developing and governing space activities to educate the space community.⁸¹⁴ Still, COPUOS members would have to agree to conduct the exercise and there is no guarantee every member will support the effort. A working group could help conduct a scoping exercise if consensus can be achieved.

Developing model ORPSAO regulations that states may use to develop domestic regulations or goal-based measures would prove difficult for COPUOS. For the same reasons discussed throughout this research, COPUOS has a hard time producing new agreements, which would hinder its ability to produce model measures or a more substantial goal-based measure. To overcome forum limitations and develop model regulations or goal-based measures, COPUOS would likely have to reform its processes, like those related to consensus, and add technical bodies to undertake the work. Indeed, the IMO, ICAO, and the internet governance communities found it necessary to create new technical bodies for each new technology area. Given

⁸¹⁴ Kenneth Hodgkins and Adam Routh, "Emergence of and perspectives for a new paradigm in space diplomacy," 46.

COPUOS' limited capacity to address existing space governance needs, it is likely a new working group, subcommittee, or similar forum for ORPSAO would be necessary.

Finally, given the work industry is doing to both develop necessary ORPSAO governance tools and advance the technology and activities, more equitable industry's involvement within COPUOS could help. COPUOS does allow industry to participate as observers or via state delegations, but the involvement is not equitable compared to states. Industry does not get a vote in COPUOS nor is industry allowed to participate in discussions or working groups as states do. It is possible to develop new ORPSAO governance with less equitable industry involvement, however given the work industry is already doing to advance ORPSAO standards, including industry could expedite developing new governance. Including industry can also encourage greater adherence to governance measures and help avoid competing with industry governance initiatives.

Developing new governance tools is necessary, but only if they are developed in a timely manner. Here the case studies offer additional useful insights for ORPSAO.

Governance Challenge and the Need to Adapt: Timely Governance

In addition to safety and transparency, timeliness of new governance was another feature common across each case study. The timelines for each emerging activity did vary, for example IoT and UAS developed more quickly than MASS. Still, governance organisations tend to respond to governance needs, which can mean governance must catch up to new activities at varying stages of development. Governing emerging activities, therefore, requires doing so quickly so as not to allow new activities to threaten safety or environmental security.

Determining what constitutes 'quick' or 'timely' governance can be subjective. International governance routinely takes years to advance. International governance is also not capable of perfectly protecting safety or the environment. So, what does timely look like? It may be useful to think of timely governance in context.

Timeliness can depend on the activity in question and output designed to address it. Some activities, like MASS, progress more slowly than others, giving the IMO more time to create necessary governance. Additionally, the volume and type of work produced over a given period also matters. COPUOS took nine years to develop a single set of non-binding sustainability guidelines during a period when space activity was maturing rapidly and space sustainability was increasingly at risk. The single set of non-binding guidelines reflects a weak governance tool given there was ample need for more substantial sustainability measures. Likewise, the speed at which it was developed was far outpaced by the activities it was designed to govern. The IMO and COPUOS examples demonstrate how understanding timeliness can vary based on governance needs. The goal here will be to provide enough context to compare case study approaches and highlight useful insights for ORPSAO.

The IMO created a MASS working group, conducted three scoping exercises, produced interim guidelines, began evaluating draft Codes, and developed goal-based instruments to regulate MASS between 2015 when it first considered MASS and 2022 (the time of writing). Seven years is not a short amount of time when assessed against the pace of technology development, but autonomous shipping is a more expensive and time-consuming endeavour than other industries, like UAS and IoT. Because MASS has a longer development timeline seven years is not too long of a time to offer safety and environmental protections. Moreover, the number of outputs and changes to the IMO as a forum is substantial. From creating new groups to developing multiple new agreements, the IMO took productive steps relative to MASS development. When considered against the nine years it took COPUOS to produce a single set of non-binding guidelines the timeline and volume of work appears impressive.

ICAO took similar action to govern UAS as the IMO. In two decades since ICAO took up UAS governance it has produced numerous measures that affect international and national UAS governance needs. ICAO produced guidance documents that would set the conditions for SARPs. At the same time, the UAS Study group was formed to support UAS governance given its novel nature within ICAO and eventually became a permanent group. The UASSG produced circular 328 to highlight gaps between UAS regulatory needs and current annexes. A year later ICAO began producing SARPs for UAS. In 2015, ICAO released the first edition of the RPAS

manual which details UAS SARPS and is designed to be iterative. ICAO continued to evolve its approach through the establishment of UAS-AG. ICAO also provides model regulations for states, educational resources, and other tools to encourage the adoption of national regulations.

There are still gaps, like UTM and ATM integration, however ICAO has established new UAS working groups and measures designed to evolve to enable new governance. One limitation was ICAO's initial decision to limit its role in UAS governance. In doing so the forum eventually had to catch up with emerging technology and lost opportunity to shape the industry early on. Thus, a lesson for COPUOS might be that it is important to consider how new activities will eventually shape the space domain, and therefore, eventually relate to its mandate before deciding what is out of scope.

For the IoT community, the development of new standards occurred rapidly. New standards organisations and market demand created a powerful incentive to create new standards. However, creating new standards often had less to do with safety or the preservation of internet interoperability. While some standards organisations create new groups to help cohere IoT standards, others were created based on market need. The decentralized nature in which IoT standards were developed has led to many new internet governance challenges. This is because the multistakeholder nature of internet governance does not provide centralized authority, so markets and community demand incentivize change for reasons often more persuasive than those encouraging IoT security and interoperability. While the IoT community can produce new governance tools, like standards, quickly, the lack of centralized control and competing incentives challenges the utility of those new IoT standards.

In each case study the creation of new working groups or entities to address the emerging technology enabled timeliness. Whether it was UAS-SG, the MASS working group, or new IoT standards organisations, these groups allowed the IMO, ICAO, and IoT community to address emerging issues through subject matter expertise and dedicated work streams. The IMO and ICAO initially created temporary groups but later made them permanent.

Another key feature of timeliness were governance measures designed to evolve or change over time. The IMO's goal-based measures and ICAO's RPAS Manual were developed to accommodate the changing nature of MASS and UAS, respectively. The IoT community has developed some standards that can evolve overtime, but the lack of coordination or centralized authority makes it difficult to understand what the future holds for a given standard.

The last element of timeliness is using a spectrum of governance tools to affect domestic and international behaviours. Governance measures like the IMO's interim guidelines for MASS trials or ICAO's model UAS regulations for national regulatory agencies were created in addition to more substantial measures, like Codes and SARPs. Codes and SARPs can take longer to produce than non-binding guidelines or a catalogue of existing UAS regulations. These tools can help shape behaviour while other measures are developed. Using a spectrum of governance tools did not apply to IoT standards in the same way. In part because standards are a principal source of IoT safety and interoperability—whereas other governance tools, like guidelines, are not—and because standards already evolve so quickly.

In sum, timeliness played an important role in governing emerging activities in each case study. New working groups and governance tools designed to evolve with technology enabled timeliness. Importantly, though the IoT standards community was capable of producing new standards far more quickly than the IMO or ICAO could develop similar governance tools, the lack of central coordination and competing incentives suggests timeliness alone does not necessarily make for effective governance.

Governance Solution via Adaptation: Coordinated, Iterative Guidance

ORPSAO activities are early in their development. Like MASS, the cost and complexity of developing ORPSAO activities slows their development. This is a good thing for space governance as it buys time to develop necessary governance tools to ensure ORPSAO are advanced safely and sustainably. A few lessons from the case studies offer useful insights.

First, while producing new agreements quickly is important, coordination and agreements that can evolve overtime are equally important. For COPUOS or industry groups, like

CONFERS, this means developing standards that can change as ORPSAO activities do. It also means that while industry groups are helpful, without support from forums, like COPUOS, industry standards could end up competing and creating a more complex governance ecosystem.

Coordinating to produce new agreements capable of accommodating ORPSAO changes will require creating new working groups or subcommittees in COPUOS or providing industry groups, like CONFERS, more influence in the forum. Given CONFERS' work and industry participation, modifying the forum to permit industry groups greater participation could offer a more expeditious way of creating a ORPSAO team focused on relevant governance. Regardless of option, COPUOS members would need to come to consensus on the creation of a new group, which is a major barrier for the reasons discussed throughout this research.

A second applicable lesson is the use of multiple governance tools. Measures like non-binding guidelines that can be produced relatively quickly can provide initial guidance while conducting research and developing additional governance measures. For COPUOS, this approach may prove tricky given how stalled the organisation has been in recent decades. Industry groups could supplement COPUOS by developing similar guidance materials, however, to have the same impact on ORPSAO governance they would likely need national or international support via state regulators or COPUOS.

In all, governing ORPSAO activities likely requires changes to COPUOS as a forum. Adjusting decision making processes to permit more agile agreement development and creating new groups to undertake the work can both help overcome existing barriers preventing the development of new ORPSAO governance. Conversely, left unchanged and unable to advance ORPSAO governance, industry groups could provide useful standards and other governance tools. It will be important for industry efforts to prioritize transparency and coordination or face similar problems as those witnessed in IoT governance.

Summarizing Lessons Learned

This chapter has shown that governing emerging technologies requires adaptation, and that adaptation can be aided by efforts to learn how new technologies or activities affect governance

needs and measures designed to mature with the technology. Indeed, learning activities, like the scope exercises, were critical for the IMO and ICAO to understand how to create benefits for its members. More than simply identifying what about emerging activities fit within organisational remits, the learning activities helped the IMO and ICAO to align activities with both ongoing governance efforts and identify what new activities and methods would be necessary overtime. Said differently, learning exercises helped the IMO and ICAO understand how to develop a runway for new governance as emerging technologies matured.

In both the IMO and ICAO examples, key to developing effective governance of new technologies and activities was accounting for member disparities through governance measures designed to mature with the technology. For example, while the slower technology development of MASS allowed the IMO to produce measures that pre-empt safety and transparency needs, the faster rate of technology maturation with UAS influenced ICAO to provide benefits via measures that help some of its members catch up with regulatory needs while helping others align regulatory practices.

Conversely, the decentralized nature of internet governance made organizing around mutual benefits difficult. Instead, benefits from IOT tended to be developed more unilaterally which created issues, like competing standards that challenges interoperability. Indeed, the benefits of coordinating the governance of new activities were lost in a decentralized approach, and the consequences are affecting some of the core qualities of the internet, namely interoperability.

Existing space governance resembles the decentralised approach of the internet more than the centralised approach of the IMO and ICAO. While taking the time to understand how emerging technologies could affect international governance of a global commons might seem like an obvious first step, such activities have not happened for many critical space activities in any sort of collective manner. Until they do it will likely remain challenging to develop effective space governance that can mature with the technology, and individual efforts by countries or companies are likely to develop. As the internet example showed, if those individual efforts mature and start producing benefits for individual actors, they can be hard to correct through centralized governance.

Governing emerging activities is not an easy task regardless of the domain or approach to governance. In many ways governance is inherently reactive. So, governing rapidly changing technologies can require governance organisations to constantly catch-up with technology. Still, governance is necessary when balancing development with sustainability. ORPSAO represent a set of activities that promise to unlock the next phase of space development. While ORPSAO activities are nascent now, their potential suggests they will not remain nascent for long.

As COPUOS or industry groups advance ORPSAO governance it will be important that they do so safely, transparently, and in a timely manner. Identifying lessons from the maritime and air domains suggest balancing development goals with environmental protections is possible, but the space governance community will have to make important changes to govern like the IMO and ICAO do. Lessons from IoT governance provide more instruction for what not to do, or what happens when central coordination does not exist, than features for space governance to emulate. For space governance it will be important that ORPSAO activities are developed with the broadest community adoption possible. Where broad community adoption is not possible, coordination among desperate ORPSAO governance groups will be necessary to avoid competing approaches to governance.

There does seem to be some time to develop ORPSAO governance but given the challenges required to meeting ORPSAO governance needs, the time afforded may not be enough. ORPSAO activities are on the horizon, so too must be new governance.

8. ANALYSIS AND CONCLUSION

Space development is occurring in new ways. Large constellations of small satellites, STM, and ORPSAO will play a central role in the next phase of space development by offering new space services and business models if they can be governed effectively. A failure to govern new space activities can put the domains security at risk.

As discussed in Chapter 5, small satellites are less sophisticated than the larger satellites used historically, which permits them to be less expensive and employed iteratively with shorter service life cycles. As technology advances, lower costs and shorter service life cycles allow small satellites to be more quickly replaced, changing the business model of operating not only one or a few satellites but thousands.

As the number of satellites in near-Earth space grows, so too does the need to manage space traffic. Discussed in chapter 6, STM is the means to organize satellite and other human made space traffic to prevent collisions and create operational efficiencies. Through proper STM, Earth orbits can host more space traffic with less risk. To develop a strong STM system requires international cooperation.

As chapter 7 detailed, more than simply having more satellites in orbit, the next phase of space development will include ORPSAO activities that permit entirely new space activities and further reduce some development barriers. More than reducing launch barriers, being able to service a satellite in orbit can change the business dynamic of some space activities and permit new commercial endeavours. For example, being able to refuel a satellite on orbit can change the design requirements and reduce large upfront capital expenses typically required to develop spacecraft.

Also discussed in chapters 5-7 are the risks these activities pose to space sustainability. Thousands of new satellites orbiting Earth can increase risk of satellite collision and add debris to an already debris riddled domain. To ensure small satellites and constellations contribute to space development sustainably, they must be designed, operated, and disposed of properly.

Increasingly congested orbits also require STM to make order out of what is arguably a rather chaotic scene of thousands of satellites orbiting Earth without common standards, norms, laws, and other measures to manage behaviour. Finally, ORPSAO requires coordination and transparency. Satellites manoeuvring in proximity and servicing one another happens at incredible speeds, meaning mistakes can cause satellites to collide, destroying spacecraft and creating debris. Moreover, the value of satellites, whether financial or for national security, is such that unapproved ORPSAO could create tension between actors. In either case, if not coordinated and transparent, ORPSAO could contribute to space unsustainability.

Whether those activities lead to another tragedy of the commons, or the long-term sustainable development of space depends on international governance. Indeed, ensuring small (or other satellites) are designed, operated, and disposed to mitigate and remove debris requires new governance, as does the rules and administration for STM and ORPSAO.

As explored in Chapter 1, effective international governance for most space activities, including the three focused on in this research does not currently exist because it has failed to adapt over time. With space development accelerating, space governance for the space activities and services expected to play a central role in space development is increasingly necessary. There are several ways to produce new governance. Standards organisations, like the ITU, COPUOS, and national regulations are a few examples. Industry groups and national efforts could also provide useful means for advancing space governance, however stitching together a patchwork of national regulations and industry best practices can be difficult and complicate matters if done poorly as evidenced by the internet case study.

COPUOS is best suited to lead space governance based on its international membership and existing focus on space governance, but the forum has struggled to meet existing space governance needs for decades and is unlikely to produce necessary space governance without reform. How the forum leverages consensus, its limited capacity through a small secretariat and organisational structure, and disagreement among members over what space topics are within its remit have plagued the organisation leaving it in a debilitated, stagnant state.

In addition to a functional forum, evolving governing these new activities also requires understanding what sort of governance measures would be most effective. Governance tools include a range of measures from standards and recommended practices to treaties, non-binding guidelines, tools for national regulators, among others. Not every measure is suited to address all governance needs. Finding which measures most effectively guide actor behaviour toward sustainable development practices requires thoughtful consideration by the organisations and actors responsible.

Moreover, as chapters five, six, and seven have shown, governance measures must continue to evolve and adapt with the changing character of their respective domains and activities. While COPUOS has struggled to find its footing in recent decades, it has not stopped attempting to advance space governance. The commitment is commendable, but the forum has had to settle for increasingly diluted and weak governance measures or shifting its focus toward education over agreement production. Such an evolution falls short of what the space domain and community require from a key governance body. The forum must find ways to continuously advance governance without resigning itself to agreements and programs of work that fall woefully short of what is needed.

New space governance is needed, and it should be developed based on the organisational features (e.g., processes, decision-making style, membership, etc.) and measures (e.g., treaties, standards, etc.) that allow space governance to evolve with emerging space activities and challenges.

The problem statement above led to the following research question:

How can other governance regimes inform the development of contemporary space governance for the space activities expected to be most essential to the sustainable development of space?

The following sections will first recap the research approach before detailing research contributions, including key themes of effective international governance organisations and

governance outputs used to effectively balance domain sustainability with development. Finally, a brief discussion on future research will be provided to place this research in broader context.

Summary of Research Approach

To explore this research's central question, it examined three case studies to understand how other governance regimes manage similar governance challenges for other global commons. The first case study explored how the IMO governs to protect the maritime environment, manages shipping traffic, and handles emerging technologies, like MASS. The second case study explored how ICAO protects the air domain from climate change caused by CO2 emissions, how ICAO governs ATM, and how the organisation addresses emerging technologies, namely UAS. The final case study examined the multistakeholder internet governance regime to understand how CIRs are protected, how internet traffic is managed, and how the multistakeholder group handles emerging internet technologies, specifically IoT technologies.

The case study research areas correlated with the challenges and activities critical to space development, like space debris' threat to Earth orbits, the need to manage space traffic, and the need to regulate emerging space activities, like ORPSAO. The examination highlighted important international governance themes and lessons for improving space sustainability, developing space traffic management, and accounting for emerging technologies.

Each case study offered differences and similarities to inform the qualities of new space governance. A principal limitation of space governance based on chapter 2's discussion of effective governance, is that it has not evolved with governance needs. Therefore, these case studies were explored under the assumption that effective governance is governance that evolves with related governance needs; governance is a process not an end state. Indeed, lack of enforcement, compliance challenges, and changing technology requires constantly updating governance.

To understand how to evolve governance this research explored qualities of the three case studies including: member or stakeholder buy in (to the processes and outputs) via trust and member engagement; organisational agility via technically and scientifically competent members

and effective decision-making processes; the effectiveness of outputs (how strong are the legal or other requirements of the output and whether the IO can assess and encourage compliance), and whether the domain can be generally assessed as better for the regime. These qualities will inform ideal organisational characteristics and governance tools capable evolving governance over time.

Research Contributions to Space Governance

New space governance requires understanding what sort of organisational qualities are necessary so a forum can continuously adapt governance, and what type of governance tools (e.g., measures, outputs, etc.) are necessary for each emerging space activity discussed in chapters 5-7. The insights collected from this research include governance approaches that have the potential to positively shape new space governance and some lessons learned that are likely to hinder the development of new space governance. Identifying both positive and negative features from the case study can provide insight into the activities to emulate and those to avoid. Importantly, the findings confirm the importance of governance evolution as detailed by the discussion of Ostrom et al in chapter 2. They also contribute to the literature by showing that IOs can adopt organisational processes and procedures and governance tools to advance governance despite the ever present influence of state politics and power, an important insight for space governance.

The following subsections will first outline key characteristics of effective international organisations identified in the case studies. The next subsections will address case study insights for governance able to positively impact domain sustainability, traffic management, and emerging technologies. The final two sections will combine key IO themes and lessons learned from the first two subsections to better understand how new space governance can balance domain sustainability and development, with a specific focus on the organisational characteristics and governance tools most likely to benefit space governance.

Characteristics that allow international governance to evolve

Six key characteristics stood out across the case studies for their ability to enable the IO to adapt governance and continuously produce benefits. Indeed, as noted in chapter two's discussion of theory, benefits are a key reason states pursue international governance and related

to a global commons producing benefits requires evolving governance over time. These themes fit into two categories: organisation qualities and governance tools.

The first characteristic relates to the size of the IO as it relates to work capacity of each organisation or network. Each has grown overtime to manage the work necessary to govern. In the IMO's case, it has an assembly, council, five technical committees and several subcommittees and working groups. It is supported by a secretariate of 300 people. ICAO is similar with an assembly, council, five technical bureaus, administrative services, regional offices, and numerous working groups. In both cases, the assembly is the chief organ of the organisation while the council is responsible for most of the routine governing responsibilities. In the case of the IMO and ICAO, the use of councils helps to expedite work, though it is less inclusive than the assembly. The internet's multistakeholder nature provides a large network of organisations that cover various governance needs. ICANN, ISOC, IETF, ISPs and numerous others all address various aspects of internet governance. Whereas the IMO and ICAO are centralized the internet governance regime is not. This impacts how coordinated the internet governance regime is when developing measures to govern. In each case, however, each had to grow to accommodate an increasing volume of governance needs.

The second characteristic is the variety of governance measures used to govern. Capable of conducting work simultaneously through their various groups, each case study organisation leverages several types of governance outputs to affect member behaviour. Conventions are a principal source of legal authority used by the IMO and ICAO, while other measures like standards and recommend practices, codes, protocols, guidelines, and educational resources support the adoption and adherence of necessary governance. The IMO and ICAO use various types of agreements based on need, and many are designed to evolve overtime. For the internet, treaties and similar agreements are not common, though standards are. The technical nature of the internet means technical standards are as important to internet governance as treaties are to the IMO and ICAO. All three case study domains are also influenced by national laws and regulations. In all three cases, a tapestry of governance measures is produced to complement measures and provide a wide variety of tools states can use to affect governance of activities. In

each case study, new measures, amendments, and other governance tools were routinely produced or updated, creating a large and ever-changing body of governance.

The third characteristic is participation schemes. Agreements are produced through various member participation schemes. For the IMO and ICAO, membership is composed mainly of states with industry participation through state delegations or industry groups. For the internet, the reverse is true; industry leads most efforts while government has less influence over the development of standards and management of internet resources. The internet technical community requires little more than technical knowledge to contribute to standards development. Market incentives produce some disparity among internet actors based on the way an internet actor's market share can produce greater influence. An issue common across each case study are challenges members have staying informed across a growing body of work. For the IMO and ICAO, numerous efforts underway simultaneously made it difficult for developing states with small delegations to stay appraised and engaged, which impacted their willingness to support agreements. For the internet, a general lack of coordination among various groups within the multistakeholder network makes staying appraised of all activities nearly impossible.

The fourth characteristic is decision-making approach. Consensus decision making is common among each case study, however, with some differences. In general, consensus was valued across organisations, but where in the diplomatic process consensus was required and how it was achieved differed. The IMO and ICAO required more rigorous consensus processes for conventions or more legally binding agreements while using tacit acceptance or similar methods for more routine work, like SARPs or technical details added to IMO agreement annexes. Consensus is also important for ICANN and IETF but is achieved differently based on the work in question. Each case study organisations tended to contemplate how the associated trade-offs of seeking consensus (I.e., higher transaction costs for great compliance) would affect their ability to produce agreements, and then chose how to balance trade-offs by deciding where in the diplomatic process consensus was needed and the ideal method for achieving it.

The fifth characteristic is the organisation's scope of work. Expanding or evaluating what topics and responsibilities fell within the organisation's remit was common across case studies.

Issues related to environmental concerns or new technologies and use cases were routinely accounted for after organisation discussions. In some cases, the organisations would approach new governance needs through familiar methods, like SARPs in the case of ICAO. In other instances, new governance required new governance measures, like CORSIA or UTM. For the internet, the need to account for new governance needs did cause some strain on the multistakeholder governance model, as evident by the growth of IoT standards organisations in response to the emergence of IoT. Despite some differences, each case study was generally willing to take on new topics and expand its scope of work to account for new governance needs.

The sixth and final characteristic is compliance. Compliance was a challenge for each case study organisation or network. By design, the case study organisations did not possess the means to enforce government measures. So, to address weak compliance or similar issues, the IMO and ICAO developed audit schemes and tools to make it easier for states to understand compliance gaps and improve their compliance. Another tool used by the IMO and ICAO was to develop multiple complementary agreements and measures such that governance gaps were filled through a complement of measures rather than relying on a single measure. In the IMO's case, the organisation linked liability and audit measures with major conventions such that together the liability and audit schemes were tied to cornerstone agreements. The IMO also legitimized, through conventions, the use of ROs, which create a market incentive for compliance. For the Internet, some technical features made compliance less of an issue (e.g., single use domain names), while the multistakeholder nature of internet governance also complicated establishing compliance measures.

	Characteristics of IO that enable governance adaptation					
	Size of IO/Capacity for issues	Variety of Governance measures routinely used	Participation scheme	Decision-making approach	Scope of work	Compliance

IMO	Assembly, council, five technical committees, several subcommittees and working groups, 251 staff, and \$53M 2021 budget	Conventions, codes, protocols, non-binding guidelines, educational resources, standards and recommended practices.	State-centric with some industry/NGO involvement	Consensus based, flexible use of consensus based on agreement (e.g., tacit acceptance), Council makes many decisions	Routinely expands/adjusts scope of work based on governance need	Struggles with compliance, has audit scheme, reporting, and educational resources to assess/improve compliance
ICAO	Assembly, council, five technical bureaus, regional offices, many working groups, 737 staff, and approx. \$107M 2021 budget	Conventions, non-binding guidelines, educational resources, standards and recommend practices, and MBM	state-centric with moderate industry/NGO involvement	Consensus based, flexible use of consensus based on agreement (e.g., tacit acceptance), Council makes many decisions	Routinely expands/adjusts scope of work based on governance need	Struggles with compliance, has audit scheme, reporting, and educational resources to assess/improve compliance
Internet	Multistakeholder group consisting of many dozens of organizations, often industry led, ICANN budget of \$129M in 2021	Technical standards, business agreements	Industry/NGO-centric with some state involvement	Variety of decision-making approaches based on org in question, ICANN uses a menu of consensus approaches based on agreement/work in question	Routinely expands/adjusts scope of work based on governance need	Technical requirements influence compliance in important areas, as do business/legal agreements
Compared to space governance						
Space	Full committee, two subcommittees, a working group or two, 25 staff, and 2021 budget of \$4.5M	Treaties (the most recent from 1979) non-binding guidelines, educational resources, protocols	State-centric with some industry/NGO involvement	Strict consensus style required for nearly all decisions	Routinely adjusts scope of work based on what can be agreed upon by the full committee agreement	No compliance measures or tools

Table 1: comparison of governance characteristics between IOs. Green represents organisational qualities while blue represents governance tools.

International Governance and Sustainability

Interestingly, none of the case study organisations considered sustainability when they were created. Instead, it became a focus after it was clear that sustainability was key to preserving the benefits of each domain. For the IMO, a series of disasters, like the Torrey Canyon incident mentioned in Chapter 5, motivated states and the IMO to adopt measure that make marine sustainability a key focus area. The IMO incorporated marine security through 21 agreements and numerous codes, guidelines, and other measures. To address the topic, the IMO had to expand the remit of the MSC and create new groups, like MEPC. The IMO has undertaken a

consistent scope of work related to marine sustainability as evident by the more than 180 amendments SOLAS has undergone since 1981. Importantly, the IMO has tied liability to certain sustainability issues, creating a financial incentive to encourage compliance. The IMO has experienced some trouble regulating fishing vessels due to the perceived economic impact new regulations could have on fishing communities.

ICAO was operational for some 30 years before it began considering environmental issues in the 1970s. ICAO addresses climate change, aircraft noise, and emissions primarily through SARPs and CORSIA. SARPs are a routine feature for ICAO but CORSIA is new. The scheme reflects ICAO's willingness to explore new regulatory measures and take a more active role in climate change efforts. To develop this work, ICAO established CAEP. ICAO has not connected sustainability issues to liability conventions like the IMO has, and some criticisms of CORSIA, like that offsetting aircraft emissions rather than reducing them is a way to pass the buck, are also warranted as discussed in chapter 5. CORSIA is still early in its implementation, so its effectiveness is still unclear. Chapter 5 also discussed how ICAO tends to value sustainability measures through an economic lens more than an environmental lens, which has drawn criticism by those who believe favouring the economics of civil aviation undermines some sustainability causes. Still, ICAO has shown an ability to advance new governance to address sustainability concerns.

For the internet, CIRs are also something the multistakeholder group had to accommodate after it became clear internet numbers would be depleted. The solution involved developing a new internet protocol to add more addresses, however adoption of the new protocol has been slow. Addressing internet resource sustainability is one topic where the multistakeholder group had to act with more coordination than is routine. Despite more coordination, the new standard did not properly consider market incentives, which has been a leading cause of its slow adoption. Regulating internet names as another sustainability focus occurs primarily through ICANN's GNSO, which works to provide fair and equitable rationing of internet names. Issues do exist, however, like the market value of older Top-level domains relative to new Top-level domains created to offset scarcity.

Across the three case studies each was reactive in addressing sustainability concerns, but once the topic required attention it remained a focus area. Related to the six IO characteristics, there are useful lessons for each. Related to IO size and capacity, addressing a new sustainability topic required each organisation or network to create new working groups, like the MEPC, CAEP, and the IPng directorate, to provide focused attention and resources to related sustainability issues. Related to the variety of governance measures, each organisation relied on familiar and new measures to address sustainability concerns. In the IMO's case, its ability to stitch together different agreements through liability and other mechanisms has aided compliance of sustainability measures, while ICAO's focus on developing measures based, in part, on what makes economic sense has been seen as a weakness. The internet's adoption of IPv6 as a means to solve internet numbers shortage without market considerations shows the importance of considering economic incentives when addressing sustainability, however.

Regarding the third characteristic, participation scheme, broad inclusivity of IO members in the development of environmentally focused measures proved tricky for each case study. In part because developing states often do not have the diplomatic resources to participate in everything an IO does, and because the structure of new working groups, like CEAP, made it difficult to be inclusive of all members. Indeed, as the scope of work increases, member inclusivity tended to suffer.

Each case study shows that for characteristic four, agreement style, consensus was important, though each used consensus differently based on the agreement in question. For example, for ICAO SARPs consensus came through tacit acceptance while developing CORSIA took a more formal process through the ICAO assembly. Exploring the scope of work, characteristic five, showed the case study organisations or network had to expand its scope of work to accommodate sustainability issues. Expanding the scope of work included the topics (e.g., CO2 emission or domain names) and working groups, like CEAP or IPng.

Characteristic six, compliance, proved the most difficult for each case study organisation or network. Compliance is a weakness of IOs by design, but through education resources, audits,

and other tools IOs do have the ability to influence compliance. For environmental issues, compliance tended to increase with liability and market concerns.

A final observation is worth noting. While the IMO and ICAO are able to address sustainability concerns through more centralized processes, the internet relied on a much more decentralized process given its multistakeholder composition. There does appear to be some limitations with a more decentralized approach to domain sustainability given the way the internet regime struggles to encourage IPv6 adoption. The decentralized multistakeholder group also struggles to address new internet sustainability concerns spurred by the rise of IoT devices, like those discussed in Chapter 7. Conversely, the centralized approach of the IMO and ICAO allowed each organisation to address emerging issues without some of the difficulties facing the internet governance community, though neither did so perfectly or without challenges.

International Governance and Traffic Management

Unlike sustainability issues, traffic management is a topic that each case study governed from the outset. For each case study, governing traffic management centred primarily on facilitating the sharing of information. Each case study also showed the need to adapt traffic management schemes based on changes in technology.

Shipping traffic is guided by VTS, which is a way to standardise and share information, organize traffic, and provide navigational advice or assistance. States are responsible for VTS adoption and a ship's Master remains in charge of the ship's navigation but uses VTS information to make informed decisions. The IMO has sought to standardise the use of VTS by instituting it through several IMO agreements across safety, sustainability, and legal focus areas. The MSC and NSCR conduct most of the ship traffic management work for the IMO. IMO efforts are intended to be results oriented while leaving execution to the ship or VTS operator. The IMO is also thinking about the future of ship traffic management through E-navigation. E-navigation is expected to improve traffic management practices through more accurate and timely information that add financial value while reducing environmental impacts.

Like the IMO, ICAO aids states in the management of air traffic by helping to organize activities through SARPs, SUPPS, and PANs. ATM was called for in the Chicago convention and has undergone considerable change over the years. States remain principally responsible for ATM but organize around a shared international and regional traffic management approach through ICAO and several of its subsidiary bodies, like the ANC and subpanels. ICAO is also helping to evolve ATM through several agreements from standards to procedures and planning tools, like the GNAP and its performance-based strategy. GNAP is expected to create efficiencies in ATM to save fuel, reduce emission, and shorten flight times. Current and future ATM is predicated on the standardization of behaviours and information flows.

In contrast to the IMO and ICAO who offer a centralized means to coordinate states as they manage traffic, internet traffic is managed without centralized control at any level. ISPs, IXPs, content providers, and other internet actors manage traffic through private contracts and technical features, like deep packet inspection, that provide network operators with information to regulate traffic effectively. As the use of the internet has changed, so too have traffic management practices. The government does play a role in internet traffic management through regulations (e.g., net neutrality), but is otherwise uninvolved. The market influences internet traffic management in important ways unique to the internet compared to aviation and shipping. The internet must also balance privacy and security concerns in the management of traffic, which is unique compared to the other case studies. The multistakeholder approach does appear to create some conflict in managing internet traffic as stakeholders tend to have different incentives and means of affecting internet traffic management.

For each case study managing traffic is intended to create efficiencies and improve the functionality of the activity in question. Concerning the first of the six effective IO characteristics, size of the organisation and capacity, each case studied relied on several organisations and actors to manage traffic, which affected how IOs or the internet community address work related to traffic management. While the IMO and ICAO allowed for greater centralization, the internet generally reflected the opposite and struggled to govern internet traffic in ways the IMO and ICAO did not.

Concerning the variety of governance measures, the second characteristic, the generally decentralized nature of managing traffic present in the IMO and internet case studies shows governance organisations were limited in their use of governance measures to affect traffic management. For example, contracts between ISPs varied as did VTS practices. ICAO has a more centralized influence over air traffic, though it was still relegated to more of a facilitation role as states were principally responsible for managing traffic. For each case study managing traffic did include some element of organizing the use of basic traffic information to standardize certain practices. In all, managing traffic relied principally on creating uniformity through education and tools designed to share best practices.

For characteristic three, member participation scheme, a key lesson is how participation is influenced by the role each organisation or actor played in the complex traffic management ecosystem. IMO and ICAO members were able to influence the traffic management tools each organisation produced but could not influence how states adopted or used those tools. That various actors held unique roles in helping to govern traffic also influence characteristic four, agreement style. While the IMO and ICAO leveraged familiar consensus decision making approaches, the internet was driven largely by commercial or market interests that tended to complicate traffic management because agreements tended to result in zero sum vs relative sum trade-offs. Indeed, the commercial incentives of internet traffic management appears less suited for global commons.

Each case study demonstrates that the scope of work (characteristic five) associated with managing traffic is constantly changing. This requires IOs and the internet community to routinely adjust their work focused on managing traffic. Whether to account for new technologies, sustainability concerns, or the actions of others (e.g., state regulations), managing traffic requires a dynamic scope of work.

Finally, the last characteristic, compliance, is largely influenced by the benefit of uniform traffic managing traffic provides whole industries. For aviation and shipping, the more traffic management practices are shared the more the industry benefitted generally due to efficiencies and safety improvements. Conversely, the internet as a series of individual networks requires

sharing traffic to function, which necessitates similar traffic management practices. However, there is some ability to negotiate the cost of sharing internet traffic. In each case study, unique traffic management requirements also influence compliance. For example, not all aviation regions shared the same SUPPs nor does every ISP choose to regulate internet traffic the same.

In sum, each case study shows the need to manage traffic because doing so was a benefit to the industry. State sovereignty or commercial roles did limit the extent to which centralized coordination of traffic was possible, however. The confluence of needs and limitations meant the value of IOs was their ability to provide useful tools for states to make informed decisions to aid cooperation. For the internet, cooperation and coordination of traffic management tended to extend as far as made business sense.

International Governance of Emerging Technology

The governance of emerging technologies requires the IMO, ICAO, and multistakeholder group that governs the internet to routinely update or develop new governance measures to balance important aspects of domain safety and security with the continued advancement of the technologies expected to advance each industry.

For the IMO, governing autonomous shipping required understanding how the new technologies would fit within existing governance measures. The IMO conducted three scoping exercises to understand how autonomous shipping aligned with its existing remit and governance agreements. The scoping exercise helped to inform recommendations to account for gaps in governance. The IMO also used different measures to close governance gaps in a manner that reflects agility and flexibility. It leveraged non-binding guidelines to quickly provide high-level safety guidance and initiate a dialogue while working to understand governance needs and produce more impactful measures. The IMO also established new groups to address the topic within the organisation given existing working groups did not offer sufficient coverage for autonomous shipping needs. Part of the IMO's approach to MASS is to guide states through safe and sustainable development of autonomous ships through performance-based measures, which help to balance the need for innovation without sacrificing sustainability. Moreover, the IMO performed this work in relatively short order between 2017 and 2022. The timeline reflects an

agile organisation with appropriate processes and stakeholder buy-in concerned with enabling shipping innovation.

In response to the growing UAS industry, ICAO performed a similar assessment to the IMO's scoping exercises to understand how the new technology will or will not fit within ICAO's remit and existing measures. The exercise led to a strategic scoping document to guide ICAO through the governance of UAS. Through new groups, like the UAS-SG, and related outputs, ICAO works to guide states by providing information to inform national regulations because uniform national regulations can facilitate the development of international measures. ICAO also develops SARPs and other standards to guide UAS use and to incorporate it into existing governance schemes, like ATM. Many of these programs of work have gone through multiple iterations to evolve as UAS needs evolve. Between the variety of outputs, the growth in working groups, and the timeline within which ICAO was able to assess needs and produce useful governance suggest ICAO is generally capable of adapting as international aviation changes without unduly limiting innovation.

Unlike the IMO or ICAO's governance of emerging technologies, governing emerging internet technologies, like IoT, is done through the multistakeholder model. While prominent internet governance organisations, like IETF and ICANN, continue to play a role, the growth of IoT has been challenging for the internet governance community to regulate. Standards play an important role in IoT governance like many features of the internet, however the growing financial value of IoT has motivated the IoT industry to diverge from traditional standards development processes and seek entirely new ones. Indeed, there has been incredible growth in IoT standards development organisations and in the number of standards designed to limit interoperability among IoT devices. The lack of centralized control over governance and the market's influence has challenged the multistakeholder model's ability to preserve important feature of the internet, like interoperability. The internet case study diverges from aviation and shipping case studies by showing how less centralized coordination of governance can prove challenging when economic incentives clash with the need to think about the domain over individual actors.

International governance is often reactive given the diplomatic nature of the work. When governing emerging technologies, the case studies show that while initial efforts to govern typically come after new technologies are sufficiently mature, governance can also shape how such technology is advanced if there is sufficient centralization. For example, the IMO and ICAO both responded to emerging technologies with governance that attempts to guide technology development and national regulations. Governance also seeks to encourage the development of those technologies while limiting harmful consequences of developing novel technologies. Conversely, the internet's lack of centralized control over governance has led to a more chaotic response that industry and the market are shaping more than what might be beneficial for the internet community broadly.

Each case study offers useful lessons for key IO characteristics. In all three case studies new technologies required the organisations or network to grow. New working groups or standards organisations were required to address more work and the novel nature of it. Similarly, each emerging technology require a variety of governance measures, often starting with measures requiring less bureaucratic processes, like non-binding guidelines, before undertaking more legally binding or comprehensive measures. To create new working groups or standards organisations and produce a variety of measures requires an inclusive member participation scheme, though for the internet participation tended to be more selfish in nature given market incentives around IoT standards. Consensus continued to play a central role in the IMO and ICAO case studies, though less so for IoT given many IoT standards organisations were created to offset the need for broad consensus. For each case study the new technology required reassessing the organisation or network's scope of work and a willingness to expand the scope of work to ensure proper governance. Compliance was harder to assess because many of the governance measures within each case study were new and either non-mandatory, designed to inform the creation of national regulations, or educational resources for states. In all, despite the important difference between autonomous shipping, UAS, and IoT, each offering insight into the governance of emerging technologies.

The themes and approaches detailed in the case studies offer several valuable lessons for how new space governance could be developed to address emerging space technologies and services while improving space sustainability.

Informative Organisational Qualities for Adapting Space Governance

The case studies offered two examples of centralized governance through IOs and one example of a decentralized approach through the multistakeholder model that governs the internet. There are some benefits to the decentralized model; industry is very closely incorporated and there tend to be fewer political and other barriers to advancing new governance measures. The multistakeholder model does struggle to coordinate governance across the ecosystem (e.g., IoT standards with privacy and security), and can be overly influenced by economic markets. For these reasons, a more centralized approach through an IO is likely better suited to address more of the governance challenges currently affecting the sustainable development of space.

Drawing on the lessons from the case studies, sustainability challenges, STM requirements, and managing emerging space technologies can all be more appropriately managed by an IO than a decentralized model. Parts of STM, like the data, could be managed by a decentralized network connecting through an impartial third party, like an IXP for SSA data, but the other features, like norms and laws for STM behaviour, would not be well suited by a decentralized model. An IO is also better suited because of the symbiotic nature of emerging space activities. As mentioned in the introduction of this section, small satellites and constellations, STM, and ORPSAO are complementary activities that affect one another. Thus, how each is governed can also affect the other activities and whether they lead to more sustainable development practices. The symbiotic relationship also suggests that governing each will require close coordination. Lastly, an IO, COPUOS, already exists.

At the heart of an effective IO is its ability to make decisions. Indeed, whether to expand the forum's remit, amend conventions, produce standards, or create a new sub-committee, a governance forum must be able to come to agreement and solidify decisions. In international fora this often depends on consensus at some point in the process. Consensus is often the preference

in international governance because it requires cooperation and because it can improve compliance. Consensus also increases transaction costs, however.

Importantly, consensus is a tool to advance governance, not a form of governance. As evident in the case studies, a thoughtful consensus decision-making process that weighs increased transactions costs with compliance needs is important for utilizing consensus effectively versus having consensus requirements stall the organisation, as is the case with COPUOS. Moreover, leveraging consensus also requires deciding where in the diplomatic process consensus is necessary. Where COPUOS requires it for nearly all decisions, the case study organisations were often more thoughtful about which decisions could be advanced without consensus. Being thoughtful about the means of achieving consensus (e.g., vote vs tacit acceptance) and where in the diplomatic process consensus was required allowed the case study organisations to leverage consensus without letting decisions get bogged down through prohibitive transaction costs.

How an organisation makes decisions can not only affect individual outputs, but the perceived significance of each. Like how economic scarcity can inflate the value of a product or service, when an IO struggles to advance governance measures each new measure can see its value inflated. As a governance measure's value increases to too does transaction costs as states work harder to see their interests accounted for in the uncommon production of a new agreement. For states, it may not be clear the COPUOS can amend or update governance in the future, so states are incentivized to press their interests at each opportunity. Conversely, if an organisation is capable of routinely advancing new agreements, states may not see the same need to fiercely defend their interests as the agreement is developed because they know amending the agreement is always possible based on the organisations history of developing and amending measures. Applying a more tactful use of consensus to adjudicate governance needs and produce outputs is, therefore, a key take way from the case studies. Indeed, without a pragmatic approach to consensus, COPUOS, or any other organisation responsible for governing space, is unlikely to evolve as governance needs change.

In addition to improved decision-making, an appropriately size and resources secretariat is also likely to increase the effectiveness of a space governance forum. A secretariate empowers the forum to undertake work outside of formal session, which was necessary across case studies and would certainly be necessary to govern emerging space activities. While the UN Office of Outer Space Affairs performs such duties for COPUOS, the Office of Outer Space Affairs is small and under resourced to take on a larger body of work necessary to see COPUOS adapt with governance needs.

Issue specific subcommittees or technical organs within COPUOS would also be necessary and offer specific and focused resources to address changing governance topics. As evident by the case studies, the number and type of forum organs should also be expected to change over time as new organs are necessary or existing organs are found unnecessary. For issues like STM, there may need to be organs, like regional offices in aviation, that help coordinate more acute issues related to governing STM. These bodies would benefit from being trusted with information, like SSA data, and empowered to act on certain matters without full committee approval. Without appropriate secretariat resources, however, it is unlikely that an IO could change in size and work volume overtime. Given COPUOS is not a specialized agency like the IMO or ICAO, but falls within the UNGA, increasing the size of the secretariate would require greater UNGA support and funding.

Finally, industry inclusivity was also shown to aid governance development. Each of the case studies included industry to a greater extent than they are included in COPUOS. While States are still the principal actors within the IMO and ICAO, the insight and, in some case influence, of industry can greatly aid in the advancement and adherence of governance. With industry leading much of space development today, it would seem short sighted not to include industry in the development of space governance to a greater extent. Space is not unique in its reliance on commercial industry compared to shipping, aviation, or the internet. What is unique is COPUOS' inability to change to accommodate industry.

The role of commercial industry in space is somewhat new and rapidly growing, yet COPUOS is structured around the role of states in space. Without an ability to change how it

operates to be more inclusive of commercial industry, COPUOS is poorly suited to leverage the value and responsibility of industry as space is developed. Conversely, as the internet case study and to a lesser extent the aviation case study show, industry involvement should be balanced to ensure market incentives and other commercial motivations do not undermine the need to balance development and sustainability. Too much commercial industry influence was shown to have a negative impact on governance in as much as it complicated coordination and addressing some sustainability issues.

While it is clear space governance needs to adapt, current political tensions within the international community are likely to make changing COPUOS' features from within the organisation difficult. A two-thirds UNGA vote could be used to force COPUOS to change, but the institutional power held by major spacefaring states, including the US, Russia, and China, could make achieving two-thirds difficult as well, though it is more feasible than change from within COPUOS. While changing COPUOS' features will require concerted political attention by leading space nations, once such change has occurred, COPUOS will be better positioned to advance new governance despite some of the political or power dynamics among its members. Indeed, to adapt space governance such that it provides better, continued benefits to states COPUOS will need to adjust its processes and procedures. Features of an IO are only half of what is necessary to effectively govern. The other half is the agreements the IO produces to govern individual activities and address issues.

Improving Space Governance via Governance Tools

In addition to the forum qualities discussed above, the types of governance measures, like conventions, guidelines, standards and recommend practices, codes, MBMs, and many others were also identified as critical to effective governance. The case studies showed that various governance outputs are suited for different governance need, and a mix of governance measures offered a complementary way to create a more adaptable and effective system of governance. Standards and recommended practices and performance-based measures offered expeditious ways to produce governance tools to guide emerging technologies and sectors with routine innovation. Non-binding measures, like guidelines, were often used to quickly inform members of key considerations and initiate dialogue on new issues while the IO worked to understand

governance needs and produced more comprehensive measures. Less substantial measures were complemented by legally binding measures, like conventions. Conventions were routinely amended or updated to ensure they provided legal means for new governance. The ability to update major governance measures through amendments or other changes is an important aspect of effective governance. Amending, rather than creating a net new agreement, can allow an organisation to evolve governance issues without higher transaction costs associated with a new legally binding agreement. Audit schemes supported agreement adherence by highlighting gaps in compliance and through the incorporation of the audit scheme into cornerstone agreements with broad IO member adoption.

Importantly, while diplomatic negotiations did affect the type of governance measure eventually produced, each case study organisation leveraged on a wide variety of available governance tools. The IMO and ICAO case studies also show that with certain topics, like liability in the IMO's case, several unique agreements can produce a complementary scheme while reducing some transaction costs incurred by more comprehensive treaties.

In contrast to the variety and routine ability to update agreement present in the case studies, COPUOS has a difficult time producing agreements of any sort. Moreover, COPUOS has demonstrated a pattern of perusing increasingly less comprehensive or binding measures over time because diplomatic processes have made it too difficult to strive for more politically sensitive agreements like conventions. The number of governance gaps in existing space governance suggest several new measures—from conventions to guidelines and everything in between—would greatly benefit the sustainable development of space.

Given the utility of scoping exercises used by the IMO and ICAO, identifying what measures are necessary for space governance could be aided by a robust scoping exercise(s) that seeks to identify gaps in existing space governance and the most pragmatic means of filling them. In terms of governing satellite standards, ORPASO, and STM, a scoping exercise would offer value by examining how existing space governance encourages the sustainable design, operation, and disposal of satellites and enables standards for basic ORPSAO activities. For STM, a scoping exercise could add value by exploring what COPUOS' role should be in

managing space traffic. Given the topic is underdeveloped in space governance broadly, COPUOS may find it difficult to understand its role. If that were the case, as ICAO has done for UTM, COPUOS could offer tools to inform states on useful STM practices while exploring how to expand its remit to offer more substantial STM governance through standards and recommended practices or other measures.

Following a scoping exercise, non-binding guidelines outlining basic, though high-level, concepts could offer COPUOS a way to initiate broader dialogue on the issue while keeping transaction costs low. The purpose of the non-binding guidelines is to initiate dialogue necessary to develop more comprehensive measures capable of influencing member state activities. While non-binding guidelines can influence state behaviour, more comprehensive measures have a greater ability to set legal precedence or create common operating standards that the case studies show to be useful in effective governance. For small satellites and constellations, non-binding guidelines designed to limit debris and promote the long-term sustainability of space already exist. However, as discussed in Chapter 3, there are gaps in the guidelines. New non-binding guidelines for satellite constellation would add value by addressing in greater detail specific design, operation, and disposal practices and concepts. For ORPSAO, non-binding guidelines would add governance value by addressing basic communication and behaviour practices designed to improve transparency of ORPSAO operations and basic safety expectations. STM guidelines could similarly add value by focusing on SSA best practices and improving communication to enhanced STM transparency and coordination.

Following non-binding guidelines, more substantial governance measures would be necessary to create a space governance regime capable of balancing sustainability and development. In some instances, amending existing agreements through codes or annexes could provide necessary updates with lower transaction costs. For example, amending the Registration convention to enhance reporting could aid STM through basic SSA data sharing improvements. In other instance, entirely new agreements would likely be necessary. ORPSA could be aided by standards and recommended practices outlining technical standards and norms of operation.

Space governance is also in need of measures that encourage compliance and enforcement. While COPUOS or another IO is not likely to have the means to ensure enforcement, audit schemes have been shown to improve compliance. Audits help to inform states of noncompliance while provides the insight to help them improve. The use of ROs for space activities could also improve compliance. By linking industry incentives to compliance through ROs for satellites, it could encourage better adherence to governance measures designed to aid space sustainability. Both measures would benefit from new liability and compensation agreements and a forum for arbitration. The case studies also show that whatever form governance measures take, they should be developed to evolve overtime or with the expectation that it may be replaced. Governance is a process, not an end state, so IO outputs must be developed accordingly.

While not all states have the same capacity to develop space, the benefits space brings are largely shared. Addressing these disparities in the creation of new governance would aid in compliance and member buy in as more states become spacefaring. Measures like GNAP, which seek to help members advance aviation capabilities overtime are well suited to address space development differences among nations. Educational resources, like model regulations, were also shown to help developing states take more active roles in advancing governance.

An organisation that can pick from a menu of governance tools is shown to empower the evolution of governance and ultimately its effectiveness. Conversely, an IO relegated to a limited set of tools is unlikely to meet ever-changing governance needs. Indeed, a menu of governance tools helps to offset political challenges of producing new measures by affording the IO with governance options that fall at different ends of the political risk spectrum (e.g., nonbinding measures are typically less politically sensitive than a treaty). For space governance, given the lack of clear institutional power by any single COPUOS member and the political tension between them, a menu of governance tools that offer the means to account for political concerns is vital to evolving governance.

Options for Future Research

While the qualities discussed above are likely to improve space governance, it is ultimately up to states to pursue and support necessary change. As has been the case in COPUOS for some time, politics and stubborn processes are likely to make reforms difficult. Creating a new IO could offer a path to overcome the roadblocks within COPUOS, but that too would require considerable political will by several major spacefaring countries. A more feasible option could be to make COPUOS a specialized agency like the IMO and ICAO. As a specialized agency COPUOS would be funded by members, rather than UN budget, so it would likely be easier to increase resources to the forum to address the growing volume of work and larger secretariat. As a specialized agency the forum would no longer report directly to the GA, and therefore, have more autonomy to change over time. Specialized agencies also tend to have more industry participation. Finally, in transitioning to a specialized agency, COPUOS could adopt many of the changes listed above as part of the transition process rather than adjudicating them individually through the forum's current structure.

Such a change would be a substantial one by most measures. By no means would making such a change be simple or require less political capital than simply reforming COPUOS as it currently sits within the UNGA. Conversely, it would require less political capital than seeking to create an entirely new organisation better suited to govern space, and a specialized agency is likely to offer more governance benefits than if COPUOS was to stay apart of the UNGA. In either case, turning COPUOS into a specialized agency deserves further research.

Additional research exploring the benefits and limitations of a specialized agency for space would be a useful first step. Future research would need to consider how to enact reforms so a new COPUOS would possess the characteristics of effective IOs detailed above. Such research would benefit from exploring ICAO and the IMO among other organisations to understand how they have managed reforms over time. Future research focused on transitioning COPUOS to a specialized agency would likely also need to explore the formal processes within the UN that would aid or hinder a transition. Another useful topic would be the diplomatic method used to organize states and their preference to transition COPUOS out of the UNGA. For example, a Chicago convention like forum could aid in establishing key elements of COPUOS as a

specialized agency following approval from the UNGA. Political considerations would be important to explore as well. Space is increasingly important for economic, military, and scientific benefits meanwhile increasing major power competition between the United States, China, and Russia suggest diplomatic headwinds would likely be strong while attempting to negotiate major changes to COPUOS. Understanding how political considerations would create barriers and opportunities would therefore be important for future research.

It would also be useful for future research to explore how space governance could adopt a multistakeholder model like the internet instead of a centralized model offered through a specialized agency. While this research suggests there are limitations to such an approach for space governance, there are aspects that could be beneficial. For example, the lack of sovereignty in space suggests an STM regime may benefit from a more decentralized data sharing model built around access to transparent, accurate, and trusted SSA data. Similarly, the internet's standards setting community offers a novel way to advance technical standards in an innovation rich industry like space. To better understand these and other possible benefits future research would be necessary.

Finally, future research should explore the cost and consequence of inaction, or not advancing new space governance. This research has made the case that the costs of inaction would be high and consequences severe. However, additional research providing a more detailed assessments of the costs and consequences of ungoverned satellites constellations, ORPSAO, and STM on space development would provide additional support necessary to motivate states and industry to develop new governance.

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