January 2022

# Is United States (U.S.) Policy Sufficient To Develop Earth-Moon Economic Zone Infrastructures By 2049?

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# IS UNITED STATES (U.S.) POLICY SUFFICIENT TO DEVELOP EARTH-MOON ECONOMIC ZONE INFRASTRUCTURES BY 2049?

by

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A Dissertation

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

Grand Forks, North Dakota

August
2022

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Degree: Doctor of Philosophy

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Department Aerospace Sciences

Degree Doctor of Philosophy

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Terry J. Jaggers
July 27, 2022

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## ACKNOWLEDGMENTS

I wish to express my sincere appreciation to the members of my advisory Committee for their guidance and support during my time in the doctor's program at the University of North Dakota. I also would also like to acknowledge the experts who participated in the interviews for this study. Their responses have not been attributed to specific data in the analysis. The participants were asked to review the document analysis results and make recommendations but were not asked to review any other material or endorse the conclusions.

## ABSTRACT

The nation first-to-develop infrastructures in the future Earth-Moon Economic Zone will set the standards that shape and govern use by others, increasing both economic and national power. Current U.S. economic and national power is built upon a legacy of infrastructure leadership on Earth and in Earth orbit. However, China has a goal to supplant U.S. infrastructure leadership on Earth and establish leadership before the U.S. in the Earth-Moon Economic Zone by 2049. While the U.S. acknowledges China's terrestrial infrastructure goals as an economic challenge, China's space infrastructure goals appear to be met as either a military challenge in Earth orbit, or a prestige challenge to land a human on the Moon. Despite China incorporating infrastructure goals into their 2017 constitution, there has been no scholarly review of U.S. policy to develop infrastructures in this zone before 2049. The purpose of this study is to explore the sufficiency of U.S. policy to develop Earth-Moon Economic Zone infrastructures by 2049. The target audience is the U.S. National Security, National Space, and National Economic Councils, U.S. Congress, U.S. Department of Commerce (DOC), U.S. Department of Defense (DoD), National Aeronautics and Space Administration (NASA), U.S. Industry, and think tanks. This study was limited to the Earth-Moon Economic Zone from Earth orbit to the surface of the Moon, and both Trump and Biden U.S. national security, national space and select NASA budget documents since 2017. A qualitative analysis was used to review U.S. policy with an initial researcher-led document analysis followed by expert interviews for corroboration and supplemental information such as new policy. If any changes or new policies were identified,

then U.S. policy reviewed was deemed not sufficient. The interview analysis corroborated five recommended changes and identified three new policies, so current U.S. policy was deemed not sufficient. While recommendations were not analyzed, the Researcher opines four as critical; adding a more unified infrastructure competition strategy across all infrastructure domains, including sustained operational dates for specific infrastructures in both policy and budgets, creating a national economic strategy for U.S. Earth-Moon Zone investment, and development of a whole-of-nation industrialization plan for Earth-Moon Zone infrastructure development.

## INTRODUCTION

The underlying premise of this study is that the nation first to shape and develop infrastructures used by other nations will establish the precedents, behaviors, and technical standards for others to follow, and as a result gain significant economic, military, and diplomatic national power over others who rely on these infrastructures. Given the strategic competition with China over space infrastructures, a focused and synchronized set of national policies and investment programs are needed to ensure the U.S. is first to develop infrastructures in the Earth-Moon Zone. The alternative is to cede the race to China and allow them to establish the precedents, behaviors and technical standards for the U.S. and others to follow. National power gained in space contributes to a nation's power on Earth, ceding economic development of Earth-Moon Zone infrastructures to China also cedes national power.

Infrastructures in market-driven economies are public public-private or private products & services to enable industry market success (a market complimentary) or address an indirect positive or negative effect from the market activity (a market externality). These services can be non-profit/public, public-private, or for-profit/private. If private with multiple offerors these infrastructures can become a market unto itself (like the U.S. telecom market). Examples on Earth include telecommunications, energy generation and distribution, highways, passenger or cargo transport systems, etc. The U.S. has a long history of developing infrastructures to enable market growth while increasing national power, such as the transcontinental railroad to open the American West, the aerospace industry after the birth of aviation, the telephone industry, and a host of public work projects at the federal, state and local levels. In the global commons such as space, one only needs to point to U.S. global satellite communication systems, or the U.S. global positioning system (GPS) as providing the underlying infrastructure for international navigation at sea and in the air, timing for global financial transactions, and of course the global internet.

As with land, air, sea and cyber, the U.S. has enjoyed a position of space infrastructure leadership on Earth and in Earth orbit since the 1960s. Since the cold-war space race, U.S. infrastructures evolved to provide access to and operate in Earth orbits, in part due to President Kennedy's national policy to land a human on the moon by the end of the decade before the Union of Soviet Socialist Republics (U.S.S.R). Today's space infrastructures enable terrestrial activities or provide access to and operations in Earth orbit, from low Earth orbit (LEO) out to geosynchronous Earth orbit (GEO). These Earth-based and Earth-orbiting space infrastructures certainly provide a common good such as Earth science and national defense, but they also generate significant economic, diplomatic and military power for the nation who develops and operates them. In fact, the U.S. has considered itself the undisputed leader in space and codified this leadership expectation in the 1982 Reagan National Space Policy by stating the U.S. shall conduct civil space programs, "to preserve the United States leadership in critical aspects of space science, applications, and technology; and to further United States domestic and foreign policy objectives" (The White House, 1982). This policy was later codified in Title 51 U.S. Code (51 USC) Subsection 20102 paragraph (a)(5) as, "The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere" (National and Commercial Space Programs, 2010), and has been a hallmark obligatory statement in every national space policy from 1982 to present, even as the U.S. expands beyond Earth orbit to the Moon and deep space. Elite discourse on returning to the Moon and beyond for scientific data gathering, human exploration and settlement, resource recovery, and defense has led to several "on-again-off-again" beyond LEO infrastructure efforts. The most ambition for human exploration was President George W. (G.W.) Bush's 2004 Vison for Space Exploration to use

the Moon to go to Mars, which prompted a number of logistics and supply chain infrastructure studies and planning efforts. However human exploration beyond LEO was scaled back by President Barack Obama's focus on commercialization of LEO infrastructures and future commercial resource recovery from asteroids.

Meanwhile, in a bid to return China to greatness through economic power, President Xi Jinping formulated the goal of displacing current U.S. global infrastructure leadership by 2049. Jinping's 2013 economic policy is termed the Belt and Road Initiative (BRI), a transcontinental long-term policy and investment program which aims at China-led infrastructure development and acceleration of the economic integration of countries, initially along the route of the historic Silk Road. The BRI was incorporated into the Chinese Constitution in 2017. In 2016, a Chinese Defense Official acknowledged the BRI includes space, specifically Earth orbit assets such as the BeiDou navigation system and in 2019 Bao Weimin, Director of the Science and Technology Commission of the China Aerospace Science and Technology Corporation (CASC), discussed an ambitious proposal to establish an Earth-Moon Economic Zone by 2049 effectively acknowledging the inclusion of the new Earth-Moon Region as part of China's BRI and economic strategy. China, through the BRI in their constitution, desire to lead infrastructures on both Earth and in space, and the U.S. through their Title 51 USC desire to preserve leadership in space, are now entangled in economic race to lead development of space infrastructures before the other. Since China's 2049 BRI goal was codified as national policy in their 2017 constitution amendment, there has been a 2017 National Security Strategy, 2020 National Space Policy and yearly NASA budget requests under President Donald Trump, and a 2021 Interim National Security Strategy Guidance, 2021 U.S. Space Priorities Framework and two NASA budget request under President Joe Biden.

To date, there has been no scholarly review of these U.S. policies to develop infrastructures in the Earth-Moon Economic Zone by 2049. Questions remain as to the sufficiency of Trump's policies, Biden's policies, and trends to ensure the U.S. has sufficient policy to develop infrastructures in the Earth-Moon Zone before 2049. While there are questions involving "should" the U.S. continue to lead in this new space zone and "if" China possess a real threat. The assumption is that the U.S. will adhere to Title 51 USC for continued space leadership and be guided by historical precedent to maintain their infrastructure leadership, and that China's incorporation of BRI into their constitution to displace U.S. infrastructure leadership and demonstrated space accomplishments indicates an economic threat. Given the assumption of a real competition for space infrastructure leadership, the question remains as to the sufficiency of U.S. policy to develop Earth-Moon space infrastructures before 2049. If U.S. policy and programs are not sufficient to develop future Earth-Moon Zone infrastructures by 2049, China may be first-to-market and set the standards that shape and govern use by the U.S. and others, increasing their economic and national power.

## BACKGROUND

The underlying premise of this study is that the nation first to develop infrastructures used by other nations will establish the precedents, behaviors, and technical standards for others to follow, and as a result gain significant economic, military, and diplomatic national power over others who rely on these infrastructures. There is ample evidence in history on Earth of how scientific exploration of the New World by European mariners, military conquest and colonization, and commercial trade has prompted both public and private investment in infrastructures to either enable these markets to fill a role for the public good (Samuleson, 1954), or profit from them both commercially and nationally once they have been established.

Infrastructures in market-driven economies such as in the U.S. are public, public-private, or private products & services to enable industry market success (a market complimentary) or address an indirect positive or negative effect from the market activity (a market externality). These services can be non-profit/public, public-private, or for-profit/private. If private with multiple offerors these infrastructures can become a market unto itself (like the U.S. telecom market). Examples on Earth include telecommunications, energy generation and distribution, highways, passenger or cargo transport systems, etc.

The U.S. has a long history of developing infrastructures to enable market growth while increasing national power, such as the transcontinental railroad to open the American West, the aerospace industry after the birth of aviation, the telephone industry, and a host of public work projects at the federal, state and local levels. In the global commons such as space, one only needs to point to U.S. global satellite communication systems or the U.S. GPS as providing the underlying infrastructure for international navigation at sea and in the air, timing for global financial transactions, and of course the global internet.

The Soviet Union launched Sputnik in 1957. As a result, the National Advisory Committee on Aeronautics quickly became the NASA and a surge of USG spending ensued through the Apollo program during the 1960s. This cemented what Dr. Mathew Weinzierl, Professor of Business Administration at Harvard Business School, called a public-sector centralized model of U.S. space financing and decision-making with NASA as the hub for the next 50 years (Weinzierl, 2018). The shift in public to private financing and decision-making is well underway to commercialize the existing USG infrastructures in near-Earth orbit, but still relies on the centralized model of U.S. financing and decision-making with NASA as hub to develop new infrastructures beyond near-Earth orbit. Given the strategic competition with China over space infrastructures, a focused and synchronized set of national policies and investment programs is needed to ensure the U.S. is first to develop infrastructures in the Earth-Moon Zone. The alternative is to cede the race to China and allow them to establish the precedents, behaviors and technical standards for the U.S. and others to follow. National power gained in space contributes to a nation's power on Earth, ceding economic development of Earth-Moon Zone infrastructures to China also cedes national power.

The U.S. has been amassing Earth orbit infrastructure leadership since the early days of the space race. As early as 1960 Von Braun spoke of the need for "space logistics" citing three regions of concern: near-Earth, the lunar region (what the Chinese call the Earth-Moon Zone today), and the planets (AIAA Space Logistics Technical Committee, 1960). Von Braun was enthralled not only with his vision of space stations, but the need to support them with propellants and fuels, crew provisions, maintenance and upkeep, waste disposal, etc. When Von Braun was put in charge of Marshall Spaceflight Center, there were several concept studies started that all involved logistics support as he envisioned it in 1960. Von Braun's team studied

extended-stay lunar missions, a large crewed solar telescope and various small space stations under the Apollo Applications Program (Benson & Compton, 1983). At the same time, the U.S. Military's Manned Orbiting Laboratory (MOL) began to mature in the 1960s and the military turned their terrestrial logistics expertise toward space logistics to support it on orbit. While the MOL did not materialize, the military paused their thinking on space logistics. In the 1970s, a very nascent civil earth orbit space logistics effort began to take shape for the Skylab space station program. Between 1973 and 1974, NASA provided support to three crewed missions. The logistics was provided by the Saturn rocket consisting primarily of crew provisions which is sometimes referred to as upmass (payload carried up to orbit from Earth) as opposed to downmass (payload carried down to Earth from orbit). With the advent of the International Space Station (ISS) becoming operational in 2000, both upmass and downmass logistics had finally been realized from Von Braun's original 1960's vision, albeit still only in near-Earth orbit.

As an artifact from the space race, the U.S. felt itself the undisputed leader in space and the Reagan Administration codified the role in the 1982 National Space Policy by stating the U.S. shall conduct civil space programs, "to preserve the United States leadership in critical aspects of space science, applications, and technology; and to further United States domestic and foreign policy objectives" (The White House, 1982). This policy has since been codified in Title 51 USC Subsection 20102 paragraph (a)(5), "The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere" (National and Commercial Space Programs, 2010). The policy for U.S. space leadership has been in place from 1982 to

present, though throughout the 1980s and 1990s, the focus has been primarily on near-Earth orbit leadership.

Since then, returning to the Moon and beyond for science/exploration, tourism/human settlements, resource extraction, and defense/intelligence has led to several "on-again/off-again" U.S. and internationally funded programs since President George W. (G.W.) Bush to President Barack Obama. There was a fervor of lunar and interplanetary space infrastructure activity during the G.W. Bush years from January 2001 to January 2009. Even though the 2006 Bush National Space Policy is devoid of any specific language on the subject of infrastructures, many programs were begun to support the February 2004 Vision for Space Exploration to "return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations" (NASA, 2004). This vision inspired an extension of space logistics and infrastructure thinking from Earth orbiting space stations to the Moon and beyond. With the creation of the Constellation Program for space access and lunar outposts serving as stepping-stones to Mars, there were several NASA funded efforts to study logistical infrastructures, to include a $3.8 million award to Massachusetts Institute of Technology (MIT) to model the interplanetary supply chain network from Earth-Moon-Mars orbits, expected landing sites, and the orbit transfer routes between them (Halber, 2007). And while NASA let contracts to study interplanetary logistics for their lunar and Mars program, they simultaneously set about commercializing a logistics support infrastructure in Earth orbit to support the ISS with the creation of the Commercial Orbital Transportation Services (COTS) program in 2005 (NASA, 2021). Unlike NASA, the military interest was in unmanned autonomous systems which were not only high risk technically but expensive. Both technical and cost considerations were partially addressed with the launch of the Air Force Research Laboratory (AFRL) Experimental Satellite System-11 (XSS-11) in 2005.

The XSS-11 was a new class of low-cost spacecraft used to explore space serving, autonomous rendezvous and proximity operations, and other militarily significant activities (AFRL, 2011). Two years later, the Defense Advanced Research Projects Agency (DARPA) created the Orbital Express Program. While XSS-11 was more a demonstration of satellite inspection using autonomous proximity operations, Orbital Express' goal was to develop safe and cost-effective approaches for autonomous rendezvous and the creation of a satellite servicing infrastructure to support their military systems in Earth orbit (DARPA, 2007).

The Obama 2010 National Space Policy was shaped by an increasingly congested, competitive and contested space environment and the cancellation of NASA's Constellation Program. A military anti-satellite (ASAT) test in 2007 led to stronger military language in space policy such as, "increase assurance and resilience of mission-essential functions enabled by commercial, civil, scientific, and national security spacecraft and supporting infrastructure against disruption, degradation and destruction, whether from environmental, mechanical, electronic, or hostile cause" (The White House, 2010, p. 4), and "The United States will pursue bilateral and multilateral transparency and confidence-building measures to encourage responsible actions in, and the peaceful use of, space" (The White House, 2010, p. 7). Space policy guidance to NASA was to forego a sustained human presence on the Moon stating, "By 2025, begin crewed missions beyond the Moon, including sending humans to an asteroid. By the mid-2030s, send humans to orbit Mars and return them safely to Earth" (The White House, 2010, p. 11). Coupled with the cancellation of the Constellation Program, much of the discourse around interplanetary and Earth-Moon supply chains and logistics stalled. However, as a result of the 2010 National Space Policy mandate for NASA to "seek and encourage, to the maximum extent possible, the fullest commercial use of space" (The White House, 2010), NASA

contracted Roger Launius to produce his book, *Historical Analogs for the Stimulation of Space Commerce*, where he investigates historical episodes in America where the U.S. undertook public-private partnership efforts to complete infrastructures on Earth (Launius, 2014). His analysis attempts to apply lessons-learned from several terrestrial infrastructure analogies to LEO including developing the transcontinental railroad, fostering the aerospace industry, creating the telephone industry, supporting scientific research in Antarctica, advancing public works, and making accessible scenic and cultural conservation zones. For the railroad case, Launius asks if cheaper transportation was the most important public-private partnership for settling the American West, analogous to wondering if cheaper access to space is the most important partnership for growing the space economy. For the telecommunications case, Launius recognizes a direct application to the establishment of the Communications Satellite Corporation (COMSAT) in 1962 as a regulated monopoly, similar to the regulated monopoly of the U.S. telephone system from 1876 until its breakup into private companies in the 1980s. Earth orbit infrastructure creation was further encouraged via the NASA Transition Act of 2017, which directed NASA to look at privatization of the entire LEO domain, prompted in part by a desire to privatize the ISS (S.442 - 115th Congress, 2017). Despite the interest in NASA commercializing their near-Earth orbit infrastructures, 2010 National Space Policy commercial space guidelines were focused on government use of commercial space, with only one passage on infrastructure stating, “Ensure that United States Government space technology and infrastructure are made available for commercial use on a reimbursable, noninterference, and equitable basis to the maximum practical extent” (The White House, 2010, p. 10). President Obama was in office from January 2009 to January 2017 during which time most Earth-Moon human exploration infrastructure activities stopped in favor of commercializing NASA Earth-

orbiting infrastructures such as the ISS and transportation to it, though he did sign the Commercial Space Launch Competitiveness Act (CSLCA) giving private property rights to "any asteroid resource or space resource obtained (S.51303 - 114th Congress, 2015, p. 721)" which was only implicitly stated in the 1967 Outer Space Treaty.

Meanwhile, China was formulating a goal of displacing current U.S. infrastructure leadership by 2049, which is the 100th anniversary of the founding of the People's Republic of China. This includes regional and global military, diplomatic and economic displacement (Doshi, 2021). China's economic policy is centered on the BRI, a transcontinental long-term policy and investment program which aims at infrastructure development and acceleration of the economic integration of countries along the route of the historic Silk Road. The Initiative was unveiled in 2013 by China`s president Xi Jinping and was incorporated into their constitution in 2017 (Chatzky & McBride, 2020). China's BRI does not end with long-term policy and investment programs aimed solely at land and sea Silk Road infrastructure, it has air, cyber and space elements. In 2016, a Chinese Defense Official acknowledged the BRI includes space, specifically Earth orbit assets such as BeiDou Navigation Satellite System to provide China-led alternatives to U.S., Russia and other global navigation satellite systems. (Siddiqui, 2019).

In 2017, President Donald Trump issued his National Security Strategy and acknowledged China's BRI stating, "China is investing billions of dollars in infrastructure across the globe" (The White House, 2017, p. 38) and "China's infrastructure investments and trade strategies reinforce its geopolitical aspirations" (The White House, 2017, p. 46). However, his national security strategy appeared to have a terrestrial-only focus. Later that year, Trump issued Space Policy Directive 1 (SPD-1) directing NASA return to the Moon by 2024 and replaced the cancelled Constellation with the Artemis Program. Once again NASA programs were focused

on returning humans to the Moon and building infrastructures to support a sustained human presence as a staging point for Mars, the purpose appeared to be one of prestige and not a counter to China's economic or infrastructure goals on the Moon.

In 2019, Trump issued SPD-4 creating the U.S. Space Force (USSF). Coupled with a planned U.S. presence on the Moon by NASA, the USSF appears to have embraced a responsibility to conduct military and intelligence operations in cislunar and has since created an "in-space logistics" initiative to study and potentially field an infrastructure to support not only their near-Earth military satellites, but military satellites in the cislunar space focused on space domain awareness (SDA) (Buehler, 2021). While the mission is military, the shared space situational awareness (SSA) to the Earth-Moon Zone would provide detection and warning to a planned human presence operating on the Moon from not only man-made objects, but natural objects and space weather as well.

The combination of NASA programs and newly created USSF spurred a renewed elite discourse in space infrastructures and their commercial opportunities, either to support government missions, privatize routine government operations to these missions, or rally private investment for a purely commercial endeavor. Both think tanks and commercial industry have been exploring the possibilities of Earth-Moon infrastructure opportunities. Aerospace Corporation did a similar study to Launius' earlier Earth orbit infrastructure study to explore cislunar infrastructure opportunities. In the April 2018 *Cislunar Development: What to Build-and Why*, James Vedda of the Aerospace Corporation's Center for Space Policy and Strategy explores ways to facilitate and accelerate the evolution of space commerce through the development of cislunar infrastructures. In the document, Vedda acknowledges the NASA Gateway and the supporting Deep Space Logistics (DSL), as well as other NASA programs to

discuss long-term demand for multipurpose space infrastructures, then posits those multipurpose infrastructures to be inter-orbit transportation from and between the Moon and Earth, on-orbit servicing for refueling, maintenance and repair, fuel storage or depots to support on-orbit servicing, energy collection and distribution (or a power grid on the lunar surface and in space), and other space utilities such as multiuse communications and navigation services, space whether forecasting on and in lunar orbit, as well as resource extraction tools (Vedda, 2018).

In 2019 China extended their BRI from space terrestrial and Earth orbit infrastructures to cislunar. China's vision beyond Earth orbit builds upon that of Dr. APJ Abdul Kalam, a scientist also known as the Missile Man of India, as well as the 11th President of India, who articulated the concept of Earth-Moon-Mars economy. His broad argument was that the Earth, Moon and Mars should be considered as single economic entity. At the 97th Indian Science Congress, which was hosted by the Indian Space Research Organization in January 2010 he said, "Scientists should start considering Earth, Moon and Mars as an economic complex for future habitat expansion of human beings." China, it appears, has taken heed of Kalam's concept. China's Bao Weimin, director of the Science and Technology Commission of the CASC discussed an ambitious proposal to establish an Earth-Moon economic zone by 2049. China expects to establish a space transportation system enabling this economy by 2040 and then, within a decade, proposes to establish the Earth-Moon space economic zone (Lele, 2019). China has assimilated this Earth-Moon region of space into its BRI strategy.

Unlike Obama, who issued the 2010 National Space Policy at the beginning of his administration, Trump issued SPDs during his administration and then consolidated them and much of the previous 2010 National Space Policy into his own National Space Policy released at the end of his administration on 9 December 2020. On the one hand, the 2020 Trump National

Space Policy states a goal to, "Extend human economic activity into deep space by establishing a permanent human presence on the Moon, and, in cooperation with private industry and international partners, develop infrastructure and services that will enable science-driven exploration, space resource utilization, and human missions to Mars" (The White House, 2020, p. 5). On the other hand, there is no further elaboration on the specific infrastructures or the time frames to complete them. Cross-sector guidelines discusses Earth orbit capabilities and access to them, and sector guidelines discusses logistical provisioning in and beyond LEO as a nod to NASA's DSL, and further elaborates on this in the civil space section by directing NASA to "Continue to grow partnerships with the commercial space sector to enable safe, reliable, and cost-effective transport of crew and cargo to destinations in low Earth and cislunar orbits, and to the lunar surface" (The White House, 2020, p. 23). Given this statement, it is unclear if the previous statement to develop infrastructures is limited to transport of crew and cargo in cislunar, and since it is under the civil space sector guidance it also implies doing this as a support contractor and not a private sector endeavor. Conspicuously absent in the 2020 National Space Policy are many of the more detailed space infrastructure thoughts contained in the 23 July 2020 *New Era for Deep Space Exploration and Development* document. The New Era document referenced many of the potential infrastructure opportunities available such as energy production and distribution, communication and navigation, space weather and on-orbit servicing and manufacturing (The White House National Space Council, 2020) similar to the Aerospace report, however specific references beyond cislunar transportation in the 2020 National Space Policy were not found. The fact that this is a National Space Council (NSC) document produced in July 2020, five months before the December 2020 National Space Policy was released, leads one to

speculate that there was lack of consensus on the importance of space infrastructures withing the Trump Administration.

Joe Biden took office in January 2021, one month after the Trump 2020 National Space Policy was released. On 3 March 2021 he released his Interim National Security Strategy Guidance document. The name would imply a final National Security Strategy to be released at some point, to which this study would hope to influence. Like the Trump National Security Strategy, the Biden document acknowledges the Chinese infrastructure threat with the statement, "We will stand with our allies and partners to combat new threats aimed at our democracies, ranging from cross-border aggression, cyberattacks, disinformation, and digital authoritarianism to infrastructure and energy coercion" (The White House, 2021, p. 19) and "We will join with like-minded democracies to develop and defend trusted critical supply chains and technology infrastructure, and to promote pandemic preparedness and clean energy" (The White House, 2021, p. 20). On 2 November 2021 at the United Nations' Climate Change Conference of the Parties (COP26) in Glasgow, President Biden unveiled his Build Back Better World (B3W) initiative which should be seen as a companion vision to his Interim National Security Guidance and infrastructure agenda, just as the Vision for Deep Space Exploration was a companion vision to the Trump National Space Policy. The international effort organized by the U.S. would fund infrastructure projects in developing countries to counter China's influential BRI. (Linskey & Birnbaum, 2021). The B3W coalition plans to fill the estimated $40 trillion gap in infrastructure funding and provide an alternative to China's Silk Road or BRI (Quinn, 2021). According to the fact sheet on Whitehouse.gov, the B3W partnership between the U.S. and G7 Leaders directly addresses the strategic competition with China for infrastructures, albeit terrestrial infrastructures. Among other infrastructure goals, the B3W will be values-driven, provide good

governance, be climate-friendly and consist of strong partnerships (The White House, 2021). Nine months later Biden released the 1 December 2021 U.S. Space Priorities Framework. Again, as the name implies, the document is a narrative of space priorities with a noticeable shift in tone and tenor from an expansion of U.S. leadership in space to a maintenance of U.S. leadership in space, and no mention of the economic race with China to create infrastructures in the Earth-Moon Zone by 2049.

Since China codified their strategy to supplant U.S. leadership in infrastructures, there have been two National Security Strategies, two National Space Policies, and several budget requests for Earth-Moon programs. However, there has been no scholarly review of these policies to assess sufficiency to develop Earth-Moon infrastructures by 2049.

## STATEMENT OF THE PROBLEM

China is challenging U.S. infrastructure leadership on Earth and in space, to include infrastructures in the future Earth-Moon Economic Zone. Both China through the BRI now in their constitution, and the U.S. through their Title 51 USC, have a goal to lead space infrastructures. While there are several Chinese and U.S. Earth-Moon programs underway, neither have yet to establish common multi-use infrastructures in this region of space. China has a stated "national goal" to lead all infrastructures, to include the Earth-Moon Zone by 2049. There does not appear to be a U.S. national goal in policy or programs to lead any specific Earth-Moon infrastructures by any specific date, let alone 2049.

A literature search was conducted to uncover any scholarly analysis on the sufficiency of U.S. policy and programs to develop Earth-Moon infrastructure before 2049. Despite China incorporating their infrastructure goals into their constitution in 2017, there has been no scholarly review of U.S. policy to develop infrastructures in this zone before 2049. This represents a gap in the body of knowledge and the need to clarify the problem and present policy alternatives to inform the national security and national space policy cycle discourse. Given the current administration has an interim national security strategy and an initial set of space priorities, this study is needed to assess the sufficiency of current policy for possible inclusion in the Biden Administration's final national security and space policies.

## PURPOSE

The purpose of this study is to explore the sufficiency of U.S. policy to develop Earth-Moon Economic Zone infrastructures by 2049. The primary purpose of the study is to inform the agenda setting and policy formulation stages of the national security policy cycle, while simultaneously providing space-related material that could potentially inform theories related to the burgeoning Earth-Moon economy or U.S. public policy at large. The study used a qualitative approach involving a researcher-led document analysis and interviews with experts to corroborate the document analysis and provide supplemental information to answer the research question, "*Is U.S. policy sufficient to develop Earth-Moon Economic Zone infrastructures by 2049?"* If any changes or new policies were identified, as judged through the document analysis and interviews with experts, then the U.S. policy reviewed is deemed not sufficient. The target audience for this study is the U.S. National Security, National Space, and National Economic Councils, U.S. Congress, U.S. DOC, U.S. DoD, NASA, U.S. Industry, and think tanks.

# SCOPE

## Limitations

The policy documents were limited to those since 2017, which is when China added the BRI to their constitution, this would limit it to the Trump and Biden administration. Geopolitics and their relationship to infrastructure competition are typically in the national security strategies and space competition in the national space policies, so the specific policy documents would be the Trump 2017 National Security Strategy and 2020 National Space Policy, and the Biden 2021 Interim National Security Strategy Guidance and 2021 U.S. Space Priorities Framework. While the Trump 2020 Vision for Deep Space Exploration is used for background context, it was not used as a Trump national policy document since it was released by the National Space Council. As well, the Biden B3W initiative with the G7 is currently still a fact paper not policy and is used for context and not reviewed.

Presidential budget requests (PBRs) were also used to reflect investment priorities and policies of the administrations, versus enacted budgets from Congress. While Biden has had two PBRs and Trump four, the study will only use the last Trump PBR which was submitted in 2020 (for Fiscal Year 2021 or FY21) and only the first Biden PBR submitted in 2021 (for FY22). Since most if not all Earth-Moon investments are in the NASA budget, the DoD PBR was not reviewed nor were the PBRs for the DOC or Federal Aviation Administration (FAA) since they do not have development programs in the Earth-Moon region.

The Earth-Moon Zone is defined as the cislunar or translunar region of space between the outer Earth orbit and lunar orbit, the lunar orbit, lunar ascent and descent, lunar surface and sub surface, and the LaGrange Points of L1 and L2. This is consistent with Bao Weimin who defined the Earth-Moon region as covering areas of space near Earth, the Moon and in between,

with the stated goal of extending commerce beyond Earth to create a new special economic zone. China's use of the term "special economic zone" for the Earth-Moon region is similar to other special economic zones they have targeted for growth on Earth. There were no infrastructures reviewed for policy beyond the Moon, in near-Earth orbit, or on the surface of the Earth, unless they supported the Earth-Moon infrastructures such as ground-based communications or the NASA exploration ground system (i.e., the launch pad).

The final limitation involves the analysis of recommendations. The purpose of the study is to answer the research question based on the number of recommended changes to existing policy or number of new policies needed. In the course of the expert interviews, recommendations were solicited as supplemental information in order to aid in the analysis and answer the research question, but no in-depth analysis was performed on each recommendation. This will be left to future study.

**Assumptions**

Two terms from the research question are defined for the purpose of the study. The first is sufficient. According to the Merriam-Webster Dictionary, sufficient is defined as "enough to meet the needs of a situation or a proposed end" (Merriam-Webster, 2022). For this study, sufficient policy is enough guidance and direction for the U.S. to have developed infrastructures in the Earth-Moon Zone by 2049, which is the proposed end. The second term is development. This study prefers the definition of space development as described in Goswami and Garretson's, *Scramble for the Skies,* in which the authors state the concept of space development as, "…the development of industries, infrastructure, and transportation infrastructure that grows the size and diversity of the in-space economy" (Goswami & Garretson, 2020, p. 7).

This study assumes Title 51 USC directing the U.S. to preserve leadership in space will apply to future policy. No attempt will be made to challenge the practicalities of this policy for an ever-expanding presence in the Universe. This is closely related to another question of "should" national space policy address development of Earth-Moon infrastructures. This question will not be addressed in this study either, it will be assumed that the U.S. should pursue economic development in this zone, given the historical return on infrastructure development in the past and the future economic challenge by China to supplant U.S. leadership. Likewise, the study assumes the BRI will remain in the Chinese constitution and China will pursue leadership in this area as a result.

Lastly, no individual Chinese programs were reviewed, primarily due to the difficulty in obtaining details on Chinse programs, budgets, and dates. It is assumed that China's goal is to pursue leadership of any infrastructure opportunity that presents itself on Earth or in space, and since their goal of 2049 is for all infrastructures, the study merely needs to assess U.S. policy in the same way, which is the U.S. ability to develop any or all future infrastructure opportunities before China does in 2049.

# LITERATURE REVIEW

## Knowledge Gaps

A search was conducted to uncover any previous policy analyses on Trump policy, Biden policy, or the combination of the two related to U.S. development of Earth-Moon Economic Zone infrastructures by 2049. The search used online space journals *Acta Astronautica, Space Policy*, and *Astropolitics*, as well as the broader Google Scholar, University of North Dakota Library, and the internet at large. A review of the literature did not uncover any scholarly attempt to analyze the sufficiency of U.S. policy to develop Earth-Moon Economic Zone infrastructures by 2049.

This knowledge gap will be addressed through the application of scholarly policy analysis methods. A literature review of these methods was conducted and are presented in the Methods and Research Design section of this report, since they are so tightly coupled to the research design. The study problem and results of the policy analysis contribute to several discourse communities, the most prominent being the national security policy community that will build upon the problem description and resultant policy options to take action at appropriate states in the policy cycle. The other contribution is to public policy theory discourse and space economy discourse, specifically in the Earth-Moon region. While this study does not attempt to analyze public policy theory or economic theory, it does provide Earth-Moon specific case material that may be of relevance to both.

## U.S. National Security Policy Cycle

While there is a need for a scholarly analysis on current U.S. policy related to the problem, there is also a need to articulate the problem to which the current policy will be analyzed. This study attempts to articulate and proffer the problem of China developing the

Earth-Moon Economic Zone before the U.S., as a central theme expanded upon throughout this report. The description of the problem not only supports the standard for the sufficiency analysis to answer the research question but offers a thoughtful articulation of the problem to space-related national security policy so that the problem can be built upon and strengthened during discourse.

With the problem articulated as context, this study applies policy analysis methods to analyze current U.S. policy documents and determine their sufficiency to address the problem. Any policy changes derived from this analysis not only supports the analysis to answer the research question but provides policy alternatives to the space-related national security discourse so any policy options can be built upon and strengthened during policy formulation.

***The Public Policy Cycle.*** Harold D. Lasswell introduced the policy cycle framework in his 1956 publication, *The Decision Process. Seven Categories of Functional Analysis*, where he described seven categories or states of functional analysis as: intelligence, promotion, prescription, innovation, application, termination, and appraisal (Lasswell, 1956, p. 23). As the field grew during the 1960s and 1970s, scholars have adapted the seven stages into variations of categories and generally considered them to be sequential. In their article, *Theories of the Policy Cycle*, Werne Jann and Kai Wegrich discuss and critique the policy cycle framework. At one point they state, "We are therefore confronted with an almost paradoxical situation: on the one hand of the policy research continues to rely on the stages or cycle perspective or is linked to one of its stages and research questions. On the other hand, the very concept of the stages perspective has become discredited by a variety of criticisms, including attacks on the theoretical status of the policy cycle as a framework, model or heuristic" (Jann & Kai, 2019, p. 56). In the same article, they describe the policy process as a sequence of discreate stages or phases consisting of

agenda-setting, policy formulation, and implementation. Others differentiate implementation with evaluation and termination, but Jann and Wegrich include it in implementation stage. They then articulate the weakness of a sequential approach as being too discrete.

While the discrete phases of the policy cycle (agenda setting, policy formulation and implementation) are criticized by some as an oversimplification of reality suffering from descriptive inaccuracies and a lack of definition for the transition between phases, the discreteness of steps provides a framework to align the articulated problem from this report to the first step of agenda setting, and potential policy alternatives derived from the analysis of this report to the second step of policy formulation.

***Contribution of Study Problem Description to Agenda Setting Discourse.*** Expanding upon the agenda setting phase of the policy cycle, John Kingdon said, "The agenda is nothing more than the list of subjects or problems to which governmental officials, and people outside the government closely associated with those officials, are paying some serious attention at any given time" (Kingdon, 1981, p. 3). Agenda-setting consists of problem recognition and articulation followed by putting the problem on the agenda for public action. In his *Agenda Setting in Public Policy*, Thomas Birkland defines agenda setting as consisting of problem recognition and articulation followed by putting problems on the agenda for public action (Birkland, 2019). He goes on to explain the social construction of problems and issues by stating, "A group that can create and promote the most effective depiction of an issue has an advantage in the battle over what, if anything, will be done about a problem" adding, "…whether a problem really is a problem at all is an important part of the political and policy debated: merely stating a problem is not enough" (Birkland, 2019, p. 80). There does not appear to be

many detractors and criticisms of problem definition in agenda setting, other than the overall criticism of the sequential nature of the policy cycle stages at large.

The articulation of the problem of China's development of Earth-Moon Economic Zone infrastructures before the U.S. is a contribution to ongoing discourse on strategic competition with China. While there is discussion on China's terrestrial infrastructure ambitions and on the potential threats from China to U.S. Earth orbiting systems, it is hoped that the articulation of this fairly niche but very important challenge to future Earth-Moon Zone infrastructure control will be strengthened through future discourse to support the first step of agenda.

***Contribution of Study Policy Options to Policy Formulation Discourse.*** Scholars have since transformed Lasswell's prescription stage into a "policy formulation" stage. Policy formulation consists of crafting a set of policy alternatives to address a problem and narrowing that set of solutions in preparation for the final policy decision (Sidney, 2019). This step assumes the policy problem has been identified and placed on the policy agenda. However, this is where the criticism of the discrete phases can be demonstrated as a criticism, since this study is both defining the problem throughout the report while simultaneously providing policy options from the analysis. This iterative process is supported by Schneider and Ingram in their *Policy Design for Democracy*, where the authors conceptualize an iterative process to the steps of the policy cycle (Schneider & Ingram, 1997). Additionally in *Policy Formulation: Design and Tools*, Mara Sidney states, "The best work on policy formulation and policy tools brings together the empirical and normative" (Sidney, 2019, p. 88). Sidney's observation bodes well for this study, since the research design combines an empirical document analysis with normative interviews from experts. Again, Sidney and other critiques on the sequential nature of policy formulation coming after agenda setting continue in the overall context of the policy cycle,

claiming studies related to agenda setting often generate recommendations. This criticism is somewhat validated by this study as it both articulates the problem and provides policy options in the same study, thus informing both states simultaneously.

Any recommended changes or new policy derived from the analysis is certainly a contribution of policy options to the discourse on national security policy. Recommendations could consist of changes to existing policy or new policy altogether, thus informing both agenda setting and policy formulation. While recommendations from this study will not be analyzed in depth, it is hoped that they, along with those generated by others in the future, will be analyzed and added to the discourse to support the second step of policy formulation in the policy cycle.

**Public Policy Theory**

The primary purpose of this study is the application of policy analysis methods to analyze current U.S. policy for sufficiency against an emergent problem articulated. A second-order result of this study is that the description of the problem for the analysis and subsequent policy options generated during analysis contributes to the larger discourse of the policy process for national security. In addition to be considered an applied study, this study could also be considered action research. In the book, *The Cambridge Guide to Research in Language Teaching and Learning*, Anne Burns defines action research as, "A research approach that is grounded in practical action while at the same time focused on generating, informing and building theory" (Burns, 2015, p. 99). As Burns points out, action research can be grounded in practical application but also contributes to theory. As such, the third-order result of this study is the contribution to public policy theory, by providing space-related policy knowledge.

***Space Policy Context.*** Before discussing theoretical frameworks on policy change, it is helpful to discuss the state of existing space policy for context. While there was an evolution of

long-range missile to space and theories on orbiting satellites as early as 1947, the Sputnik moment occurred in 1957 and the foundations of present-day space policy were set in place at that discrete point. Space policy is centered on this Cold-War military and diplomatic prestige competition with the USSR evolving very little over the 1950s and 1960s focusing on missiles and humans in orbit and on the Moon. As access to space became more routine in the 1970s and 1980s, commercialization of several civil Earth orbiting activities was added to policy. As the terrestrial economic and military reliance on U.S. space systems became evident in the 1990s and 2000s, policy was added to address the vulnerabilities of U.S. space systems and protect them, even the recent creation of the U.S. Space Force is for that purpose. And while there was a brief vision of returning to the Moon and onward to Mars in the 2000s under Bush, and another resurgence recently under Trump policies, the policy stasis has remained one focused on exploration, prestige, and military support. Even the promotion of commercial space over the last few decades is centered on privatization of many NASA logistics-related to LEO. This study assumes the 2017 proclamation by China to lead development of an Earth-Moon Economic Zone by 2049 to be valid requiring a departure from the current stasis. On one hand, this issue could be framed as an extension of the strategic terrestrial competition with China to control other economic trade zones in African, the South Pacific or South America and change the balance of power becoming a strategic imperative for U.S. policy. On the other hand, this could be viewed as just another commercial competitor vying for a piece of space market share, not unlike the Europe's challenge to the U.S. launch market with Ariane. Regardless, space policy for the last 70 years has been in relative equilibrium and changes very incremental. It is unknown if a competition with China to control an Earth-Moon Economic Zone by 2049 will be seen as incremental, or another defining Sputnik moment for U.S. policy.

***Public Policy Theoretical Frameworks***. The literature is filled with many public policy theories and models developed by scholars since the 1940s, some of which have been retired, combined, or added. This review identified at least 39 policy theories summarized on the Walden University Online Library (Walden University, 2021). However, the most credible list appears to be in the 2018 Fourth Edition of *Theories of the Policy Process*, where the authors list and discuss six: The Multiple Streams Framework, Punctuated Equilibrium Theory, Policy Feedback Theory, The Advocacy Coalitions Framework, The Narrative Policy Framework, The Institutional Analysis and Development Framework and Socio-Ecological Systems Framework, and the Innovation and Diffusion Models (Weible & Sabatier, 2018). This academic text includes their criteria for including the most established theories such as: a focus on developing scientific theory of policy processes, the presence of an active research community, an effort toward making research as public as possible, and continual growth in knowledge about policy processes (Weible & Sabatier, 2018, pp. 5-6). The book is especially helpful in culling down the theories to the most established and credible.

The Multiple Streams Framework (MSF) was put forth by John Kingdon (Kingdon, 1981). He was inspired by Cohen, March and Olsen's 1972 garbage can model of organized choice (Cohen, March, & Olsen, 1972). MSF is a process that emphasizes timing of merging problem, political and policy streams in the future, creating a window of opportunity for both agenda setting and decision making to come together. The assumption is that there is no rational solution but a multitude of solutions. Like the garbage can model, MSF assumes the three streams develop and mature independently and unpredictably before coming together. Given the close and relatively small national security space community, independence of streams does not seem a fathomable model to explain the incremental changes to space policy over the years. As

it pertains to the changes from this study, the problem stream is likely the articulation of the China problem and the policy stream represented by the alternatives derived during the analysis. If widely disseminated, this study could rise to the attention of interest groups and some select government officials, but under the MSF model there may be no forcing function to bring the three activities together in a timely window for change, as China continues to pursue their space investment programs to build Earth-Moon Economic Zone infrastructures before 2049.

Punctuated Equilibrium Theory (PET) was developed by Frank Baumgartner and Bryan Jones (Baumgartner & Jones, 1993). PET contends that although generally stable and incremental, the political process sometimes produces large-scale departures from the past. Whereas most models are designed to explain either stability or change, the PET model is designed to explain both. The model was crafted from a longitudinal study of political institutions and decision making. In the study, Baumgartner and Jones found that policy making undergoes both leaps and undergoes periods of near statis as issues emerge on and recede from the public agenda. The American political institutions exacerbate this tendency toward punctuated equilibria and combined with special interest groups, occupy what the authors termed "policy monopolies." Policy monopolies refer to institutions conservatively designed to resist efforts to change which keeps the equilibrium, then are responsible for policymaking in a single area which leads to incremental approaches to change. The PET model appears to fit the history of space policy well in that the institutions responsible for space are focused in single areas (NASA for exploration, U.S. Air Force now U.S. Space Force for protection and military support, etc.), which explains the void in economic competition. As it relates to the problem presented in this study, these same space institutions (neither of which are responsible for building infrastructures to win an economic competition) are policy monopolies and will likely

be resistant to a change in mission, such as investing in Earth-Moon public-use infrastructures. However, PET offers hope in that with the proper articulation of the problem and policy options, this could prompt a punctation to the current space policy equilibrium and make policy change on a scale as significant to the Sputnik moment. As the policy issue identified in this study gains momentum in the discourse community, there may also be opportunities to contribute to the PET case study as a space-related data source for future regression analysis to further the PET model. Upon review of their case studies, PET appears to be lacking space material.

Policy Feedback Theory (PFT) was developed by Suzanne Mettler and Mallory Soss. As Mettler and Soss framed it in *The Consequences of Public Policy for Democratic Citizenship: Bridging Policy Studies and Mass Politics*, enacted policies shape the attitudes and behaviors of political elites and mass politics and effect policy making institutions and interest groups, as a result this affects subsequent policy making (Mettler & Soss, 2004). While this theory may have explained the development of national space policy over the years, it would appear that PFT suffers a weakness in that it relies on enacted policy to inform future policy, which creates an issue if there is only small incremental policy changes in enacted policies there may be no way to inform future policy on radical issues not in current policy. This model might not explain how an issue such as the one in this study ever makes its way into future policy. Oddly this criticism is supported by Metter and Soss who provide recommendations for future research on PFT by stating, “Furthermore, today more than ever, the creation of new policies is deeply influenced by the existence of other policies, many of which reshape the political landscape in multiple profound ways” (Mettler & Sorelle, Policy Feedback Theory, 2018, p. 127). While stated in the positive, this supports the criticism just brought up by the Researcher, in other words the primary influence in future policy is current policy.

The Advocacy Coalition Framework (ACF) was developed in the 1980s and published by Paul Sabatier and Hank Jenkins-Smith (Sabatier & Jenkins-Smith, 1993). ACF is concerned with persistent patterns of conflict involving different beliefs which provide rationale for policy change. The ACF is actor-centered and contends policy is changed by actors' beliefs and learning. ACF appears to be a reaction to theories of the 1970s when scientific data was taking on more prominence in the field of policy science, and the need to ensure actor belief systems were taken into account. The Researcher would consider this framework of limited value to space policy, certainly for national security space policy since the actors change frequently and space security tends to be more technical, or physics based, not so much on a belief system or attitudes more prevalent in social issues. Other than the early "belief and attitude" in John F. Kennedy's decision to use space for political gain, technical decisions have traditionally shaped space policy over the years. However, since the current problem is so closely related to the belief and "gut feelings" of an existential threat to the U.S. balance of power with China, it could provide a framework for ensuring beliefs are catered to in the agenda setting phase.

The Narrative Policy Framework (NPF) is a relatively new theory that focuses on storytelling and its impact on public policy. It was introduced by Mark Jones and Mark McBeth (Jones & McBeth, 2010). NPF argues that policy debates are fought and won based on narratives, and narratives can affect the policy process at different points in the policy cycle process. Evidence to support this model are pulled from famous orators like Franklin Roosevelt or Winston Churchill and how their storytelling heavily influenced politics and policy. Because of its newness, the NPF is still being widely tested and improved. The Researcher especially resonated with the authors' core elements in defining the narrative as: providing the setting, identifying characters, describe the plot and character relationships, and ending on a moral note

to the story. It would be the Researcher's aspiration for the readers of this report to identify these elements from the problem description. In addition to the policy changes proposed in this report, the history of space policy is strongly influenced by narratives at the Presidential level, department and agency levels, and especially prominent space influencers in industry and academia. It may be too early to provide any criticisms of NPF, since the co-author and others state, "Having been developed over the better part of a decade, the NPF is reaching its teenage years" (Shanahan, Jones, McBeth, & Radaelli, 2018, p. 202).

The Institutional Analysis and Development (IAD) Framework was developed by Elinor Ostrom. IAD seeks to explain the logic, design, and performance of institutions and how actors' behavior is shaped by those institutions. It consists of seven components: an actor situation, actors, rules, community attributes, physical and material attributes, outcomes and evaluative criteria (Ostrom, 2009). Ostrom also authored the Social-Ecological System Framework (SES) or as some would call it, the offspring of the IAD Framework. The SES identifies 10 subsystem variables that affect the likelihood of self-organization in efforts to achieve a sustainable SES (Ostrom, 2009). The SES essentially "emphasizes the interactions between actors and the ecological systems" (Schlager & Cox, 2018, p. 216). It would appear from the literature that the IAD is established but the SES Framework is still evolving. It is hard for the Researcher to apply these frameworks to existing space policy, or to the policy change this study might afford. Even the literature states these are frameworks and still evolving as theory.

***Contribution of Study to Public Policy Theory Discourse.*** Coupling the context of space policy stasis and potential changes to it with some of the more prominent public policy theories uncovered, the Researcher postulates several contributions of this study to policy theory discourse. The Researcher concludes that national space policy is best characterized as being in

a relative state of equilibrium after the initial shocks to the nation from Sputnik and the Cold-War race to the Moon that established it. This state is very similar to the equilibrium state characterized by Baumgarten and Jones' PET. History has shown that large scale national events such as another Sputnik moment or new Cold "Earth-Moon" War could very well punctuate the equilibrium of space policy again. This punctuation would be very similar to the punctuation characterized by PET as a large-scale departure from the past. Other models can be employed to explain how this punctuation could occur, such as culminating in a "punctuation window" after years of problem, policy and political stream development under the MSF, or culminating in another punctuation window after years of story narratives characterize under the NPF. While perfectly acceptable models for the American Democracy, time may not afford this luxury given the 2049 goal and the amount of investment and program development that would be needed well before this date. Given the urgencies for policy now, the ACF might be an ideal model to take the problem streams and narratives defined by this study, and have them come together and articulated by a visionary and credible leader, whether a future President or a distinguished spokesperson on par with Martin Luther or another non-political leader. The urgencies of the issue may require the narrative of an impending Sputnik moment to punctuate the current national security policy equilibrium sooner than later, and ACF provides a model to do that. As case studies are explored to further PET, MSF, NPF and ACF theories, this study might provide a valuable contribution of a space-related material to further their discourse.

**Space Economy Theory**

This study primarily contributes to national security policy cycle discourse with an articulated problem description and policy alternatives. To a lesser degree, it also contributes to public policy theory discourse providing space-related material noticeably absent from many of

the major theories. And to an even lesser degree still, it also contributes to emerging space economic discourse providing Earth-Moon infrastructure-related material absent in some of the emerging space economic frameworks that have to date, been focusing on commercial LEO infrastructures.

***U.S. and China Infrastructure Economy Context.*** While advertised as a communist economic system, in practice China operates as a socialist political system with a State-sponsored capitalist market economy targeting specific areas they wish to grow. In essence, China uses their single-party political system to plan and target markets that will contribute to their party goals. They identify those markets as special economic zones and operate as state-sponsored capital markets to grow them. China has over 200 of these special economic zones and has identified the Earth-Moon region as a new Earth-Moon Special Economic Zone to develop and control by 2049. China's socialist political system coupled with state-sponsored capitalism in these special economic zones allows them to focus investment on national goals with little to no debate on national policy to achieve them.

While advertised as a capitalist free-market system, in practice the U.S. operates as a mixed-market economy with a combination of a free-market system and government intervention in areas where markets have failed the public good, or to regulate establish markets. In cases where markets have failed the public, the U.S. has a history of intervening through a combination of policy to encourage private investment, while using government investment to seed development and reduce risk for eventual private market to invest later. This has been demonstrated in times of war, pandemics and other national crises. As a space-related example, the Cold-War of the 1950s and 1960s was seen as a military and diplomatic (or prestige) imperative internationally, so the U.S. government intervened in the free-market economy to

create new space markets that did not yet exist. This intervention was codified in both national security and national space policy, reflected in national budgets, and even led to the creation NASA in 1958.

While it may be easier for China to focus investment and policy in special economic zones like the Earth-Moon region, the U.S. has a long history of focusing investment and policy in special markets that have failed the public, or those needed for national military, diplomatic or economic security. It is within reason to expect a punctuated moment of action by the U.S., if the case is made that it is a national security issue.

***Space Economic Framework.*** So important is economic priorities to this study, a space-related article was introduced in the background section of this report. *Space, the Final Economic Frontier* is a peer-reviewed article written by Dr. Matthew Weinzierl and published in the Journal of Economic Perspectives (Weinzierl, 2018). The purpose of the article is to provide a framework for understanding and managing the development of the future "commercial" space economy using a classic economic analysis and the role of the U.S. government as the underpinning economic theory to space infrastructure investment. The three components of the framework are: 1) establishing markets through decentralization of decision-making and financing, 2) refining markets through policies that address market failures and ensures a healthy market structure, and 3) tempering markets through regulation in pursuit of social objectives. The first component is aimed at the establishment of new markets and the third at regulating established markets. Of greater significance to this study is the second component addressing market failures similar to those discussed earlier. Weinzierl argued two market failures having a direct bearing on infrastructures: 1) the need for complimentaries and coordination, and 2) the need to address externalities. Complimentaries it is argued, require business models or

infrastructure to be in place to enable other models or markets to succeed (for instance low-cost access to space must occur before tourism can be realized). Externalities it is argued, are the unintended consequences that must be delt with by the public sector. Weinzierl used the same six historical analogies used by Roger Launius' NASA study, and his in-depth analysis of LEO space infrastructures from: the construction of the U.S. transcontinental railroad, fostering the aerospace industry at the turn of the century, creating the telephone industry, supporting research in Antarctica, advancing public works, and making accessible conservation zones for scenic and cultural purposes (Launius, 2014).

Clearly the economic concept of complimentaries is highly supportive in linking Earth-Moon Zone infrastructures needed to allow individual space markets to grow, as well as the national policy to enable them. Just as important to complimentary infrastructures that enable markets, is the need for government intervention to create infrastructures to address externalities, whether the externality is space debris caused by others or the protection of national security interests in the Earth-Moon Zone. Clearly a need articulated in this study is U.S. developed Earth-Moon infrastructures to address the externalities of China's stated national goal to develop them first.

***Contribution of Study to Earth-Moon Economic Discourse.*** This study is fundamentally about the sufficiency of U.S. policy to intervene in the free-market development of the Earth-Moon Economic Zone in order to address the externality of China's challenge to develop and lead infrastructures in this zone by 2049. In his article, Weinzierl presented a free-market economic model and used the Launius examples from six episodes in U.S. history such as transcontinental railroads, fostering the aviation/aerospace industry, etc. leveraging the LEO infrastructure analogues used by Launius' NASA study. However, the focus of Launius NASA

study and hence Weinzierl's, was on LEO infrastructures where the U.S. currently has the lead, and not Earth-Moon infrastructures where no one has the lead. The addition of this report could provide additional material to Weinzierl or other economists theorizing about U.S. space-related economic frameworks and encourage even greater discourse on the national security issue related to the Earth-Moon Economic Zone.

## METHODS & RESEARCH DESIGN

This study uses methods and a research design to answer the research question, "*Is U.S. policy sufficient to develop Earth-Moon Economic Zone infrastructures by 2049?"* If changes to existing or new policies were identified, as judged through the document analysis and interviews with experts, then the U.S. policy reviewed was deemed not sufficient.

### Policy Analysis Methods

The research question involves a policy analysis, which meets most if not all characteristics for a qualitative research design in Creswell's, *Research Design: Qualitative Quantitative and Mixed Methods Approaches*; No numerical quantification of sufficient policy exists, no hypothesis or test can be performed to measure sufficiency in quantifiable terms, the research question enables the Researcher to be the key instrument in examining the documents and interpreting the information surrounding it, to address bias experts could provide another source of data, the analysis will be inductive, the study involves learning the meaning of the document and expert opinions, it is emergent and will evolve based on the interactions with experts, and it tries to provide a holistic picture (Creswell & Creswell, 2018). The use of a qualitative approach for policy analysis is supported by Alan Sadovnik who advocates the virtues of using qualitative research for public policy in his, *The Handbook of Public Policy Analysis, Theory, Politics, and Methods*. Sadovnik states, "Unlike quantitative research, which is usually deductive (theory testing), qualitative research is usually inductive (theory construction)" (Sadovnik, 2019, p. 373). Sadovnik goes on to describe the types of qualitative research including ethnography, case study, grounded research and action research which Sadovnik calls a type of qualitative method "aimed at improving a certain practice, organizational context or way of life" (Sadovnik, 2019, p. 374), which certainly characterizes this action study.

Sadovnik lists several criteria for evaluating qualitative research designs to include data collection protocols, rationale for sampling procedures such as choice of participants and size of cohort, data collection instruments for interviews and documents, and reliability of sample size which he emphasizes is an important one. He also states the results are, "more easily influenced by the researchers' personal biases and idiosyncrasies" (Sadovnik, 2019, p. 377), which is of concern for this study since it involves the interpretation of policy documents by the researcher. In the same handbook, a separate article from Dvora Yanow entitled, *Qualitative-Interpretive Methods in Policy Research,* focuses on interpretive qualitative research for policy analysis. To underscore the applicability of qualitative research to policy analysis, Yanow states, "Others have based qualitative studies on in-depth interviews with various policy actors; and still other studies draw on legislative, agency, and other documents" (Yanow, 2007, p. 361). Yanow goes on to state that policy analysis is interpretive in nature and details several methods of gathering data for the interpretation, to include interviewing and reading documents with the purpose of thematic analysis (Yanow, 2007). To both compliment and contrast Yanow's qualitative-interpretive body of knowledge, Hendrik Wagenaar's article, *Interpretation and Intention in Policy Analysis*, states there are "flavors" of interpretation, to include intention that a policy writer may have had. Wagenaar uses and example in the article that explores intention, which is instructive for this study. He uses an example of an Israeli policy with the "intention" of creating community centers in new settlements in the 1970s that was eventually deemed a failure. However, the policy remained in place for over 20 years due to popular political support for the public's "interpretation" that the policy was about settlement and not community centers (Wagenaar, 2019). For this study, one could also imagine a lack of intention either intentional or

unintentional, to which interviews with experts may be able to identify and provide supplemental information such as missing policies.

The use of qualitative analysis and interpretation for the Trump and Biden policy documents dictates a review of document analysis tools and techniques. In Glenn Bowen's *Document Analysis as a Qualitative Research Method*, the author details document analysis as examining and interpreting written material in order to elicit meaning, gain understanding, and develop empirical knowledge. The analytic procedure entails finding, selecting, appraising, and synthesizing data contained in documents by yielding data that is then organized into themes and categories (Bowen, 2009). Bowen goes on to elaborate on analyzing the documents through an iterative process of skimming and interpretation and then combining the elements of content with thematic analysis. Thematic analysis and development is a form of pattern recognition in the data and extracting themes to form categories for analysis (Fereday & Muir-Cochrane, 2006) and will be a major step in this study. Reducing data into themes, coding data elements and creating categories is the same process for all sources containing text. Referred to as thematic development and analysis, an article in the *Journal of Nursing Education and Practice* outlines the phases and stages of theme development in qualitative content and thematic analysis studies (Vaismoradi, 2016, p. 103). The four phases consist of; 1) an initiation phase to read transcripts and highlight meaning, 2) a construction phase to classify, compare, label, translate, and describe, 3) a rectification phase to relate themes to established knowledge, and 4) a finalization phase to develop the story line.

Vaismoradi's steps are helpful in constructing the overall research design for this study, however methods are needed to guide the textual content analysis. In an article in The Qualitative Health Research Journal entitled, *Three Approaches to Qualitative Content Analysis*,

Hseih and Shannon's purpose was to recognize the growing use of document content analysis in health studies citing a growth in qualitative content analysis studies (Hsieh & Shannon, 2005, p. 1277). The authors go on to describe three approaches to content analysis and their respective strengths and weaknesses. While all three interpret meaning from content text data, they describe conventional content analysis as being a method used to describe a phenomenon by allowing the categories to "flow" from the textual data. This approach is used when existing research on the topic is limited (Hsieh & Shannon, 2005, p. 1279). Strengths are gaining information directly from the source without imposing any preconceived categories. Weaknesses of this type of analysis is failing to completely understand the context. Directed content analysis leverages existing theory about the phenomenology prior to the research. The authors state the goal of directed approach is to validate or extend conceptually theoretical frameworks. The authors state, "If data are collected primarily through interviews, an open-ended question might be used but would include targeted questions about predetermined categories" (Hsieh & Shannon, 2005, p. 1281). The authors go on to state that directed content analysis "offer supporting and non-supporting evidence for a theory. This evidence can be presented by showing codes with exemplars and by offering descriptive evidence" (Hsieh & Shannon, 2005, p. 1282). A strength of the directed approach is that it can extend the theory, a weakness is that it introduces the bias of the researcher. Finally, the authors introduce summative content analysis. Summative identifies and quantifies the use of certain words in "an attempt not to infer meaning but, rather, to explore usage" (Hsieh & Shannon, 2005, p. 1283). A strength is that it is unobtrusive, a weakness is that it does not attend to broader meanings in the data. Hsieh & Shannon provide a methodological framework for various textual content analyzes needed in this study, for instance a directed content analysis during document analysis

might involve ascertaining the infrastructure opportunities available for policy to address, and during an interview analysis it might provide an opportunity to corroborate and remove bias from a document analysis performed by the researcher.

An example of qualitative content approaches to a space-related study was presented in, *The American Space Exploration Narrative from Cold War Through the Obama Administration*, where the authors attempt to document how the narrative and the policies of space exploration have changed from the Eisenhower through the Obama administrations. To understand the narrative evolution, the authors identify five rhetorical themes: competition, prestige, collaboration, leadership, and "a new paradigm" with which to analyze the content of 40 policy documents (Holland & Burns, 2018). The method used was a qualitative document analysis where the authors counted the number of times the themes appeared in each administration's documents providing an interesting trend analysis from Eisenhower through Obama Administrations. They cited only one source for the content analysis, which was the *Three Approaches to Qualitative Content Analysis* paper by Hsieh and Shannon. The authors clearly used a directed content analysis to devise the initial five themes, then a summative analysis to count word occurrences and compare changes over time. While the authors cited a peer-review of the manuscript, they did not mention any other analysis such as interviews, which might indicate a shortfall of the study by not addressing bias through the use of another source.

As Yanow and others point out, a major concern of a single source such as documents alone, introduces bias from researcher interpretation. To elaborate on this, a journal article by Carol Cardno lists the disadvantages of document analysis to include the lack of detail, bias, and lack of credibility of performing document analysis alone (Cardno, 2018).

An example of a researcher-led document analysis without triangulation is Marcia Smith's, *President Obama's National Space Policy: A change in tone and a focus on space sustainability*. In the article, the author compares and contrasts the 2010 Obama National Space Policy to the 2006 G.W. Bush National Space Policy using her own expertise as researcher to compare similar texts and extract meaning. As an example, she compares the Bush passage, "The United States considers space systems to have the right of passage through, and operations in space, without interference. Consistent with this principle, the United States will view purposeful interference with its space systems as an infringement on its rights" with the Obama passage, "The United States considers the space systems of all nations to have the right of passage through, and conduct of operations in, space without interference. Purposeful interference with space systems, including supporting infrastructure, will be considered an infringement of a nation's rights" (Smith, 2011, p. 21). The author then goes on to point out that the "tone" of the Obama policy was friendlier and more inclusive than the "tone" of the Bush policy. No methodology is presented in assessing the tone or themes and there was no evidence of using other sources to check for bias, resulting in some validity and reliability issues. The analytical rigor in this study was greatly lacking, but the tool and technique of document analysis used for space policy analysis was demonstrated to be helpful to this Researcher, despite the lack of integrity measures.

An example of textual analysis of transcripts again illustrates the problem of bias by not having an alternate source as an integrity measure. In John Logsdon's, *Analyzing the New Kennedy Tape* in the Journal of Space Policy (Logsdon, 2011), the author reviews portions of an 18 September 1963 tape recording between President John F. Kennedy, NASA Administrator James Webb and Secretary of Defense Robert McNamara. The author's purpose is to refute

those who contend that Kennedy was looking for a way out of the commitment to landing a man on the Moon, by not only interpreting the portions that were released and reviewed but putting the recording in context of the political and budget environment in the U.S. during September of 1963. Logsdon concludes that Kennedy was actually seeking to bolster his support for the program by adding military value, though the validity and reliability of the approach taken by the author is in question since it is not a textual analysis of the entire interview transcripts nor corroborated by others, rather an interpretation of the recording itself just as if the author were summarizing the interpretation in a press conference immediately after the interview. While there is a reputation that imparts credibility, the credibility of the analysis could be greatly enhanced by adding other sources to the analysis, since validity and reliability in qualitative studies is the extent to which the data and interpretation of the data are credible.

Creswell identifies eight strategies for validity (prolonged engagement to ensure it's not an isolated phenom, rich/thick description of the phenom, triangulation uses multiple-data sources, member checking with participants to ensure their comments were accurate, discrepant information to show anything running contrary to proposed themes, clarifying any researcher bias, peer debriefing to review findings, external auditor to ensure consistency (Creswell & Creswell, 2018). A theme in the policy analysis method literature that intersects with Creswell's integrity measures is triangulation through multiple sources. Triangulation services multiple purposes, it not only addresses the credibility issues of using a single source or single researcher, but it also provides a means to corroborate themes between the multiple sources to seek both agreement and disagreement to aid in analysis. In *The Handbook of Public Policy Analysis, Theory, Politics, and Methods*, Yanow states, "Document reading can be part of an observational study or an interview-based project. Documents can provide background information prior to

designing the research project, for example, or prior to conducting interviews. They may corroborate observational and interview data – or they may refute them" (Yanow, 2007, p. 365). A key point Yanow makes is that data in documents and interview data can be used to both corroborate (if in agreement) or refute (challenge). Adding expert interviews to this study would address both the need to add additional sources to remove bias but can be a tool to finding missing policy or changes to existing policies needed to ensure the U.S. can develop future Earth-Moon infrastructures by 2049.

While adding experts as sources to remove bias and help corroborate results, interview analysis has an issue of determining the appropriate sample size to avoid the point of diminishing returns from the interview themes (Mason, 2010). Mason argues the sample size should be large enough to ensure diverse opinions but not too large. Mason uses the term "saturation" to determine sample size (Mason, 2010, p. 2). The concept of saturation was originally coined by Glaser and Straus as a specific element of constant comparison related to Grounded Theory (Glaser & Straus, 1999), but has been applied to other qualitative research methods since. There is considerable literature searching for the elusive sample size to add credibility to qualitative studies. Much of the literature explores both the justification for sample sizes, and whether to make the determination before or after the interviews. In an attempt to find best practices for sample size, the authors of, *Does Sample Size Matter in Qualitative Research? A Review of Qualitative Interviews in IS Research*, perform a meta study reviewing 83 qualitative information systems (IS) studies for the purpose of justifying sample sizes for various qualitative studies. The authors acknowledge the issue of saturation but also acknowledge that "scant attention is paid to estimating sample size for qualitative interviews" (Marshall, Cardon, Poddar, & Fontenot, 2013, p. 11). They go on to state, "There are no rules for sample size in qualitative

inquiry. Sample size depends on what you want to know, the purpose of the inquiry, what's at stake, what will be useful, what will have credibility, and what can be done with available time and resources" (Marshall, Cardon, Poddar, & Fontenot, 2013, p. 12). On the other hand, the authors were able to make four recommendations from their analysis; grounded theory studies should contain 20-30 interviews, single case studies should contain 15-30 interviews, and qualitative researchers should adhere to expectations of their intended journal outlets based on history and culture.

As an alternative to finding the elusive "exact" sample size number, the authors of *Sample Size in Qualitative Interview Studies: Guided by Information Power* contend that an initial sample size is needed for planning purposes, but the adequacy of the final sample size is not to address saturation but to address validity by providing justification for the final size in terms of their contribution of new knowledge to the analysis (Malterud, Dirk Siersma, & Dorrit Guassora, 2016). The method used by the authors was to use a fictional study to inductively develop a model, then to validate the model with a focus group. The information power model as they call it, states the larger the information power in the sample, the lower the sample size *N* is needed, and vice versa (Malterud, Dirk Siersma, & Dorrit Guassora, 2016, p. 1754). The five factors to which their information power model depends on are shown in Figure 1. The first factor is the aim of the study – a narrow study can use a small sample versus a broad study that needs a larger sample. This study is very narrow in terms of limited policy in the niche Earth-Moon space and focused on infrastructures versus broader exploration goals. The second factor is sample specificity – a dense group of experts on the topic can use a small sample versus a sparse group of non-experts on the topic needed a larger sample. This study will need a dense group of experts on the topic of space infrastructures, but that can be incorporated into the

participant selection process. The third factor is established theory – applying a theory for expert review dictates a smaller sample than using no theory. Based on earlier literature a directed content approach providing an initial theory to the interview participants is planned as a way to refine the theory and remove bias. This study will attempt to use the Researcher's document analysis results as the theory to which a small group of interview participants will review. The fourth factor is quality of dialog – strong and clear communication between the researcher and the interview participants would need a smaller sample than a weak, ambiguous and unfocused interview. This study intends to use the initial theory to conduct one-on-one interviews providing strong unambiguous communication. And finally, the fifth factor is analysis strategy – a case or in-depth specific analysis approach with a few experts necessitates a smaller sample versus a cross-cut exploratory case. The authors' acknowledged their model was similar to others, including Spradley's "good informants" model (Spradley, 1979). The information power model appears to be ideally suited to this study, if population sample and code saturation can be continuously monitored after each interview and information power assessed before adding subsequent interviews.

**Figure 1.** Information Power Model

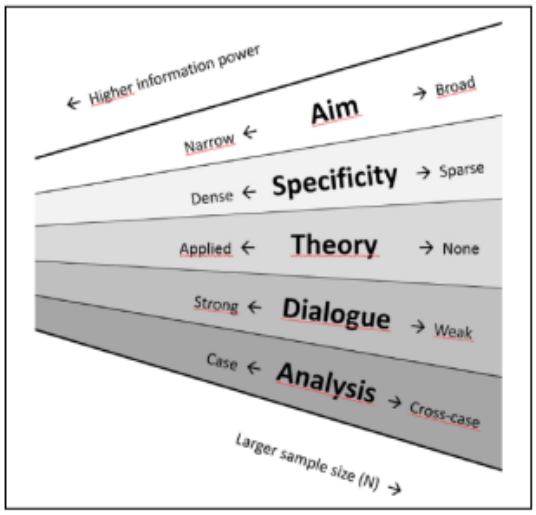


*Figure 1.* Information Power – Items and Dimensions. Reprinted from Sample Size in Qualitative Interview Studies: Guided by Information Power, K Malterud, V. Dirk Siersma and A. Dorrit Guassora, 2016, *Qualitative Health Research*, p. 1756

A final consideration in interviews is the type and structure. In his paper, *Interviewing as a Data Collection Method: A Critical Review*, Hamza Alshenqeeti details each type of interview

listing their strengths and weaknesses (Alshenqeeti, 2014). The first type of interview is the structured interview which are mostly yes or no responses to a set of predetermined direct questions. This type of interview provides the interviewer and interviewee very little freedom. The second type is the open-ended (unstructured) interview. Unlike the structured interview, this kind provides the greatest flexibility for the interviewer and interviewee in terms of elaboration of issues. The third type of interview is the semi-structured interview, which is more flexible than the structured interview but also provides the opportunity to guide and direct the interview using main questions, follow up questions and probing questions for the interview participant to expand upon. This type of interview is best served by creating an interview checklist or guide to stay on track with the questioning (Alshenqeeti, 2014, p. 40). The fourth type is focus group interviewing where the group is focused or collectively has expertise on a given topic. In group settings, focus group interviews have some obvious challenges related to the complexities of group dynamics and behavior. Alshenqeeti goes on to provides a critical evaluation of the interviewing method where he sums the advantages as; high return rate, fewer incomplete answers, can involve reality, can control the answering order, is relatively flexible and the disadvantages as: time-consuming, use for small scale studies only, it is never 100% anonymous, has the potential for subconscious bias, and has a potential for inconsistencies (Alshenqeeti, 2014, p. 43). A semi-structured type of interview appears suitable to this study, since a modicum of structure is required to guide the interviews using a directed content approach from the previous document analysis.

Regarding semi-structured interviews, Rosanne E. Roberts wrote an article in The Qualitative Report meant to be a tutorial but provides some content on what might be included in a semi-structured interview guide. Entitled, *Qualitative Interview Questions: Guidance for the*

*Novice Researcher,* Roberts provides a list of considerations as a checklist for those new to qualitative interviews. After a brief background and list of literature on the use of qualitative interviews as a research method, Roberts suggests preparation of an interview guide that contains orienting questions to set the stage, main questions aligned to the theme and purpose of the study, follow up questions to explore the interview participants view thoughts and feelings, and probes used to keep the subject talking or for clarification on earlier points (Roberts, 2020). For the questions themselves, good interview questions should contribute thematically to knowledge production and dynamically to promoting a good interview interaction (Brinkmann & Kvale, 2015, p. 157). Furthermore, interview questions must align with the purpose and goals of the study and be carefully worded so as to be easily understood and allow the interview participant to share freely (Brinkmann & Kvale, 2015). More specifically, interview questions can be direct or in-direct asking about highlights, turning points, comparisons and various dimensions of an issue (most, least, best, worst) and if main questions, be broken up into essential components (Rubin & Rubin, 2012).

**Research Design**

An overall qualitative approach to this policy analysis is supported by the methods found in literature (Creswell & Creswell, 2018) (Sadovnik, 2019) (Yanow, 2007) (Wagenaar, 2019). A key element used to analyze and interpret the policy will consist of a researcher-led policy document analysis (Bowen, 2009) (Yanow, 2007) (Wagenaar, 2019). However, the literature suggests adding other sources to address bias of the researcher and corroborate the document analysis, as well as identify supplemental or new information (Cardno, 2018) (Creswell & Creswell, 2018). As a result, interviews with experts were added to the research design. The combination of an initial researcher-led document analysis and subsequent

expert interview analysis will serve as the two phases of the research design, with the document analysis being the first phase. The second expert interview phase will be used to corroborate the document analysis and remove bias, but also be used to identify new themes not apparent in the document sources needed to produce the results and answer the research question, "*Is U.S. policy sufficient to develop Earth-Moon Economic Zone infrastructures by 2049?"* If any changes or new policies are identified, as judged through the document analysis and interviews with experts, then the U.S. policy reviewed will be deemed not sufficient.

Figure 2 presents the overall research design, reflecting two analytical phases to the study, a researcher-led document analysis followed by an interview analysis to both corroborate the researcher-led results and provide supplemental information to ascertain as missing policy or changes needed to existing policy.

**Figure 2.** Overall Approach Highlighting Document Analysis Phase

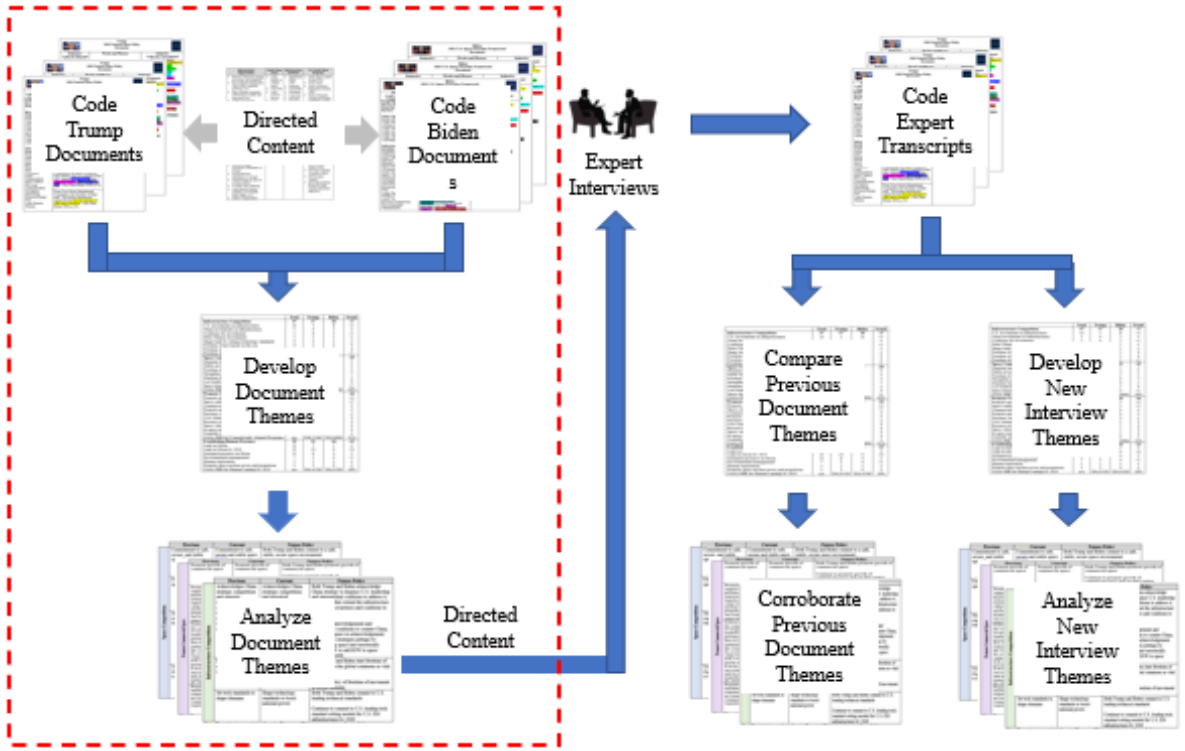


*Figure 2.* The figure is a graphical representation of the overall research approach. The initial document analysis phase is represented within the red dashed lines.

**Document Analysis Phase**

The initial document analysis phase is represented within the red dashed lines on Figure 2. The document analysis phase will serve as the primary method to develop and analyze document themes and policy elements. The methodical steps within the document analysis were inspired by the research methods identified in the literature (Bowen, 2009) (Fereday & Muir-Cochrane, 2006) (Vaismoradi, 2016). The first step is to code the individual Trump and Biden policy documents, the second step is to combine the codes and develop overall U.S. policy document themes, and the third step is to analyze the words and phrases of the policies from each administration to characterize consistent or divergent policy elements in order to identify the more sufficient policies to lead Earth-Moon infrastructures by 2049.

***Document Data Used.*** The BRI was placed in the Chinese constitution in 2017 to displace current U.S. infrastructure leadership, with space highlighted for inclusion as reflected in Bao statements in 2019 that BRI includes the Earth-Moon Economic Zone. Over this period, there have been two U.S. administrations, the Trump administration from 2016 to 2020 and Biden administration from 2021 to present. As a result, data will include documents from both the Trump and Biden administration.

National and international terrestrial infrastructures are primarily a U.S. national security policy concern and activities in the Earth-Moon Zone are primarily a national space policy concern. Since this study analyzes space infrastructures in the Earth-Moon Zone, applicable Trump administration documents include the 2017 National Security Strategy and the 2020 National Space Policy. Applicable Biden administration documents will include the 2021 Interim National Security Strategy Guidance and the 2021 U.S. Space Priorities Framework.

Other documents from both administrations will be used for context but will not be included in the document analysis.

China's BRI goals are to invest in funded programs to displace the U.S. where U.S.-led infrastructures currently exist or invest in programs to create new Chinese-led infrastructures where no U.S. infrastructures exist. The Earth-Moon Zone is an area where no nation's infrastructures currently exist so both China and the U.S. have investment programs underway that could establish infrastructure primacy for this emerging economic zone. Access to individual Chinese budgets is not accessible, so the study will assume China's goal is to address as many Earth-Moon infrastructure opportunities as possible and complete them by 2049 to meet their BRI constitutional goal. The primary U.S. investment documents to be reviewed are the NASA PBRs for the Trump and Biden administrations. While there are some nascent studies ongoing by the DoD for a cislunar SDA capability and in-space logistics to maintain it, there is currently no investment in major systems on the scale that NASA has underway to enable a sustained human presence and seed several commercial space infrastructure technologies. And while there are some regulatory budgets associated with the DOC and Department of Transportation (DOT), only government funded space technology investment programs will be reviewed under the premise that they reduce technology risk needed for private investment, may lead to a public-private-partnerships, or could lead to privatization of a support contract later. Realizing that budgets within administrations change only slightly, the study will review budgets across the two administrations to identify priorities, which would be the last Trump NASA PBR submitted in 2000 (the FY21 NASA PBR) and the first Biden NASA PBR submitted in 2021 (the FY22 NASA PBR). Only PBRs will be reviewed as they reflect the investment priorities of the

President, enacted budgets will not be included as they reflect the priorities of the Congress and not necessarily presidential policy.

***Document Coding Method.*** Coding is another word for categorizing and is a common technique applicable to qualitative data sources, as it enables the researcher to categorize words and phrases of interest to the topic at hand and combine or group those categorized words and phrases into themes not readily apparent to the reader in order to draw conclusive results. A seminal source for coding methods is Johnny Saldana's, *The Coding Manual for Qualitative Researchers,* in which Saldana more eloquently defines coding as "A code in qualitative analysis is most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data. The data can consist of interview transcripts, participant observation field notes, journals, documents, open-ended survey responses, drawing, artifacts, photographs, video, websites, e-mail correspondence, social media, academic and fictional literature, and so on." (Saldana, 2021, p. 26). Saldona acknowledges the use of Computer-Assisted Qualitative Data Analysis Software (CAQDAS) for studies involving multiple participant interviews. Given interview transcripts will be added during phase two, CAQDAS was chosen as an aid to code the policy documents in phase one in order to more efficiently identify themes between these coded policy documents and the subsequent coded interview transcripts from phase two later. Saldona presented 21 vetted CAQDAS products on the market. From this list, the Researcher selected MAXQDA due to availability and other factors. All six policy documents were ingested into the MAXQDA tool, directed content codes were then added as the initial code book, and subsequent new codes were added to the code book during conventional coding in accordance with the types of content analysis methods in the literature (Hsieh & Shannon, 2005). The six policy documents reviewed

consist of over 2,000 pages which precludes providing the coded documents in this report. The coded documents will remain in the MAXQDA database and are available for inspection.

After each individual document was coded, the derived codes and number of times the code was used (summative code count) for that document was transferred to a table. At the end of the coding, there were six tables; the 2017 National Security, 2020 National Space and FY21 NASA PBR documents from the Trump Administration, and the 2021 Interim National Security, 2021 Space Priorities and FY22 NASA PBR documents from the Biden Administration. The NASA PBRs represent a coding challenge since there are numerous combinations of words and phrases from the NASA Administrator and individual NASA programs coupled with numerous budget data for each program. Coding of the narratives was similar to the textual coding of the narratives in the National Security and National Space policy documents, but as was expected the coding for multiple programs that enable multiple infrastructures resulted in a matrix that graphically portrays the various combinations of programs-to-infrastructure opportunities in order to code the program budgets against infrastructure opportunities vice programs. Using the matrix of programs aligned to infrastructures and budgets aligned to programs, it is now feasible to align programs in the NASA PBR to infrastructure opportunities. Adding budget information greatly complements the coding during trend analysis between each administration.

***Development of Directed Content Codes.*** Of the three types of textual content coding analysis identified in the methods literature, a directed content analysis is an appropriate first step in the initial document analysis phase (Hsieh & Shannon, 2005). Since the purpose of the study is to review policy related to infrastructures in the Earth-Moon Zone, the goal for a directed or structured framework analysis is to identify relevant infrastructure opportunities in the Earth-Moon Zone to serve as the directed codes which will then guide the policy document

coding and extract relevant themes related to those infrastructures. Since there are no commercial infrastructures in the Earth-Moon Zone yet, related government programs likely address most infrastructure opportunities since companies with contracts awarded from the government will likely have interest in privatizing those contracts or using the government funding for technology risk reduction and maturation to one day seek private investment for their own commercial infrastructure venture. As a result, commercial infrastructure opportunities are a mirror of planned government infrastructures at the present time, certainly given the newness of the Earth-Moon Zone. Since most government activity in the Earth-Moon Zone is currently NASA, the study reviewed the NASA Artemis Plan to identify potential infrastructures that might be created for both civil human exploration and as seed funding for commercial use through later privatization.

The Artemis plan (NASA, 2020) is replete with NASA scientific data gathering projects, with the goal of creating a scientific data gathering infrastructure on the surface of the Moon through programs like the Commercial Lunar Payload Services (CLPS) program, Payloads and Research Investigations on the Surface of the Moon (PRISM), and other lunar instrument programs. In addition to scientific data gathering, CLPS is also demonstrating technologies needed for a future commercial mining and in-situ resource utilization (ISRU) capability. To support lunar mining and ISRU, the Lunar Reconnaissance Orbiter (LRO) will provide lunar remote sensing. While CLPS also supports a cargo transportation infrastructure to return the science and resources from the Moon, the major crew and cargo transportation infrastructure will be provided by the Space Launch System (SLS), the Orion crew vehicle as transportation to lunar orbit, and the Human Landing System (HLS) as transportation to and from the lunar surface. Once on the lunar surface, the Artemis plan has numerous programs to develop lunar

rovers and other lunar surface transportation infrastructure. For their stay in lunar orbit and on the lunar surface, the crew will require habitats and human life support systems. Human activity in lunar orbit and on the surface will require a sustained communications and networking infrastructure, to include a navigation infrastructure for crew and cargo mobility. The Artemis plan provides several initiatives to develop an electrical power generation, storage and distribution system infrastructure as well as several initiatives to develop fuel for a propulsion infrastructure. The Gateway lunar outpost features prominently in the plan to provide in-space vehicle servicing for both the HLS and the Orion crew vehicle. Of course, the sustained presence of Gateway in lunar orbit and other activities on the surface of the Moon will require space weather monitoring and forecasting as well as other SSA infrastructure to protect both humans and equipment. In addition, The Artemis Plan also cites rendering aid or safe harbor to humans in need which the Artemis Plan calls, "emergency assistance" in support of the Astronaut Rescue and Return Agreement (NASA, 2020, p. 72). One of the other major priorities in the Artemis Plan is autonomous manufacturing on the lunar surface to support construction. Unfortunately, the Artemis Plan has only a passing reference to the sustainability of the lunar environment from human activity, mostly focused on lunar orbital debris but a broader environmental management infrastructure could be envisioned on the surface of the Moon.

While there are no defense budgets in the document review, there could be policy related to infrastructure opportunities for the USSF and their contractors, especially if they are collaborating with NASA. The following is an excerpt from a NASA and USSF Memorandum of Understanding (MOU), *"*When established in December 2019, the USSF was tasked with defending and protecting U.S. interests in space. Until now, the limits of that mission have been in near Earth, out to approximately geostationary range (22,236 miles). With new U.S. public

and private sector operations extending into cis lunar space, the reach of USSF's sphere of interest will extend to 272,000 miles and beyond – more than a tenfold increase in range and 1,000-fold expansion in service volume. USSF now has an even greater surveillance task for space domain awareness in that region, but its current capabilities and architecture are limited by technologies and an architecture designed for a legacy mission (NASA, 2020, p. 2)." While there are several ground-based telescopes that contribute to deep space SSA, the new USSF has a vision for assets in the Earth-Moon Zone to augment ground-based telescopes and provide SDA to track not only man-made assets, but natural events such as space weather. As well, the USSF has a vision of in-space logistics, similar to NASA's DSL support to Gateway (NASA, 2022), as their version of an infrastructure to provide transportation and in-space vehicle servicing to these SDA assets positioned in the cislunar space (U.S. Space Force, 2020, p. 37). Table 1 shows the combined NASA and USSF infrastructure opportunities. These 18 infrastructure opportunities will serve as directed content during document coding.

Table 1

*Earth-Moon Infrastructure Opportunities*

| **NASA Interest** | **USSF Interest** | **Infrastructure Opportunities for Document Analysis** |
|---|---|---|
| Planetary (Lunar) Science, Human effects | | Scientific Data Gathering |
| Human Exploration to and from Moon | | Crew Transportation |
| Human occupation in lunar orbit and on Lunar surface | | Habitats |
| All Human Exploration | | Human Life Support (includes space suits) |
| SSA for natural effects like space weather to support Human Exploration | SSA for U.S. and foreign asset tracking | Space Domain Awareness |
| Human exploration provisioning in lunar orbit or lunar surface | In-Space logistics to SDA | Cargo Transportation |
| Human exploration or planetary science in orbit or on lunar surface | In-Space logistics to SDA | In-Space Vehicle Servicing and Inspection |

| | | |
|---|---|---|
| All Human Exploration | | Communication |
| All Human Exploration | | Navigation |
| All Human Exploration | | Networking |
| Human Exploration in lunar orbit and on surface | | Electrical Energy and Power |
| Human Exploration in lunar orbit and on lunar surface | | Fuel and Propulsion |
| Human Exploration from lunar orbit or on lunar surface | | Lunar Remote Sensing |
| Human Exploration on lunar surface | | Lunar Surface Transportation |
| Human Exploration ISRU | | Resource Extraction |
| Human Exploration (habitat waste) or orbit debris | | Space Environment Management |
| Human Exploration construction in lunar orbit or on lunar surface | | In-Space Manufacturing |
| All Human Exploration | | Rendering Aid |

*Note.* Column one shows the infrastructure opportunities that will serve as the structured framework of directed codes used during the document analysis.

***Document Theme Development.*** To develop U.S. policy themes for infrastructures in the Earth-Moon Zone since 2017, the derived codes and summative code counts for all six documents were combined from the individual Trump and Biden document coding. Codes that are the same were merged and their code counts added to each other and listed in order from most to least code counts. This provided a sense of the most important codes across all policy documents. Codes were then reviewed, and patterns identified to extract themes across the documents for thematic analysis commensurate with the methods from the literature (Fereday & Muir-Cochrane, 2006). This was done by grouping like or similar codes into major categories or themes. Theme names were chosen to capture the codes and align to the overall theme of the study which is creating infrastructures in the Earth-Moon Zone by 2049. Theme categories summed the code counts within their group for an overall theme count and listed them in order from most to least code counts, again to reflect a degree of priority among the themes.

***Document Theme Analysis.*** A summative content analysis was performed to identify trends between the Trump and Biden administration for each theme and sub theme (or policy

element) developed (Hsieh & Shannon, 2005). The total code counts for each major theme and code or policy element within that theme was apportioned to the administration from which the code came. Then the differences were tabulated to show net increase or decrease in the code counts. For the NASA PBR budgets, dollars were also used to show net increase or decrease in budget requests which reflects administration priorities to Congress. Following coding, the policy documents from each administration were analyzed by theme and code to find supporting phrases and passages as exemplars and descriptive evidence to support the sufficiency analysis. Individual administration approaches were reviewed to understand the differences and identify the most sufficient policies across both to enable the U.S. to lead Earth-Moon infrastructures by 2049. This initial document analysis and recommendation for each theme will be corroborated by experts during the interview analysis phase to identify sufficient policy and changes needed to existing policy. Table 2 presents an example of the results of a document analysis theme.

Table 2

*Example of Results of Document Theme Analysis*

| | **Trump** | **Biden** | **Document Analysis** |
|---|---|---|---|
| **Theme 1** | Commitment to… | Commitment to… | Both Trump and Biden commit to…<br><br>Recommend: U.S. continue commitment to… |
| | Extend SSA… | Maintain SSA… | Trump extended SSA and Biden maintains SSA…<br><br>Recommend: U.S. continue the Trump policy to extend SSA… |

*Note.* The table is an example of the results of a document analysis for an individual theme.

**Interview Analysis Phase**

An interview phase was added to the research design to address the disadvantages of researcher-led document analysis alone, to include the lack of detail, bias and lack of credibility of performing document analysis by the researcher alone (Cardno, 2018). Indeed, one strategy

from the literature to ensure validity is triangulation from multiple-data sources (Creswell & Creswell, 2018). Furthermore, data from interviews can be used to both corroborate (if in agreement), refute (challenge) or add supplemental information (Yanow, 2007). Adding expert interviews to the document analysis addresses both the need to add additional sources to remove bias through corroboration or triangulation and will also be used tool to finding missing policy or changes to existing policies needed to ensure the U.S. can develop future Earth-Moon infrastructures by 2049.

The interview analysis phase is represented within the red dashed lines on Figure 3. The interview analysis will serve as the secondary method to triangulate the document analysis, as well as provide supplemental or missing information not discovered during the document analysis. The first step is to conduct interviews to obtain the transcript data, the second step is to

**Figure 3.** Overall Approach Highlighting Interview Analysis Phase

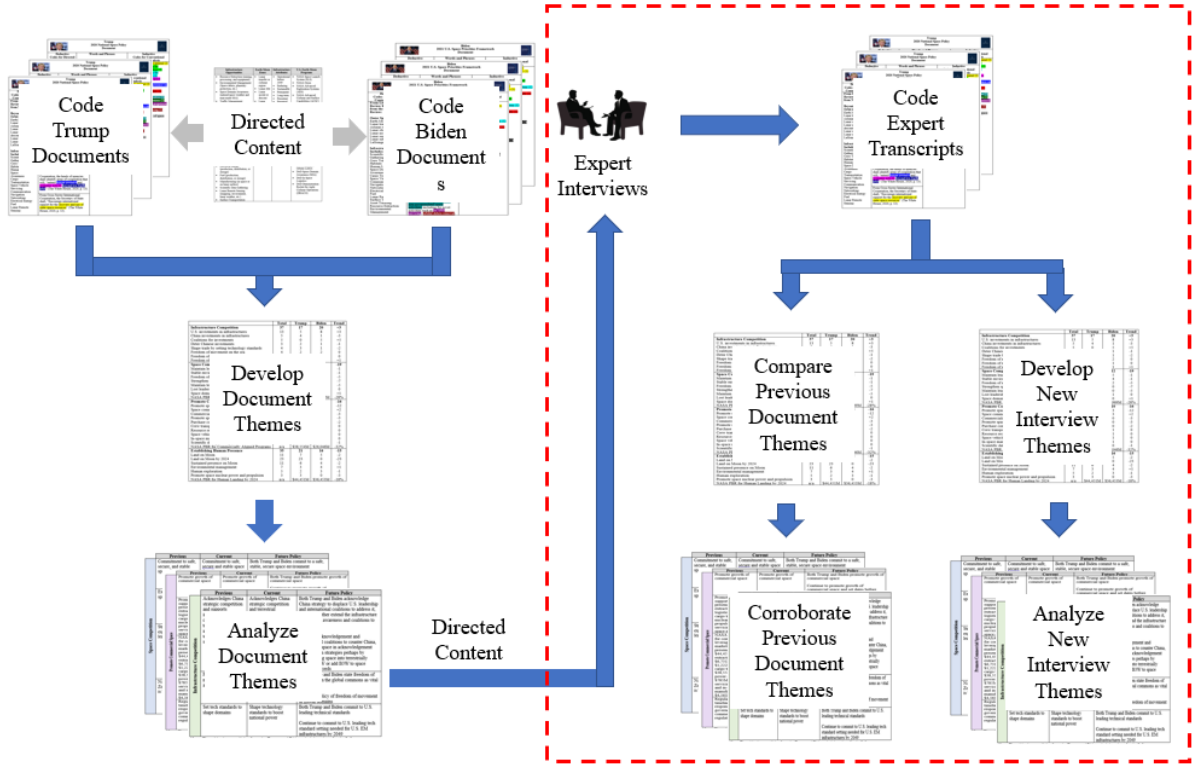


*Figure 3.* The figure is a graphical representation of the overall research approach. The second phase is interview analysis represented within the red dashed lines.

code the individual expert transcripts, the third step is to compare document themes and corroborate previous document analysis, and the fourth step is to develop any new themes and analyze them for potential supplemental information or missing policy.

***Interviews and Transcript Data Used.*** The methods literature lists several interview types from structured, open-ended or unstructured, semi-structured, and focus group (Alshenqeeti, 2014). Coupled with a directed content approach to provide an initial theoretical theme to the interviewees, a semi-structured open-ended interview is appropriate for this study. From Roberts, The methods literature also suggests an interview guide or checklist be created as a method to stay on track with the initial theoretical themes and facilitate the semi-structured interviews (Roberts, 2020), and incorporating interview questions to contribute thematically to the knowledge as suggested methods to focus interviews (Brinkmann & Kvale, 2015).

Interview data consisted of textual transcripts developed from interviews with experts in the field. These transcripts were generated from one-on-one interviews with subject matter experts lasting approximately 30 minutes each. Candidate participants were identified from known discourse literature using non-probability sampling criteria (Vehovar, Toepoel, & Steinmetz, 2016) involving; familiarity with national space policy and Earth-Moon activities, as well as a background in civil, military or commercial space sectors of the U.S. The study strove for diverse backgrounds of experts to ensure an aggregate balance among all three space sectors. Each was recruited through direct email or telephone. Participants who agreed to interviews were required to sign a Consent to Participate in Research Form. After participants signed the consent form, they were provided the phase one document analysis summary as directed content prior to the interview. Participant names were not attributed to individual responses, analysis, or recommendations. All interviews were conducted online using the Zoom video teleconferencing

software. Before recording, participants were asked to provide the percentage of their career spent among the three sectors of civil, military, and commercial space, the results of which was used to ensure the probability sampling of the experts represented a balance across the three sectors. The interview script contained two semi-structured questions, and the format was open-ended with prompts from the interviewer to allow each participant to expand on what they felt was important to the overall purpose of the study. The first question was designed to solicit responses that corroborate or triangulate the phase one document analysis results, and the second question was designed to solicit responses that provide supplemental or missing information from the previous document analysis. Recordings were saved using the Zoom option to save the recording locally to the Researcher's external hard drive, then desktop software was used to transcribe the Zoom audio into textual transcripts for coding and later analysis. There was one transcript for each participant. Any personally identifying information (PII) was removed before the transcripts were included in this report. Participants were given the opportunity to review their transcripts after the interview for accuracy, after that the Zoom audio/video recordings were destroyed. No follow-up interviews were needed.

***Monitoring Saturation and Population Sample.*** The information power model presented by suggests a small sample size for this study for planning purposes, based on the study having a narrow aim, a dense sample specificity, use of the directed theme as established theory, a strong and clear dialog between the Researcher and interview participants, and the in-depth specific analysis strategy related to cislunar infrastructures (Malterud, Dirk Siersma, & Dorrit Guassora, 2016). However, saturation must be continually monitored to provide situational awareness on saturation and information power to know when to stop the interviews (Glaser & Straus, 1999) (Mason, 2010). On-going checks for a balanced aggregate population

sample and code saturation were performed after each successive interview by adding each new expert's space sector background to the running aggregate background totals, and by coding each new expert transcript and monitoring for any new codes not found previously. No new codes are an indication of no new information indicating saturation and appropriate information power. Once the aggregate population sample has reached a relative 33% balance between civil, military, and commercial expertise, and no new codes were identified from the transcript coding, the interviews stopped and information power assumed.

***Transcript Coding Method***. The methods of coding text are the same for all textual content, whether they are the policy documents or the interview transcripts. As such, the same methods of coding the policy documents during phase one was used to code the interview transcripts during phase two. As with the document coding, a combination of directed content and conventional content coding approaches was used. However, rather than using Table 1 as the directed content for the interviews, the resultant codes from the document analysis subsequently served as the directed content for the secondary interview analysis in order to identify codes in the expert interviews that might corroborate the document analysis. In parallel, conventional content coding was also used to identify any new codes and new code counts as supplemental or missing information not previously identified in the document analysis. As with the policy document coding, all interview transcripts were coded within the MAXQDA software to enable corroboration analysis of the transcripts with the policy documents. After each transcript was coded, the codes and code counts for each transcript was transferred to a table for each expert and listed in order of most to least code counts.

***Comparing and Corroborating Previous Document Themes.*** Resultant phase two interview codes identical to those resulting from the phase one document analysis were used to

corroborate and triangulate the results. Just as was done during the document analysis, resultant interview codes were counted and listed in order from most code counts to least under each of the previous document themes. Changes in code counts between the document analysis and interview analysis was displayed in tables to aid in the analysis. After comparing codes and code counts, the transcript text from each expert were analyzed by theme and code to find supporting phrases and passages as exemplars and descriptive evidence to corroborate the document analysis results. Absence any specific transcript code or passage was taken as corroboration since the experts were provided the document analysis prior to the interview and had the opportunity to respond. Using the summative code counts from the interview analysis helped focus on the relevant transcript phrases and passages related to the document analysis results. Using the previous themes and policy elements from the document analysis as taxonomy, a side-by-side comparison of the previous document analysis results to the interview analysis results was made to determine if existing policy is sufficient or changes are needed. If changes are needed to existing policy, a recommendation was included to aid in later reconciliation of results. Table 3 provides an example of the side-by-side document corroboration analysis.

Table 3

*Example of Results of Document Corroboration Analysis*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| **Previous Theme 1** | Both Trump and Biden commit … | No changes needed to existing policy. | U.S. continue commitment … |
| | Trump did X and Biden is doing Y… | Changes needed to existing policy. According to experts… | U.S. policy should be changed to… |

*Note.* The table is an example of the summary results of the corroboration of the previous document analysis with the interview analysis.

***Developing and Analyzing New Interview Themes.*** The same method used to develop themes during the policy document analysis was used to develop new interview themes from the interview analysis. From the interview analysis, new codes not previously identified during document analysis were derived using conventional coding to uncover themes that were absent from the policy documents reviewed in phase one. To develop new themes, the new codes and code counts for all expert transcripts were combined on a table. New codes that were the same as other new codes were merged and their counts added to each other and listed in order from most to least code counts. This provided a sense of the most important codes, as judged by the experts. After codes are merged, similar codes were grouped into new themes. New theme categories summed the code counts within their group and were ordered from most to least total counts to provide an overall priority of any new themes. Theme names were chosen to capture the codes and align to the overall theme of the study which is creating infrastructures in the Earth-Moon Zone by 2049.

As during the corroboration analysis, once new themes were developed, the transcripts from each expert were analyzed by theme and code to find supporting phrases and passages to serve as exemplars and descriptive evidence to substantiate the results. This study is not striving for consensus, rather highlighting the individual opinions of experts to expose issues and foster a discourse not currently present in U.S. Earth-Moon infrastructure policy. Using the new themes and policy elements from the interview analysis as taxonomy, the new policy element was noted as a policy not currently in existing documents and needed, as judged by an expert. For each new policy needed, a recommendation was included to aid in the reconciliation of results. Table 4 provides an example of the results of new interview theme analysis.

Table 4

*Example of Results of New Interview Theme Analysis*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| **New Theme 1** | Not in documents reviewed. | New policy needed. According to experts… | Direct… |
| | Not in documents reviewed. | New policy needed. According to experts… | Create… |

*Note.* The table is an example of the summary results of the new theme analysis.

**Discussion of Results**

***Results "by Theme."*** Interview analysis results across all previous document and new interview themes were tabulated by theme and separated into three categories to address the research question; 1) no changes needed to existing policy, 2) changes needed to existing policy, and 3) new policy needed. The results of the three categories were summarized for each theme and presented in a table. Table 5 provides an example of the results by theme.

Table 5

*Example of Results of Corroborated Document and New Interview Theme Analysis*

| Themes and Number of Policy Elements | Corroborated No Changes | Corroborated Changes | New Policy Needed |
|---|---|---|---|
| Previous Document Theme 1 (3) | 1 | 2 | 0 |
| Previous Document Theme 2 (4) | 2 | 3 | 0 |
| New Interview Theme 1 (2) | 0 | 0 | 3 |
| New Interview Theme 2 (5) | 0 | 0 | 4 |
| | 3 | 5 | 7 |

*Note.* The table is an example of the summary results of the corroboration of the previous document analysis with the interview analysis.

***Results "by Recommendation."*** It was anticipated that there would be an artificiality in the number of changes recommended and number of new policies recommended categories when tabulating by theme. For instance, there may be redundant recommendations between themes,

and multiple similar recommendations within themes. Therefore, a reconciliation of the narrative recommendations is required to obtain the final tabulation by recommendation for any changes or new policies needed. These reconciled results (by recommendation) for each of the three categories of; 1) no changes to existing policy, 2) changes to existing policy, and 3) new policies were ultimately used to answer the research question, not the tabulated results by theme.

***Research Question.*** The research question is, "*Is U.S. policy sufficient to develop Earth-Moon Economic Zone infrastructures by 2049?"* If there is no new policy or changes to existing policy identified, as judged through a document analysis and interviews with experts, then U.S. policy is sufficient. If changes to existing policies or new policies are identified, then U.S. policy will be deemed not sufficient. Tabulating reconciled recommendations for each category provided the results needed to answer the research question. It was anticipated that the experts would identify a combination of new policy and changes to existing policy, which was the case as shown in the analysis section. As a result, the answer to the research question is, "*U.S. policy is not sufficient to develop Earth-Moon infrastructures by 2049*."

Per the scope, this study will not analyze individual recommendations in-depth, rather simply tabulate the number of recommendations for changes and new policies needed, in order to answer the research question. Recommendations were summarized and put forth in the conclusion section as considerations for future study.

## ANALYSIS

Analysis was performed in accordance with the methods and research design to answer the research question, "*Is U.S. policy sufficient to develop Earth-Moon Economic Zone infrastructures by 2049?"* As judged through a document analysis and interviews with experts, if there is no new policy or changes to existing policy identified, then U.S. policy is sufficient. If new policy or changes to existing policy are identified, then U.S. policy will be deemed not sufficient. The analysis consisted of two phases, a document analysis phase and an interview analysis phase. The document analysis phase coded Trump and Biden documents to develop overall U.S. policy themes between the two administrations, then the policy documents from each administration were analyzed by theme and code to find supporting phrases and passages as exemplars and descriptive evidence to substantiate the document analysis results.

The interview analysis phase was used to corroborate the document analysis results, as well as develop new themes and codes to identify supplemental information such as new policies or changes to existing policies through themes that might not have been uncovered during the document analysis phase. As was done during the document analysis, the transcripts from each expert were analyzed by theme and code to find supporting phrases and passages as exemplars and descriptive evidence to support both the corroboration of the document analysis results and the new codes and themes. The interview analysis results from all documents were summarized by themes and grouped into three categories; 1) no changes needed to existing policy, 2) changes needed to existing policy, and 3) new policy needed. Then, recommendations within each of the three categories were reconciled for redundant recommendations between themes, and subordinate recommendations within themes. The reconciled results were then used to answer the research question.

**Document Analysis Phase**

The document analysis phase is highlighted within the red dashed lines on Figure 4. This phase first coded the Trump 2017 National Security Strategy, 2020 National Space Policy, and

**Figure 4.** Overall Approach Highlighting Document Analysis Phase

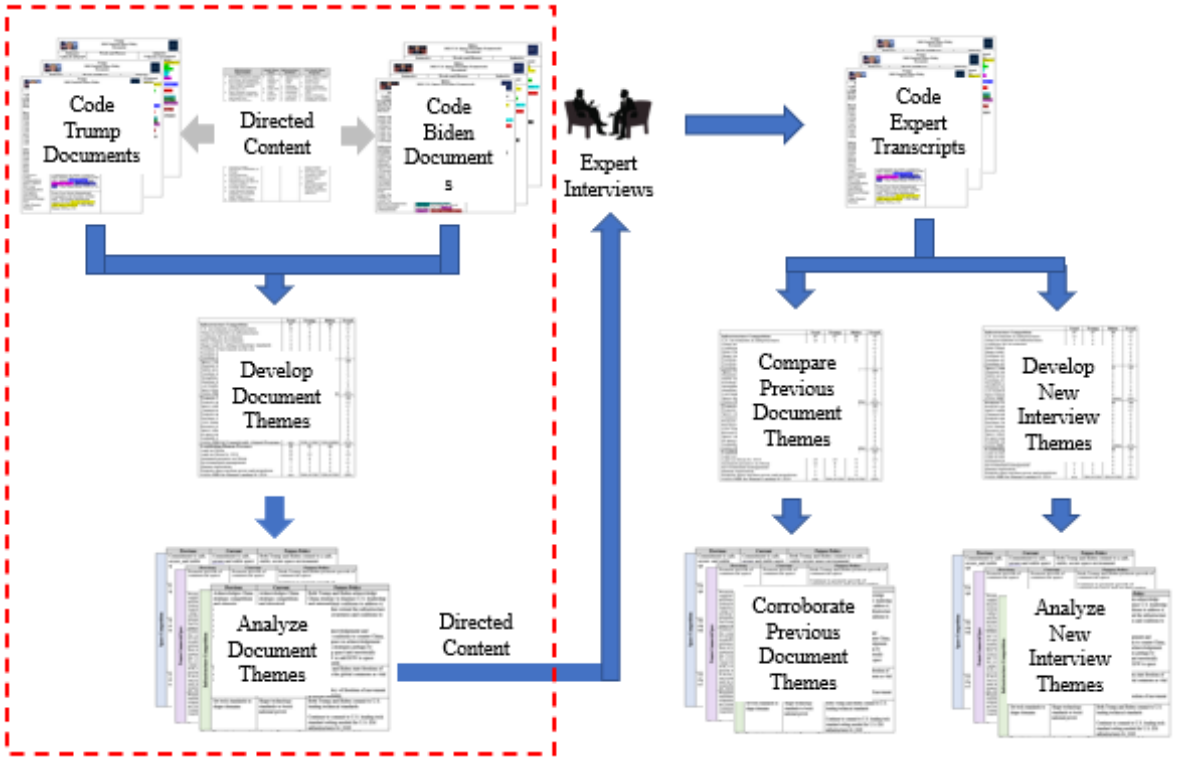


*Figure 4.* The figure is a graphical representation of the overall research approach. The initial document analysis phase is represented within the red dashed lines.

FY21 NASA Budget Request Documents, then coded the Biden 2021 Interim National Security Strategy Guidance, 2021 Space Priorities Framework, and FY22 NASA Budget Request Documents. Codes from all documents were then consolidated and themes developed related to the U.S. leading Earth-Moon Zone infrastructure development by 2049. After the themes were developed, the policy documents from each administration were analyzed by theme and code to find supporting phrases and passages as exemplars and descriptive evidence to support the sufficiency results.

## Coding Trump Documents

The directed content was the 18 infrastructure opportunities, then other codes were derived during the coding process to enable development of themes. The first document reviewed was the Trump 2017 National Security Strategy. The tone and tenor of the document provided several sub contexts for the analysis. The overall focus of the document was on strengthening military and economic power of the U.S. and making space a priority for the administration. While the infrastructure opportunity codes were used initially, they were too specific for high level national security strategy, so the more general terms of space and infrastructure were used which yielded several relevant codes. Coding was done using the MAXQDA software. The codes derived from the Trump 2017 National Security Strategy document analysis are presented in Table 6.

Table 6

*Trump 2017 National Security Strategy Document Codes*

| **Directed Content Codes** | **Derived Codes (and Code Counts)** |
|---|---|
| Space Infrastructures | U.S. investments in infrastructures (5)<br>China investments in infrastructures (4)<br>Freedom of movement in space (3)<br>Promote space commerce (3)<br>Strengthen capabilities in space (2)<br>Freedom of movement on the sea (2)<br>Maintain leadership (2)<br>Deter investments (2)<br>Stable environments benefit economy (1)<br>Freedom of movement on the ground (1)<br>Shape trade by setting technology standards (1)<br>Maintain leadership in space exploration (1)<br>Space commerce regulations (1)<br>Lost leadership (1) |

*Note.* Document codes listed show the counts in parentheses reflecting the number of times the code was found in the document. Codes are listed in order of code counts from highest to lowest.

The second document reviewed was the Trump 2020 National Space Policy National Space Policy. The tone and tenor of the document provided several sub contexts for the analysis. It was organized into cross-sector and sector guidance which helped greatly for context. The overall focus of the document was on bolstering U.S. space civil, commercial, and military power. Civil space was very specific focused on returning humans to the Moon by 2024 with maintaining a sustained human presence by 2028, commercial space was focused on growing markets related to a return of humans to the Moon and reducing regulations, and military space was focused on protecting Earth orbital and critical infrastructure provided by space. There were no references to infrastructures directly, though infrastructures were inferred to sustain human presence by 2028 and sustain commercial activities like resource extraction. However, there was no reference to the strategic competition with China for infrastructures in space, either directly or indirectly. Once again, directed codes were used to screen the document but this time there was much more success using the infrastructure opportunity codes. This is because the entire document is a lower-level space document, providing much more specificity. Coding was done using the MAXQDA software. The codes derived from the Trump 2020 National Space Policy document analysis are presented in Table 7.

Table 7

*Trump 2020 National Space Policy Document Codes*

| **Directed Content Codes** | **Derived Codes (and Code Counts)** |
|---|---|
| Space | Promote space commerce (11) |
| Infrastructures | Strengthen space capabilities (5) |
| Earth-Moon Zone | Freedom of movement in space (4) |
| Lunar transfer or cislunar region | Stable environments benefit economy (4) |
| Lunar obit | Commercialize routine government functions (3) |
| Lunar ascent or descent | Environmental management (3) |
| Lunar surface | Sustained presence on Moon (3) |
| Lunar subsurface | Commercial space nuclear power and propulsion (3) |

| | |
|---|---|
| LaGrange points | Purchase commercial products and services (2) |
| Scientific Data Gathering | Land on the Moon (2) |
| Crew Transportation | Human exploration (2) |
| Habitats | Maintain leadership in space (2) |
| Human Life Support | Maintain leadership in space exploration (2) |
| Space Domain Awareness | Shape trade by setting technology standards (2) |
| Cargo Transportation | Commercial Crew transportation (1) |
| Space Vehicle Servicing | Space domain awareness (1) |
| Communication | Commercial Resource extraction (1) |
| Navigation | Commercial Scientific data gathering (1) |
| Networking | Commercial Space vehicle servicing (1) |
| Electrical Energy | Commercial In-space manufacturing (1) |
| Fuel and Propulsion | |
| Lunar Remote Sensing | |
| Surface Transportation | |
| Asset Tracking | |
| Resource Extraction | |
| Environmental Management | |
| Manufacturing | |
| Rendering Aid | |

*Note*. Document codes listed show the counts in parenthesis reflecting the number of times the code was found in the document. Codes are listed in order of code counts from highest to lowest.

The third document reviewed was the Trump FY21 NASA PBR. The Trump PBR provided codes in three significant areas needed to support the analysis of U.S. policy trends and sufficiency. First, the PBR had a message from the Trump-appointed NASA Administrator Jim Bridenstine that provided codes reinforcing and adding to word counts in Trump's 2020 National Space Policy. Second, the Trump PBR listed programs that could be coded for alignment to the 18 infrastructure opportunities which provided the ability to identify sets of programs supporting individual Earth-Moon infrastructures, as well as sets of programs supporting broad codes in the Trump National Space Policy such as human exploration or resource recovery. And third, the PBR identified budgets and completion dates for each program, which coupled with the alignment to the infrastructure opportunities provided inferred budgets and dates for them. While coding was done using MAXQDA for Bridenstine's message and program alignment to

infrastructure opportunities, the budgets for each program were readily identifiable in the budget summary table (NASA, 2020, pp. BUD-3-6) without the need for coding.

Programs names were coded for alignment to the infrastructure opportunities which provided the ability to identify sets of programs supporting individual Earth-Moon Zone infrastructures, as well as sets of programs supporting broad codes in the Trump National Space Policy such as human exploration or resource recovery. Since there were multiple programs aligned to multiple infrastructure opportunities, a matrix was used to more easily identify the coding related to programs and infrastructure opportunities. The results are shown in Figure 5, the numbers indicated in the intersection are the code counts of infrastructure opportunities for

**Figure 5.** Trump FY21 NASA PBR Program-to-Infrastructure Opportunities Matrix

| | Land on Moon in 2024 | Sustained Presence in 2028 | Scientific Data Gathering | Crew Transportation | Habitats | Human Life Support (& space suits) | Space Domain Awareness | Cargo Transportation | In-space Vehicle Servicing | Communication | Navigation | Networking | Electrical Energy and Power | Fuel and Propulsion | Lunar Remote Sensing | Lunar Surface Transportation | Resource Extraction (and in-situ) | Asset Tracking | Space Environment Management | In-Space Manufacturing | Rendering Aid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Human Exploration | | | | | | | | | | | | | | | | | | |
| | | | | | | | Resource Recovery | | | | | | | | | | | | | | |
| Orion | 4 | 1 | | 3 | | | | | | | | | | | | | | | | | 1 |
| Space Launch System (SLS) | 4 | | | 4 | | | | 3 | | | | | | | | | | | | | |
| Exploration Ground System (EGS) | | | | 3 | | | | 3 | | | | | | | | | | | | | |
| Advanced Exploration Systems (AES) | | | | | 6 | 7 | | | | | | | | | | | | | | | |
| Advanced Cislunar and Surface Capabilities (ACSC) | 1 | | | | 3 | | | | 1 | | | | | | 1 | 4 | | | | | |
| Gateway | 4 | | | | 3 | 5 | | 2 | 2 | 2 | 1 | 1 | 2 | | | | | | 1 | | |
| Human Landing System | 5 | | | 1 | | | | | | | | | | | | | | | | | |
| Early-Stage Innovation and Partnerships (ESIP) | | | | | 4 | | | | | 1 | | | 2 | 2 | | 2 | 1 | | 1 | 2 | |
| Tech Maturation | 1 | | | 4 | | 1 | | 4 | 1 | 2 | 1 | 1 | 6 | 5 | | | 10 | | | 4 | |
| Solar Electric Propulsion | 2 | | | | | | | | | | | | 2 | 2 | | | | | | | |
| OSAM | | | | | | | | | 1 | | | | | | 1 | | | | | 1 | |
| Small Spacecraft Tech | | | | | | | | | | | 1 | | | | | | 2 | | | | |
| Space Nuclear | | | | | | | | | | | | | 2 | 2 | | | | | | | |
| Archinaut | | | | | | | | | 1 | | | | | | | | | | | 1 | |
| Small Business Inov Research/Tech Transfer (SBIR/STTR | | | 1 | | | | | | | | | | 1 | | | 1 | | | | | |
| Space Comm Networks | 1 | | | | | | | | | 2 | | 2 | | | | | | | | | |
| Commercial Lunar Payload Services (CLPS) | | | 1 | | | | | 1 | | | | | | | | 1 | 2 | | | | |
| Lunar Reconnaissance Orbiter (LRO) | | | | | | | | | | | | | | | 1 | | | | | | |
| Lunar Instruments | | | 2 | | | | | | | | | | | | | | | | | | |
| Lunar International Mission Collaboration (LIMC) | | | | | | | | | | 2 | 1 | | | | 1 | | | | | | |
| Volatiles Investigation Polar Exploration Rover (VIPR) | 1 | | | | | | | | | | | | | | 1 | 3 | 3 | | | | |

*Figure 5.* The matrix shows the NASA programs identified in the Trump FY21 NASA PBR and the infrastructure opportunity codes and code counts associated with each. The matrix also identifies programs that had Moon landing and sustained presence dates, as well as the grouping of infrastructures and programs supporting human exploration and resource recovery which are codes from the Trump policies and PBR.

each program in the PBR. Also shown are the Moon landing and sustained presence dates for each program and the alignment of programs to the broader categories of human exploration and resource extraction.

The PBR identified budgets for each program which, coupled with the alignment to the infrastructure opportunities and completion dates, provides a budget estimate for each infrastructure opportunity group such as human exploration or resource recovery. While program budgets themselves are not particularly informative in policy analysis, they prove informative in analyzing only those NASA programs aligned to the Earth-Moon Zone infrastructures and in the trend analysis between administrations. Lastly, it is very useful to look at government seed funding for a particular commercial infrastructure by cross-referencing the programs aligned to that infrastructure and the total budget for each of those programs.

Realizing the importance budgets will have in trend analysis between administrations, normalization is required to compare Trump's budget request submitted in the year 2020 to the Biden budget request submitted in the year 2021. All PBRs contain an upcoming fiscal year, followed by four more FYs (a total of five FYs in each PBR). Trump's last NASA PBR submitted in year 2020 contained program budgets for FY21-25 but since Biden's NASA PBR submitted a year later contain program budgets for FY22-26, the analysis of Trump's NASA PBR in this study will only include FY22-25 (since Biden will not have an FY21 in his budget). In the same respect, the Biden budget to be analyzed later will have an FY26 that the Trump PBR does not, so the FY26 year in Biden's PBR will be excluded. Removing FY21 from the Trump PBR and FY26 from the Biden PBR will allow for a trend analysis that is consistent between both administrations for the years FY22-FY25. However, one more adjustment needs to be made to accurately analyze the Trump budget submitted in year 2020 to the Biden budget

submitted a year later in 2021, and that is using an inflation factor to adjust Trump's 2000 dollars to 2001 dollars in Biden's budget submitted a year later. The inflation factor of 1.037% was used on the Trump budget which is consistent with the inflation factor used by NASA (NASA, 2022). Table 8 identifies the total NASA budget and the budgets for all programs that align to all 18 infrastructure opportunities, in both 2020 dollars and the inflation-adjusted 2021 dollars.

Table 8.

*Trump FY21 NASA PBR Inflation-Adjusted to 2021-Year Dollars*

| | | **2020 Dollars ($M)** | **Inflation Adjusted to 2021 Dollars ($M)** |
|---|---|---|---|
| | | **FY22-25** | **FY22-25** |
| Total NASA Budget | | 110,184 | 114,261 |
| Deep Space Exploration Programs | Orion | 5,038 | 5,224 |
| | SLS | 8,666 | 8,987 |
| | EGS | 1,782 | 1,848 |
| | AES | 634 | 657 |
| | ACSC | 5,141 | 5,331 |
| | Gateway | 2,047 | 1,122 |
| | HLS | 17,887 | 18,548 |
| Exploration Technologies | ESIP | 767 | 796 |
| | Tech Maturation | 2,790 | 2,893 |
| | SEP | 40 | 42 |
| | OSAM-1 | 191 | 198 |
| | Small Spacecraft | 1,828 | 1,895 |
| | Space Nuclear | 757 | 785 |
| | Archinaut | 18 | 19 |
| | SBIR and STTR | 2,048 | 2,124 |
| Spaceflight Operations | Comm Networks | 1,168 | 1,211 |
| Science: Lunar Discovery and Exploration Program | LRO | 88 | 91 |
| | Lunar Instruments | 289 | 300 |
| | CLPS | 1,016 | 1,053 |
| | LIMC | 4 | 4 |
| | VIPR Rover | 90 | 93 |
| Total Earth-Moon Related Budget | | 52,291 | 54,226 |
| Total Other NASA | | 57,893 | 60,035 |

*Note.* The table shows the Trump FY21 PBR Programs, FY22-25 budgets for each program in 2020-year dollars, and FY22-25 budgets for each program inflation adjusted by 1.037% to 2021-year dollars. All budgets are in Millions of $.

Using the inflation-adjusted FY22-25 column in Table 8, the NASA total budget request is $114,261M, the NASA Programs for Earth-Moon Infrastructures (budget request for programs aligned to Earth-Moon Zone infrastructure opportunities) is $54,226M, and the NASA Programs for Earth-Moon Infrastructures supporting Human Exploration driven by a 2024 landing date (budget request for programs aligned to Earth-Moon Zone infrastructure human exploration opportunities possessing a Moon landing date) is $44,451M. The NASA Programs for Earth-Moon Infrastructures supporting Commercialization (budget request for programs aligned to individual infrastructures that could be commercialized) is dependent on the specific infrastructure and supporting NASA programs. The combined codes from the Bridenstine message and budgets (matrix of programs aligned to infrastructures from Figure 5 and budgets in Table 8) are shown in Table 9 as the Trump FY21 NASA PBR code results.

Table 9

*Trump FY21 NASA PBR Codes from Bridenstine Message and Programs*

| **Directed Content Codes** | **Derived Codes (and Code Counts)** |
|---|---|
| Space<br>Infrastructures<br>Earth-Moon Zone<br>Lunar transfer or cislunar region<br>Lunar obit<br>Lunar ascent or descent<br>Lunar surface<br>Lunar subsurface<br>LaGrange points<br>Scientific Data Gathering<br>Crew Transportation<br>Habitats<br>Human Life Support<br>Space Domain Awareness<br>Cargo Transportation<br>Space Vehicle Servicing<br>Communication | Sustained presence on Moon (3)<br>Land on Moon (5)<br>Maintain leadership in space exploration (2)<br>Promote space commerce (1)<br>NASA PBR for Earth-Moon Programs (1)<br>NASA PBR for Human Landing by 2024 (1)<br>NASA PBR for Commercially Aligned Programs (1) |

| | |
|---|---|
| Navigation<br>Networking<br>Electrical Energy<br>Fuel and Propulsion<br>Lunar Remote Sensing<br>Surface Transportation<br>Asset Tracking<br>Resource Extraction<br>Environmental Management<br>Manufacturing<br>Rendering Aid | |

*Note*. Document codes listed show the counts in parenthesis reflecting the number of times the code was found in the document. Codes are listed in order of code counts from highest to lowest.

**Coding Biden Documents**

The fourth document reviewed was the Biden 2021 Interim National Security Strategy Guidance. The tone and tenor of the document provided several sub contexts for the analysis. The overall focus of the document was on renewing international engagements, clean energy, climate change, pandemic response, extremism, and the peaceful use of space, with significant passages on strategic competition with China's terrestrial infrastructure investments. While recognizing the competition with China for terrestrial infrastructure investments, there was no extension of the infrastructure competition to space, despite China's stated ambition to lead space infrastructures by 2049. As with the Trump National Security Strategy, the infrastructure opportunity codes were too specific, and the more general space and infrastructure codes were used to yield more relevant codes. Coding was done using the MAXQDA software. The codes derived from the Biden 2021 Interim National Security Strategy Guidance document analysis are presented in Table 10.

Table 10

*Biden 2021 Interim National Security Strategy Guidance Document Codes*

| **Directed Content Codes** | **Derived Codes (and Code Counts)** |
|---|---|
| Space Infrastructures | U.S. investments in infrastructures (8)<br>Coalitions for investments (3)<br>Freedom of movement on the sea (2)<br>Freedom of movement in the air (1)<br>Stable environments benefit economy (1)<br>Freedom of movement on the ground (1)<br>Freedom of movement in space (1)<br>Shape trade by setting technology standards (1)<br>China investments in infrastructures (1)<br>Deter Chinese investments (1)<br>Lost leadership (1) |

*Note.* Document codes listed show the counts in parenthesis reflecting the number of times the code was found in the document. Codes are listed in order of code counts from highest to lowest.

The fifth document reviewed was the Biden 2021 Space Priorities Framework. The tone and tenor of the document provided several sub contexts for the analysis. The document was focused on peaceful use of space, landing a human on the Moon, as well as enabling and clarifying regulations for commercial use. There was no acknowledgement of strategic competition with China's Earth-Moon infrastructures goals. Again, using the more specific infrastructure opportunity codes for this lower-level space document provided much more specificity for the codes. Coding was done using the MAXQDA software. The codes derived from the Biden 2021 Space Priorities Framework document analysis are presented in Table 11.

Table 11

*Biden 2021 Space Priorities Framework Document Codes*

| Directed Content Codes | Derived Codes (and Code Counts) |
|---|---|
| Space | Maintain leadership in space (5) |
| Infrastructures | Stable environments benefit economy (3) |
| Earth-Moon Zone | Space commerce regulations (3) |
| Lunar transfer or cislunar region | Environmental management (4) |
| Lunar obit | Commercial Resource recovery (1) |
| Lunar ascent or descent | Commercial Crew transportation (1) |
| Lunar surface | Commercial Space vehicle servicing (1) |
| Lunar subsurface | Commercial In-space manufacturing (1) |
| LaGrange points | Land on Moon (1) |
| Scientific Data Gathering | Human exploration (1) |
| Crew Transportation | Freedom of movement in space (1) |
| Habitats | Promote space commerce (1) |
| Human Life Support | |
| Space Domain Awareness | |
| Cargo Transportation | |
| Space Vehicle Servicing | |
| Communication | |
| Navigation | |
| Networking | |
| Electrical Energy | |
| Fuel and Propulsion | |
| Lunar Remote Sensing | |
| Surface Transportation | |
| Asset Tracking | |
| Resource Extraction | |
| Environmental Management | |
| Manufacturing | |
| Rendering Aid | |

*Note*. Document codes listed show the counts in parenthesis reflecting the number of times the code was found in the document. Codes are listed in order of code counts from highest to lowest.

The sixth document reviewed was the Biden FY22 NASA PBR. Like the Trump PBR, the Biden PBR provided codes in three significant areas needed to support the analysis of U.S. policy trends and sufficiency. First, the PBR had a message from the Biden appointed NASA Administrator Bill Nelson which were enlightening since the Biden policies are still relatively

new. Second, the Biden PBR listed programs that could be coded for alignment to the 18 infrastructure opportunities which provided the ability to identify sets of programs supporting individual Earth-Moon Zone infrastructures, as well as sets of programs supporting broad codes in the Biden Space Priorities Framework such as human exploration or resource recovery. And third, the Biden PBR identified budgets and completion dates for each program, which coupled with the alignment to the infrastructure opportunities provided a budget estimate by infrastructure opportunity. While coding was done using MAXQDA for Nelson's message and program alignment to infrastructure opportunities, the budgets for each program were readily identifiable in the budget summary table (NASA, 2021, pp. BUD-1-6) without the need for coding. Programs were coded for alignment to the 18 infrastructure opportunities which provided the ability to identify sets of programs supporting individual Earth-Moon Zone infrastructures, as well as sets of programs supporting broad codes in the Biden Space Priorities Framework such as human exploration or resource recovery. As with the Trump PBR analysis, there were multiple programs aligned to multiple infrastructure opportunities, so a matrix was used to more accurately present the coding related to programs and infrastructure opportunities. The results are shown in Figure 6, the numbers indicated in the intersection are the code counts of infrastructure opportunities for each program. While there were a few minor changes in word counts from the Trump PBR, the most noticeable change was the lack of dates for the Moon landing and sustained presence for each program.

The Biden PBR identified budgets for each program which, coupled with the alignment to the infrastructure opportunities, provides an estimate for each Earth-Moon Zone infrastructure opportunity or group such as human exploration or resource recovery. As in the Trump PBR analysis, while program budgets themselves are not particularly informative in policy analysis

**Figure 6.** Biden FY22 NASA PBR Program-to-Infrastructure Opportunities Matrix

| | Land on Moon in 2024 | Sustained Presence in 2028 | Scientific Data Gathering | Crew Transportation | Habitats | Human Life Support (& space suits) | Space Domain Awareness | Cargo Transportation | In-space Vehicle Servicing | Communication | Navigation | Networking | Electrical Energy and Power | Fuel and Propulsion | Lunar Remote Sensing | Lunar Surface Transportation | Resource Extraction (and in-situ) | Asset Tracking | Space Environment Management | In-Space Manufacturing | Rendering Aid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Human Exploration | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | Resource Recovery | | | | | | | | | | | | | | |
| Orion | | | | 3 | | | | | | | | | | | | | | | | | 1 |
| Space Launch System (SLS) | | | | 3 | | | | 2 | | | | | | | | | | | | | |
| Exploration Ground System (EGS) | | | | 3 | | | | 3 | | | | | | | | | | | | | |
| Advanced Exploration Systems (AES) | | | | | 5 | 9 | | | | 1 | 1 | | 1 | 1 | 1 | | | | | 1 | |
| Advanced Cislunar and Surface Capabilities (ACSC) | | | | | 4 | | | | | | | | | | 1 | 6 | | | | | |
| Gateway | | | | 1 | 4 | 5 | | 2 | 3 | 2 | 1 | 1 | 2 | 2 | | | | | 1 | | |
| Human Landing System | | | | 1 | | | | 1 | | | | | | | | | | | | | |
| Early-Stage Innovation and Partnerships (ESIP) | | | | | | | | | | 1 | | | 5 | 2 | | 2 | 7 | | 1 | 2 | |
| Tech Maturation | | | | 2 | | 1 | | 2 | 1 | 2 | 2 | 2 | 5 | 2 | 2 | 3 | 8 | | | 6 | |
| Solar Electric Propulsion | | | | | | | | | | | | | | 3 | | | | | | | |
| OSAM | | | | | | | | | 1 | | | 2 | | | 1 | | | | 1 | | |
| Small Spacecraft Tech | | | | | | | | | | | 1 | | | | | | 2 | | | | |
| Space Nuclear | | | | | | | | | | | | | 2 | 2 | | | | | | | |
| Archinaut | | | | | | | | | 1 | | | | | | | | | | | 1 | |
| Small Business Inov Research/Tech Transfer (SBIR/STTR | | | 1 | | | | | | | | | | | | | 1 | | | | | |
| Space Comm Networks | | | | | | | | | | 2 | | 2 | | | | | | | | | |
| Commercial Lunar Payload Services (CLPS) | | | 1 | | | | | 1 | | | | | | | | 1 | 2 | | | | |
| Lunar Reconnaissance Orbiter (LRO) | | | | | | | | | | | | | | | 1 | | | | | | |
| Lunar Instruments | | | 2 | | | | | | | | | | | | | | | | | | |
| Lunar International Mission Collaboration (LIMC) | | | | | | | | | | 2 | 1 | | | | 1 | | | | | | |
| Volatiles Investigation Polar Exploration Rover (VIPR) | | | | | | | | | | | | | | | 1 | 3 | 3 | | | | |
| Development and Adv. Of Lunar Instrumentation (DALI) | | | 1 | | | | | | | | | | | | | | | | | | |
| Trailblazer | | | | | | | | | | | | | | | | | | | | | |
| Payloads and Research In on Surface of Moon (PRISM) | | | 1 | | | | | | | | | | | | | | | | | | |

*Figure 6.* The matrix shows the NASA programs identified in the Biden FY22 NASA PBR and the infrastructure opportunity codes and code counts associated with each. As in the Trump PRB matrix, the matrix reflects the grouping of infrastructures and programs supporting human exploration and resource recovery.

for a given year, they prove very informative in analyzing only those NASA programs aligned to the Earth-Moon Zone infrastructures and very informative in the trend analysis between administration priorities as programs, budgets, completion dates and alignment to infrastructure opportunities change. Recall the Trump PBR required truncation of the FY21 budget year to realize an FY22-25 total, and inflation adjustment from 2020 to get to 2021-year dollars. The Biden PBR will truncate the FY26 budget year to get an FY22-25 total and is already in 2021-year dollars so no inflation adjustment is needed. Table 12 identifies the total NASA budget and budgets for those NASA programs aligned to the 18 infrastructures.

Table 12.

*Biden FY22 NASA PBR in 2021-Year Dollars*

| | | **2021 Dollars ($M)** |
|---|---|---|
| | Total NASA Budget | 102,427 |
| Deep Space Exploration Programs | Orion | 5.070 |
| | SLS | 9,729 |
| | EGS | 2,176 |
| | AES | 780 |
| | ACSC | 1,298 |
| | Gateway | 3,031 |
| | HLS | 6,031 |
| Space Technologies | ESIP | 598 |
| | Tech Maturation | 2,024 |
| | SEP | 77 |
| | OSAM-1 | 1,012 |
| | Small Spacecraft | 877 |
| | Space Nuclear | 342 |
| | MOXI (Fission Surface Power) | 3 |
| | Archinaut | 33 |
| | SBIR and STTR | 1,184 |
| Spaceflight Operations | Comm Networks | 1,518 |
| Science: Lunar Discovery and Exploration Program | LRO | 88 |
| | Lunar Instruments | 231 |
| | CLPS | 1,016 |
| | LIMC | 4 |
| | VIPR Rover | 1,675 |
| | DALI | 60 |
| | Lunar Trailblazer | 27 |
| | Payloads and RI on Moon (PRISM) | 85 |
| | Total Earth-Moon Related Budget | 38,969 |
| | Total Other NASA | 63,459 |

*Note.* Space Technologies is a change from Trump's Exploration Technologies. Nuclear surface fission power was moved from Trump's space nuclear to Mars MOXI. DALI, Lunar Trailblazer and PRISM were added by Biden.

Using the program budgets from Table 12, the NASA total budget request is $102,427M, the NASA Programs for Earth-Moon Infrastructures (budget request for programs aligned to Earth-Moon Zone infrastructure opportunities) is $38,969M, and the NASA Programs for Earth-

Moon Infrastructures supporting Human Exploration driven by a landing date in the future (budget request for programs aligned to Earth-Moon infrastructure human exploration opportunities possessing a Moon landing date) is $36,453M. The NASA FY22 Programs for Earth-Moon Infrastructures supporting Commercialization (budget request for programs aligned to individual infrastructures that could be commercialized) is dependent on the specific infrastructure and supporting NASA programs. The combined codes from the Nelson message and budgets (matrix of programs aligned to the 18 infrastructures in Figure 6 and budgets in Table 12) are show in Table 13 as the Biden FY22 NASA PBR code results.

Table 13

*Biden FY22 NASA PBR Codes from Nelson Message and Programs*

| **Directed Content Codes** | **Derived Codes (and Code Counts)** |
|---|---|
| Space<br>Infrastructures<br>Earth-Moon Zone<br>Lunar transfer or cislunar region<br>Lunar obit<br>Lunar ascent or descent<br>Lunar surface<br>Lunar subsurface<br>LaGrange points<br>Scientific Data Gathering<br>Crew Transportation<br>Habitats<br>Human Life Support<br>Space Domain Awareness<br>Cargo Transportation<br>Space Vehicle Servicing<br>Communication<br>Navigation<br>Networking<br>Electrical Energy<br>Fuel and Propulsion<br>Lunar Remote Sensing<br>Surface Transportation<br>Asset Tracking | Sustained presence on Moon (5)<br>Land on Moon (3)<br>Human exploration (2)<br>Promote space commerce (2)<br>Coalitions for investment (2)<br>NASA PBR for Earth-Moon Programs (1)<br>NASA PBR for Human Landing by 2024 (1)<br>NASA PBR for Commercially Aligned Programs (1) |

| | |
|---|---|
| Resource Extraction<br>Environmental Management<br>Manufacturing<br>Rendering Aid | |

*Note*. Document codes listed show the counts in parenthesis reflecting the number of times the code was found in the document. Codes are listed in order of code counts from highest to lowest.

**Developing Document Themes**

All Trump and Biden document derived codes were consolidated. Codes that were the same were combined and their word counts added to each other and listed in order from most code counts to least. NASA program budget data from Tables 8 and 12 was added, as was the specific Moon landing date word counts from Figures 5 and 6. Then, the combined codes of all documents were grouped into major policy themes.

The first major theme that emerged was space competition, no doubt to the large volume of space content in the national space policies versus that in the national security strategies. There was no mention of space infrastructures, the Earth-Moon Zone per se, nor the competition for economic power in the Earth-Moon Zone. The second major theme to emerge was an infrastructure competition theme, not for space infrastructure, but for China or U.S. investments and the geopolitical competition for terrestrial infrastructure leadership and influence. Most of the codes were from the national security strategies since they focused on terrestrial infrastructure competition. The fourth theme that emerged was promote commercial space. Again, there was no mention of the strategic economic competition for Earth-Moon infrastructures, most of the codes were related to overall messages that the U.S. government wishes to see more space commerce. The last theme to emerge was establishing a human presence on the Moon. Most codes were related to landing a human on the Moon, again under the premise of human exploration and the civil space program, but no purpose was given. The

combined codes ranked in order from most to least code counts are shown in column one on Table 14, and the same codes grouped by policy theme are shown in column two on Table 14.

Table 14

*Combined Trump and Biden Document Codes Grouped by Policy Themes*

| Combined Codes (and Code Counts) | Grouped Codes (and Code Counts) by Theme |
|---|---|
| Promote space commerce (18) | **Space Competition (42 total)** |
| U.S. investments in infrastructures (13) | Maintain leadership in space (9) |
| Land on Moon (11) | Stable environments benefit economy (9) |
| Sustained presence on Moon (11) | Freedom of movement in space (9) |
| Maintain leadership in space (9) | Strengthen space capabilities (7) |
| Stable environments benefit economy (9) | Maintain leadership in space exploration (5) |
| Freedom of movement in space (9) | Lost leadership (2) |
| Strengthen space capabilities (7) | Space domain awareness (1) |
| Environmental management (7) | NASA PBR for Earth-Moon Programs (2) |
| Maintain leadership in space exploration (5) | **Infrastructure Competition (37 total)** |
| China investments in infrastructures (5) | U.S. investments in infrastructures (13) |
| Human exploration (5) | China investments in infrastructures (5) |
| Coalitions for investments (5) | Coalitions for investments (5) |
| Space commerce regulations (4) | Deter Chinese investments (3) |
| Shape trade by setting technology standards (4) | Shape trade by setting technology standards (4) |
| Freedom of movement on the sea (4) | Freedom of movement on the sea (4) |
| Commercialize routine government functions (3) | Freedom of movement on the ground (2) |
| Deter Chinese investments (3) | Freedom of movement in the air (1) |
| Commercial space nuclear power and propulsion (3) | **Promote Commercial Space (36 total)** |
| Freedom of movement on the ground (2) | Promote space commerce (18) |
| Purchase commercial products and services (2) | Space commerce regulations (4) |
| Lost leadership (2) | Commercialize routine government functions (3) |
| Commercial Crew transportation (2) | Commercial space nuclear power and propulsion (3) |
| Commercial Resource recovery (2) | Purchase commercial products and services (2) |
| Commercial Space vehicle servicing (2) | Commercial Crew transportation (2) |
| Commercial In-space manufacturing (2) | Commercial Resource recovery (2) |
| NASA PBR for Earth-Moon Programs (2) | Commercial Space vehicle servicing (2) |
| NASA PBR for Human Landing Programs by 2024 (2) | Commercial In-space manufacturing (2) |
| NASA PBR for Commercially Aligned Programs (2) | Commercial Scientific data gathering (1) |
| Space domain awareness (1) | NASA PBR for Commercially Aligned Programs (2) |
| | **Establishing Human Presence (35 total)** |
| | Land on Moon (11) |

| | |
|---|---|
| Freedom of movement in the air (1)<br>Commercial Scientific data gathering (1) | Land on Moon by 2024 (from Table 9 and Table 13)<br>Sustained presence on Moon (11)<br>Environmental management (7)<br>Human exploration (5)<br>Promote space nuclear power and propulsion (3)<br>NASA PBR for Human Landing Programs by 2024 (2) |

*Note.* The table shows the combined codes ranked in order by most code count to least code count, and the same codes grouped by major policy theme.

Table 15 shows these same themes with their respective code count totals and budgets for each administration, as well as the trend in code count and budgets from the previous Trump to current Biden administration. While not a pure measure of trends, the code counts were fairly accurate when supported by cited passages in the analysis.

Table 15

*Combined Trump and Biden Document Codes, Themes and Trends*

| | **Total** | **Trump** | **Biden** | **Trend** |
|---|---|---|---|---|
| **Space Competition** | **42** | **31** | **12** | **-19** |
| Maintain leadership in space | 9 | 4 | 5 | -1 |
| Stable environments benefit economy | 9 | 5 | 4 | -1 |
| Freedom of movement in space | 9 | 7 | 2 | -5 |
| Strengthen space capabilities | 7 | 7 | 0 | -7 |
| Maintain leadership in space exploration | 5 | 5 | 0 | -5 |
| Lost leadership | 2 | 1 | 1 | 0 |
| Space domain awareness | 1 | 1 | 0 | +1 |
| NASA PBR for Earth-Moon Programs | n/a | $54,224M | $38,969M | -28% |
| **Infrastructure Competition** | **37** | **17** | **20** | **+3** |
| U.S. investments in infrastructures | 13 | 5 | 8 | +3 |
| China investments in infrastructures | 5 | 4 | 1 | -3 |
| Coalitions for investments | 5 | 0 | 5 | +5 |
| Deter Chinese investments | 3 | 2 | 1 | -1 |
| Shape trade by setting technology standards | 4 | 3 | 1 | -2 |
| Freedom of movement on the sea | 4 | 2 | 2 | 0 |
| Freedom of movement on the ground | 2 | 1 | 1 | 0 |
| Freedom of movement in the air | 1 | 0 | 1 | +1 |
| **Promote Commercial Space** | **36** | **26** | **10** | **-16** |
| Promote space commerce | 18 | 15 | 3 | -12 |
| Space commerce regulations | 4 | 1 | 3 | +2 |
| Commercialize routine government functions | 3 | 3 | 0 | -3 |

| | | | | |
|---|---|---|---|---|
| Commercial space nuclear power and propulsion | 3 | 3 | 0 | -3 |
| Purchase commercial products and services | 2 | 2 | 0 | -2 |
| Commercial Crew transportation | 2 | 1 | 1 | 0 |
| Commercial Resource recovery | 2 | 1 | 1 | 0 |
| Commercial Space vehicle servicing | 1 | 1 | 1 | 0 |
| Commercial In-space manufacturing | 1 | 1 | 1 | 0 |
| Commercial Scientific data gathering | 1 | 1 | 0 | -1 |
| NASA PBR for Commercially Aligned Programs | n/a | $63,319M | $47,457M | -25% |
| **Establishing Human Presence** | **35** | **21** | **16** | **-15** |
| Land on Moon | 11 | 7 | 5 | -2 |
| Land on Moon by 2024 | 23 | 23 | 0 | -23 |
| Sustained presence on Moon | 11 | 6 | 4 | -2 |
| Environmental management | 7 | 3 | 4 | +1 |
| Human exploration | 5 | 2 | 3 | -1 |
| NASA PBR for Human Landing by 2024 | n/a | $44,451M | $36,453M | -18% |

*Note.* The table show the major themes, codes and code counts by administration, and the trends in code counts and budget changes from the Trump to Biden administration.

**Analyzing Document Themes**

Each administration's overall policies were reviewed against these four themes. The purpose is to understand the differences and uncover the most sufficient policies across both to enable the U.S. to develop Earth-Moon infrastructures by 2049. Code counts and their trends need to be augmented with passages from each policy since code counts provides priority, but not content or context.

***Space Competition Theme*.** About 28% of the code counts were related to space competition. Among the four themes, the space competition theme represents the largest negative trend in code count from Trump to Biden. Free movement in space was addressed in the infrastructure competition theme to be consistent between administrations and broadly falls under the freedom of movement in the global commons statement. Equally consistent is that both administrations lament a "lost leadership" of space, but that thought may be related to the near-Earth regime where it has become congested, contested and competitive so it may not apply to the Earth-Moon Zone.

Another area of consistency but specific to space is the belief that safe, secure and stable environments are good for investment and economic growth. To illustrate the consistency in policies, Trump states the U.S. will, "Create a safe, stable, secure, and sustainable environment for space activities" (The White House, 2020, p. 5) and Biden states, "We will explore and use outer space to the benefit of humanity, and ensure the safety, stability and security of outer space activities" (The White House, 2021, p. 17). However, that may be where the consistency ends.

While space domain awareness is one of the infrastructure opportunities it is highlighted under space competition because SDA provides military, civil and economic power to the nation that has it. Clearly Trump prioritized SDA high by stating the U.S. will, "Expand SSA to deep space" (The White House, 2020, p. 15) and, "Improve, develop, integrate, demonstrate, and proliferate in cooperation with relevant interagency, international, intergovernmental, and commercial entities, space domain awareness capabilities to predict, detect, warn, characterize, and attribute human-caused and naturally occurring activities that pose threats to space systems of United States interest" (The White House, 2020, p. 29). Biden states, "The United States will increase efforts to mitigate, track, and remediate space debris" (The White House, 2021, p. 7) which implies SDA only Earth orbit as opposed to deep space.

The other area of significant difference is expanding (or strengthening) space leadership versus maintaining (or preserving) space leadership. As it applies to the Earth-Moon Zone where no infrastructures currently exist, preserving leadership only maintains the status quo of no presence as long as no other nation attempts to have a presence, while strengthening or expanding leadership where no infrastructures currently exist implies a first-to-market strategy which might be more appropriate given the race with China. Trump states, "We will strengthen America's capabilities-including in space…" (The White House, 2017, p. 4) and, "We will

preserve and expand United States leadership in the development of innovative space technologies, services, and operations." (The White House, 2020, p. 6). On the other hand, Biden states, "The United States will maintain its leadership in space exploration and space science" (The White House, 2021, p. 5) which has two issues, it is a strategy of preservation and it only explicitly addresses exploration and science versus commercial industrialization. Clearly Trump has an expansionist policy to strengthen and expand U.S. space leadership and Biden has a maintenance or preservation policy. For terrestrial infrastructure competition or even Earth orbit infrastructures where the U.S. has an existing global leadership position, a preservation or maintenance policy is sufficient. For the Earth-Moon infrastructure competition where the U.S. has no existing global leadership position yet, a growth or strengthen policy may be more appropriate.

Last is the major difference in the NASA budget requests between Trump and Biden. The Trump NASA budget request for NASA Earth-Moon aligned programs was $54,224M and the Biden NASA budget request for the same years was $38,969M. The Biden request for NASA Earth-Moon programs is 28% less than Trump's. The document analysis for the space competition theme is summarized in Table 16.

Table 16

*Results of Document Analysis for Space Competition Theme*

| | Trump | Biden | Document Analysis |
|---|---|---|---|
| **Space Competition** | Commitment to safe, secure, and stable space domain. | Commitment to safe, secure, and stable space domain. | Both Trump and Biden commit to a safe, stable, secure space environment<br><br>Recommend: U.S. continue commitment to safe, secure, stable environment to attract U.S. private capital and investment. |
| | Extend SSA to deep space. | Increase efforts to track space debris. | Trump extended SSA to deep space which includes Earth-Moon Zone, Biden appears limited to Earth orbit debris. |

| | | | |
|---|---|---|---|
| | | | Recommend: U.S. continue the Trump policy and extend SSA to deep space to serve as an infrastructure for the Earth-Moon Zone. |
| | Strengthen and expand U.S. space leadership. | Maintain space leadership (in exploration and science). | Trump had an expansionist strategy for all space which would address new infrastructures in Earth-Moon Zone, Biden has a maintenance strategy and only for exploration and science which may not be appropriate for creating new infrastructures where none exist.<br><br>Recommend: U.S. continue the Trump policy to strengthen U.S. space leadership, but focus strengthening on establishing U.S. infrastructures in the Earth-Moon Zone before others. |
| | NASA Earth-Moon Zone budget request is $54,224M. | NASA Earth-Moon Zone budget request is $38,969M. | Biden budget request is 28% less than Trump budget request for the same Earth-Moon programs.<br><br>Recommend: Continue the Trump policy to identify dates of infrastructures needed before 2049 and request appropriate budget to support initial and sustained presence for each. Cut appears negative but without dates there is no way to know. |

*Note.* The table shows policies from the Trump and Biden administrations for the Space Competition theme and provides a discussion of sufficiency needed for future policy to compete with China's BRI goals to lead the Earth-Moon infrastructures by 2049.

***Infrastructure Competition Theme***. Roughly 25% of the code counts were related to infrastructure competition. The small positive trend in code count compared to others from Trump to Biden is negligible and their policies relatively consistent. Both administrations have been consistent in acknowledging Chinese infrastructure goals but Trump's acknowledgement appears most direct by stating, "China is investing billions of dollars in infrastructure across the globe" (The White House, 2017, p. 38) and, "China's infrastructure investments and trade strategies reinforce its geopolitical aspirations" (The White House, 2017, p. 46). Biden too has acknowledged the strategic competition by stating, "Taken together, this agenda will strengthen

our enduring advantages, and allow us to prevail in strategic competition with China or any other nation" (The White House, 2021, p. 20). Both administrations appear to have interest in international infrastructures. Trump states, "We will strengthen cooperation with allies on high-quality infrastructure" (The White House, 2017, p. 57) and Biden states, "We will renew our commitment to global development and international cooperation" (The White House, 2021, p. 6). However, their strategies diverge where Trump implements an economic sanctions approach with, "Economic tools—including sanctions, anti-money-laundering and anti-corruption measures, and enforcement actions—can be important parts of broader strategies to deter, coerce, and constrain adversaries" (The White House, 2017, p. 44) and Biden puts forth an international investment coalition approach offers alternatives to China's BRI investments with statements like, "We will stand with our allies and partners to combat new threats aimed at our democracies, ranging from cross-border aggression, cyberattacks, disinformation, and digital authoritarianism to infrastructure and energy coercion" (The White House, 2021, p. 19) and, "Through our development agencies and financing tools, we will provide foreign assistance to promote global stability and offer an alternative to predatory development models" (The White House, 2021, p. 12). While not policy per se, Biden has created a Build Back Better World (B3W) initiative with the G7 to implement this policy in an effort to counter China terrestrial investments. Unfortunately, nether administration recognized the competition beyond terrestrial.

Both administrations were consistent in freedom of movement in the global commons. While Biden had a more terrestrial focus with, "We will continue to defend access to the global commons, including freedom of navigation and overflight rights, under international law" (The White House, 2021, p. 20), Trump policy was more applicable to the Earth-Moon Zone with the statement, "Free access to the seas remains a central principle of national security and economic

prosperity, and exploration of sea and space provides opportunities for commercial gain and scientific breakthroughs" (The White House, 2017, p. 40). Both policies could refrain from using freedom of action (military term), freedom of navigation (sea fairing) and freedom of overflight (airspace) in favor of the more generic "freedom of movement" that underscores an economic tone implying the free flow of goods and services.

Lastly, both had consistent policy for the U.S. to lead global technology standard setting, which would be important for future U.S. infrastructure technologies. Biden's policy was, "We will shape emerging technology standards to boost our security, economic competitiveness, and values" (The White House, 2021, p. 18) and Trump's policy was, "The United States will provide leadership and technology to shape and govern common domains—space, cyberspace, air, and maritime—within the framework of international law" (The White House, 2017, p. 41). There is a nuance in policies. Where Trump will set technology standards to shape domains (like space), Biden will shape technology standards for economic competition which is not necessarily shaping domains. Table 17 summarizes the document analysis for the infrastructure competition theme.

Table 17

*Results of Document Analysis for Infrastructure Competition Theme*

| | Trump | Biden | Document Analysis |
|---|---|---|---|
| **Infrastructure Competition** | Acknowledges China strategic competition and supports international coalitions to invest in terrestrial infrastructures and use of economic | Acknowledges China strategic competition and terrestrial investments and supports international coalitions to invest in terrestrial infrastructures and use of G7 | Both Trump and Biden acknowledge China strategy to displace U.S. leadership and international coalitions to address it, however neither extend the infrastructure competition awareness and coalitions to space.<br><br>Recommend: Continue acknowledgement and international coalitions to counter China but include space in acknowledgement and coalition strategies perhaps by incorporating space into terrestrially focused B3W or add |

| | | | |
|---|---|---|---|
| | sanctions to counter. | coalitions financing. | B3W to space Artemis Accords to enable Earth-Moon infrastructures. |
| | Freedom of movement on the seas and in space. | Freedom of movement in global commons. | Both Trump and Biden state freedom of movement in the global commons as vital interest.<br><br>Recommend: U.S. continue policy to ensure freedom of movement in the commons to enable trade. |
| | Set tech standards to shape domains. | Shape technology standards to boost national power. | Both Trump and Biden commit to U.S. leading global technical standards.<br><br>Recommend: U.S. continue policy to lead technology standards to ensure control of future Earth-Moon infrastructure standards. |

*Note.* The table shows policies from the Trump and Biden administrations for the Infrastructure Competition theme and provides a discussion of sufficiency needed for future policy to compete with China's BRI goals to lead the Earth-Moon infrastructures by 2049.

***Promote Commercial Space Theme.*** Codes related to promoting commercial space represented 24% of the total code counts. The second largest negative trend in code counts from Trump to Biden is the promote commercial space theme. An area of common agreement is the growth of commercial space and the commercialization of government space products and services as Trump states, "Agencies shall, pursue opportunities for transferring routine operational space functions to the commercial space sector" (The White House, 2020, p. 21) and Biden states, "The United States will leverage new commercial space capabilities and services to meet national security requirements" (The White House, 2021, p. 6). The areas with key differences are in the specific markets each explicitly promote, the level of NASA funding for commercial to leverage for these markets, and regulatory positions.

On specific markets, the first Trump statement directly promotes commercial infrastructure development to support the NASA human space program and resource recovery by stating, "Extend human economic activity into deep space by establishing a permanent human presence on the Moon, and, in cooperation with private industry and international partners,

develop infrastructure and services that will enable science-driven exploration, space resource utilization, and human missions to Mars" (The White House, 2020, p. 5). He further promotes commercial support to NASA's human space program by directing commercialization of Gateway logistics with, "Encourage the growth of United States commercial human space exploration, including logistical provisioning, delivery, and the continued commercialization of operations in and beyond low Earth orbit" (The White House, 2020, p. 21), and commercialization of crew and cargo transportation with, "The NASA Administrator will, continue to grow partnerships with the commercial space sector to enable safe, reliable, and cost-effective transport of crew and cargo to destinations in low Earth and cislunar orbits, and to the lunar surface" (The White House, 2020, p. 23), and commercial partnerships with NASA in nuclear power and propulsion with, "The Secretary of Commerce shall promote responsible United States commercial space nuclear system investment, innovation, and operations" (The White House, 2020, p. 17). The only equivalent Biden statement promoting commercial support to human space at NASA is, "The United States will continue to leverage civil space activities to foster new commercial space services such as human space transportation" (The White House, 2021, p. 5). Trump goes on to promote specific on-orbit servicing and in-space manufacturing markets with, "Agencies shall, "leverage satellite servicing or on-orbit manufacturing, and public-private partnerships" (The White House, 2020, p. 20).

On the level of NASA funding for commercially aligned programs cited by Trump, his budget request for NASA programs supporting crew and cargo transportation was $38,554M, resource extraction $6,731M, in-space manufacturing $4,563M, nuclear power and propulsion $785M, on-orbit servicing $10,564M, and Gateway logistics $2,122M (NASA, 2020, pp. BUD-3-6). The total for these Trump commercially aligned programs is $63,319M. While not

specifically called out by Biden in his policy, his budget request for NASA programs supporting crew and cargo transportation was $26,046M and for the other programs mentioned by Trump it was; resource extraction $6,190M, in-space manufacturing $4,447M, nuclear power and propulsion $345M, on-orbit servicing $7,398M, and Gateway logistics $3,031M (NASA, 2021, pp. BUD-1-6). The total for these Biden programs is $47,457M The result is a Biden budget request for NASA that is $12,508M or 32% less for crew and cargo transportation, $541M or 8% less for resource extraction, $116M or 3% less for manufacturing, $440M or 56% less for nuclear space, $3,166M or 30% less for on-orbit servicing, but a $909M or 43% increase for Gateway logistics. The total difference is $15,863M less or 25% less requested by Biden than Trump for the same commercially aligned programs.

Finally, on the matter of regulating commercial markets, Trump requires a regular assessment of agency responsiveness to commercial needs by stating, “Regularly assess existing guidelines for non-government activities in or beyond Earth orbit and maintain a timely and responsive regulatory environment for licensing those activities” (The White House, 2020, p. 15), whereas Biden has declared a regulation review to provide clarity in authorizing several commercial activities with, “U.S. regulations must provide clarity and certainty for the authorization and continuing supervision of non-governmental space activities, including for novel activities such as on-orbit servicing, orbital debris removal, space-based manufacturing, commercial human spaceflight, and recovery and use of space resources” (The White House, 2021, p. 5). Table 18 summarizes the document analysis for the promote commercial space theme.

Table 18

*Results of Document Analysis for Promote Commercial Space Theme*

| | Trump | Biden | Document Analysis |
|---|---|---|---|
| **Promote Commercial Space** | Promote growth of commercial space. | Promote growth of commercial space. | Both Trump and Biden promote growth of commercial space but lack specific on Earth-Moon Zone.<br><br>Recommend: U.S. continue to promote growth of commercial space but focus on Earth-Moon Zone and completion before 2049. |
| | Promotes commercial support to human presence, resource extraction, Gateway logistics, crew and cargo transportation, nuclear power and propulsion, on-orbit servicing, and in-space manufacturing. | Promotes commercial support to crew transportation. | While Trump explicitly identifies several commercial markets, Biden only addresses one of them implying a shift in priorities and focus.<br><br>Recommend: Identify commercial market priorities for Earth-Moon infrastructures by 2049 and list for both industry guidance and in NASA enabling programs. |
| | NASA budget request for commercial leverage in the Trump markets was: human presence $44,451M, resource extraction. $6,731M, Gateway $1,222M, crew and cargo transportation $38,554M, nuclear power and propulsion $785M, on-orbit servicing $10,564M, and in-space manufacturing $4,563M. | NASA budget request for the same commercial leverage programs delineated by Trump is: human presence $36,453M, resource extraction. $6,190M, Gateway $3,031M, crew and cargo transportation $26,046M, nuclear power and propulsion $345M, on-orbit servicing $7,398, and in-space manufacturing $4,447M. | Biden budget request is 25% less than Trump request for the same commercial markets listed by Trump. While Trump explicitly identifies markets, neither identify dates.<br><br>Recommend: Identify commercial market priorities and dates before 2049. for Earth-Moon infrastructures, and list for both industry guidance and in NASA enabling programs. |
| | Regularly assess timeliness and responsiveness of government commercial regulations. | Clarify regulations for on-orbit servicing, debris removal, in-space manufacturing, human spaceflight and resource recovery. | Trump's policy was on-going to ensure responsiveness, Biden's policy to review regulations has no end date |

| | | | |
|---|---|---|---|
| | | | Recommend: Set date for completion of regulation review and ensure regulatory environment supports commercial investment in Earth-Moon infrastructures by 2049. |

*Note.* The table shows policies from the Trump and Biden administrations for the Promote Commercial Space theme and provides a discussion of sufficiency needed for future policy to compete with China's BRI goals to lead the Earth-Moon infrastructures by 2049.

***Establishing Human Presence Theme*.** About 23% of the total code counts were related to establishing a human presence. Third largest negative trend in code count from Trump to Biden is the establishing human presence theme. Consistent policies exist between the commitment to human exploration and space environmental management (or planetary contamination from human microbes on planets). Trump policy states, "The Office of Science and Technology Policy (OSTP) shall look for cooperation for, the appropriate protection of planetary bodies" (The White House, 2020, p. 14) which is consistent with Biden policy that states, "The United States will work with other nations to minimize the impact of space activities on the outer space environment, including avoiding harmful contamination of other planetary bodies." (The White House, 2021, p. 7). While laudatory to focus on planetary contamination, it could be argued to expand the focus to include lunar contamination from a sustained human presence. Planetary implies the Moon to be excluded but environmental management on the Moon or in lunar orbit is a potential infrastructure opportunity that could be missed by focusing only on planetary contamination.

The other consistent policy is to land on the Moon and sustain a human presence, however the date of the landing is now a major difference between the Trump and Biden policies. It could be argued the Trump Moon landing of 2024 and sustained presence of 2028 were unachievable with the budget and technological challenges, however it could also be argued that continuing with a budget that has no date will not compete with China who has established

2049 as their goal. There is ample Trump policy to support the Moon landing and sustained presence dates, as well as guidance to develop supporting infrastructures. The most substantial Trump policies are, "Beginning with missions beyond low Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization" (The White House, 2020, p. 23) and, "The NASA Administrator will, lead a program to land the next American man and the first American woman on the Moon by 2024, followed by a sustained presence on the Moon by 2028" (The White House, 2020, p. 23). Of interest in this study is the infrastructure vision which is clearly articulated by Trump as, "…, develop infrastructure and services that will enable science-driven exploration, space resource utilization, and human missions to Mars" (The White House, 2020, p. 5). The equivalent Biden policy is, "U.S. human and robotic space exploration missions will land the first woman and first person of color on the moon…" (The White House, 2021, p. 5), but no date is provided. In fact, the code counts on landing dates between Trump and Biden show Trump used 2024 as a Moon landing date at least 23 times in all policies and his NASA budget request, where Biden does not reflect a 2024 Moon landing or any date for initial Moon landings or a sustained presence.

Realizing NASA is recalibrating budget priorities for the new administration to focus on more Earth science for climate monitoring, they are also re-evaluating their technical challenges and re-baselining landing dates. The Trump NASA budget request for NASA human presence on the Moon by 2024 was $44,451M and the Biden NASA budget request for the same programs (less a landing date) was $36,453M. The Biden request for human presence on the Moon is 18% less than Trump's. In deference to NASA, this could be a re-planning year because all reference to 2024 landing dates were removed from the Biden budget request. Table 19 summarizes the document analysis for the establishing human presence theme.

Table 19

*Results of Document Analysis for Establishing Human Presence Theme*

| | Trump | Biden | Document Analysis |
|---|---|---|---|
| **Establishing Human Presence** | Avoid planetary contamination. | Avoid planetary contamination. | While both Trump and Biden address planetary contamination, neither address contamination of the Moon as an externality of sustained human presence.<br><br>Recommend: Continue planetary contamination but expand to contamination on Moon due to sustained human presence and consider it as a future U.S.-led environmental infrastructure in the Earth-Moon Zone. |
| | U.S. will develop infrastructures to land on the Moon by 2024 with sustained presence by 2028. | U.S. will land on the Moon and have a sustained presence. | Trump set date for initial landing and sustained presence, however Biden has no dates in policy.<br><br>Recommend: Set date for initial landing and sustained presence and include Earth-Moon infrastructures and dates to develop before 2049. |
| | NASA budget request for human presence (for programs with 2024 landing date) is $44,451M. | NASA budget request for human presence (for same programs with 2024 landing dates) is $36,453M. | Biden request is 18% less than Trump request and the landing and sustained presence dates have been removed.<br><br>Recommend: Set dates for initial landing and sustained presence before 2049 and request appropriate funding to meet challenges associated with dates in Earth-Moon Zone. |

*Note.* The table shows policies from the Trump and Biden administrations for the Establishing Human Presence theme and provides a discussion of sufficiency needed for future policy to compete with China's BRI goals to lead the Earth-Moon infrastructures by 2049.

**Interview Analysis Phase**

The interview analysis phase is highlighted within the red dashed lines on Figure 7. The interview analysis served as the secondary method to both corroborate the previous document analysis and to provide supplemental information. Tables 18-21 from the document analysis phase were provided to each interview participant as directed content. A total of six interviews were conducted from 15-28 March 2022 to obtain the transcript data for the analysis. Aggregate

**Figure 7.** Overall Approach Highlighting Interview Analysis Phase

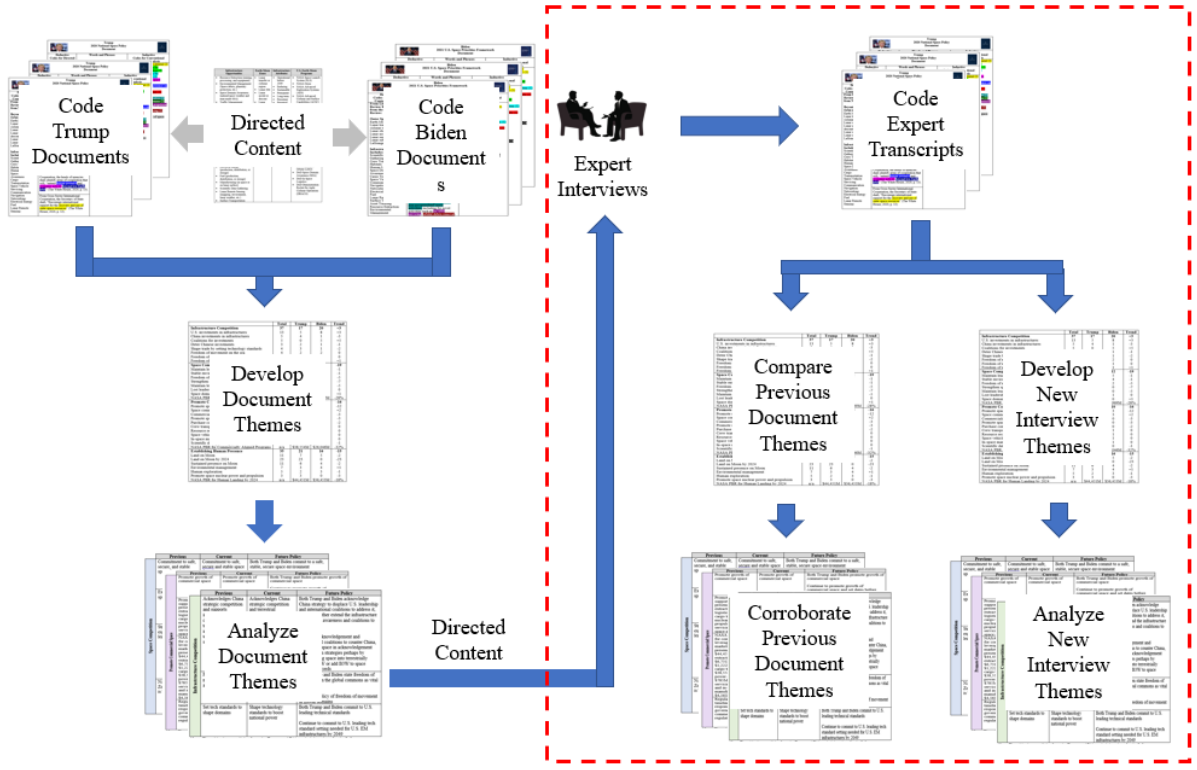


*Figure 7.* The figure is a graphical representation of the overall research approach. The second phase is interview analysis represented within the red dashed lines.

population sample experience and code saturation were monitored after each successive interview and transcript coding event to determine information power and when to stop conducting interviews. After all transcripts were coded, the codes were consolidated and code counts summed. Codes identical to the previous document analysis were separated and used to corroborate the document analysis. The remaining new codes were used to develop new themes. As was done during the document analysis, the transcripts from each expert were then analyzed to find supporting phrases and passages as exemplars and descriptive evidence to support the sufficiency analysis.

***Monitoring Saturation and Population.*** On-going checks for a balanced population sample and code saturation were performed after each successive interview and coding event.

Population sample was monitored by adding each new expert's background to the running totals of percent experience between military, civil and commercial sectors. Saturation was monitored by reviewing new codes not previously derived from previous expert transcripts. Once the aggregate population sample had achieved a relative 33% balance between civil, military, and commercial expertise, and no new codes were identified from the most recent transcript coding, the interviews were stopped. After the sixth interview, the aggregate expert population sample was 36% miliary, 32% civil and 33% commercial which was an acceptable balance, and there were no new codes derived from the sixth transcript coding event indicating saturation. At that point the interviews were stopped.

**Interviewing Experts and Coding Transcripts**

As with the document coding, a combination of directed content and conventional content coding approaches were used to code expert transcripts. The directed content was the phase one document analysis results provided to the experts prior to the interview and used to identify corroborating themes. The conventional coding was used to derive new codes and themes that might provide supplemental information. Like the document coding, all transcripts were coded within the MAXQDA software. There were two types of codes generated during the interview analysis, those that were identical to those found during the document analysis phase and new codes not previously identified during the document analysis phase. Interview codes identical to the document analysis codes were used to corroborate the results from the document analysis. New codes not previously identified were used to uncover themes that were absent from the document analysis.

Expert 1 was interviewed on 15 March 2022 and has expertise spanning 75% in military space, 20% in civil space and 5% in commercial space. The tone and tenor of the Expert 1

interview focused on emerging Earth-Moon infrastructures being developed by NASA that have not been adequately architected as commercially viable to compete in the future Earth-Moon economy. In a mutual dialog with the Expert 1, it was concluded that NASA is an explorer and is optimizing infrastructures to accomplish their exploration mission, they are not optimizing infrastructures to be commercially viable to win a strategic economic power competition. The other major concern was the "ax" or "anchor" as Expert 1 put it, of old costly infrastructure being maintained by NASA that precludes the Nation from investing in newer more cost-effective infrastructure needed to be competitive with China.

***Saturation and Population Status.*** After one interview the average population sample diversity remains at 75% military, 20% civil and 5% commercial so balance across the sample population has not yet been achieved. The codes derived from the Expert 1 transcript analysis are presented in Table 20. Of the 25 total codes, 11 were the same as those identified during the previous document analysis and 14 are new codes. The presence of so many new codes indicate a lack of theme saturation and the need to continue expert interviews to gain information power.

Table 20

*Expert 1 Transcript Codes*

| **Directed Content** | **Derived Codes (and Code Counts)** | **New Not Previously Derived** |
|---|---|---|
| Document Analysis Summary Tables 16-19 | Architecting commercially viable infrastructures (18) | X |
| | Future infrastructure needs and priorities (12) | X |
| | NASA legacy infrastructures (9) | X |
| | NASA acquisition and ownership model (5) | X |
| | NASA adoption of commercial standards (4) | X |
| | Industry and private capital (4) | X |
| | Unrestricted users for open trade (4) | X |
| | **Sustained presence on Moon (3)** | |
| | **Infrastructure competition (3)** | |
| | **Coalitions for investments (2)** | |
| | **China investment in infrastructures (2)** | |

| | | |
|---|---|---|
| | **Space domain awareness (2)** | |
| | Economic Zone Vision (2) | X |
| | National priorities and purpose (2) | X |
| | NASA roles and mission (2) | X |
| | NASA adoption of commercial services (2) | X |
| | NASA budget (2) | X |
| | **Promote commercial space (1)** | |
| | **Land on Moon by 2024 (1)** | |
| | **Strengthen capabilities in space (1)** | |
| | **Freedom of movement in space (1)** | |
| | **Space competition (1)** | |
| | **Shape trade by setting technology standards (1)** | |
| | National resourcing strategy (1) | X |
| | Congressional and constituency support (1) | X |

*Note.* Transcript codes listed show the counts in parenthesis reflecting the number of times the code was found in the transcript. Codes are listed in order of code counts from highest to lowest. Codes in bold red font are identical to those found in the previous document analysis and black font are new codes. An X indicates a code not previously identified.

Expert 2 was interviewed on 15 March 2022 and has expertise spanning 40% in military space, 10% in civil space and 50% in commercial space. The tone and tenor of the Expert 2 interview was a focus on more commercial industry participation in policy. The content of the interview was near-term on some policy initiatives of the current administration related to on-orbit servicing and manufacturing, notably in the near-Earth region but applicable to the Earth-Moon Economic Zone as an infrastructure of the future.

***Saturation and Population Status.*** After two interviews the average population sample diversity is now 58% military, 15% civil and 28% commercial so balance across the sample population has not yet been achieved. The codes derived from the Expert 2 transcript analysis are presented in Table 21. Of the 17 total codes, 6 were the same as those identified during the previous document analysis and 11 are new codes, one of which was not identified in the previous interview. The presence of one new code not identified in the previous interview indicates new information and a lack of theme saturation, so interviews continued in order to attain information power.

Table 21

*Expert 2 Transcript Codes*

| Directed Content | Derived Codes (and Code Counts) | New Not Previously Derived |
|---|---|---|
| Document Analysis Summary Tables 16-19 | National priorities and purpose (5)<br>Architecting commercially viable infrastructures (4)<br>Unrestricted users for open trade (4)<br>**Promote commercial space (3)**<br>**Infrastructure competition (3)**<br>National resourcing strategy (3)<br>Interagency effort (3)<br>Industry and private capital (3)<br>NASA adoption of commercial services (3)<br>**Space competition (2)**<br>**Establishing human presence (1)**<br>**Sustained presence on Moon (1)**<br>**Commercial space vehicle servicing (1)**<br>Economic Zone Vision (1)<br>Future infrastructure needs and priorities (1)<br>Congressional and constituency support (1)<br>NASA acquisition and ownership model (1) | X |

*Note.* Transcript codes listed show the counts in parenthesis reflecting the number of times the code was found in the transcript. Codes are listed in order of code counts from highest to lowest. Codes in bold red font are identical to those found in the previous document analysis and black font are new codes. An X indicates a code not previously identified.

Expert 3 was interviewed on 16 March 2022 and has expertise spanning 0% in military space, 90% in civil space and 10% in commercial space. The tone and tenor of the Expert 3 interview was a focus on the duality of NASA acquisition and ownership models involving commercially procured services such as COTS, CLPS and Commercial LEO Destinations (CLD) primarily employed by the science missions, and government owned systems such as SLS, Orion, Gateway and HLS employed by human exploration missions. Expert 3 had deep expertise to provide insights into NASA cultural challenges of moving from an explorer that owns and operates systems, to that of infrastructure developer that procures commercially owned and operated infrastructures.

***Saturation and Population Status.*** After three interviews the average population sample diversity is now 38% military, 40% civil and 22% commercial so balance across the sample population is close but has not yet been achieved. The codes derived from the Expert 3 transcript analysis are presented in Table 22. Of the 18 total codes, 4 were identified during the previous document analysis and 14 are new codes, one of which was not identified in previous interviews. The presence of one new code not identified in previous interviews indicates new information and a lack of theme saturation, so interviews continued in order to attain information power.

Table 22

*Expert 3 Transcript Codes*

| Directed Content | Derived Codes (and Code Counts) | New Not Previously Derived |
|---|---|---|
| Document Analysis Summary Tables 16-19 | NASA roles and missions (14)<br>NASA acquisition and ownership model (4)<br>NASA adoption of commercial services (4)<br>National resourcing strategy (3)<br>Architecting commercially viable infrastructures (3)<br>National priorities and purpose (2)<br>Future infrastructure needs and priorities (2)<br>Unrestricted users for open trade (2)<br>Industry and private capital (2)<br>NASA legacy infrastructures (2)<br>NASA adoption of commercial standards (2)<br>**Space competition (1)**<br>**Establishing human presence (1)**<br>**Human exploration (1)**<br>**Promote commercial space (1)**<br>Economic Zone Vision (1)<br>Strategic communications and awareness (1)<br>Interagency effort (1) | <br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br>X<br> |

*Note.* Transcript codes listed show the counts in parenthesis reflecting the number of times the code was found in the transcript. Codes are listed in order of code counts from highest to lowest. Codes in bold red font are identical to those found in the previous document analysis and black font are new codes. An X indicates a code not previously identified.

Expert 4 was interviewed on 22 March 2022 and has expertise spanning 30% in military space, 20% in civil space and 60% in commercial space. The tone and tenor of Expert 4 interview was focused on ensuring commercial utilization markets are identified and represented in future Earth-Moon Economic Zone planning. Several other discussion points were made regarding a broader interagency approach to planning for the future Earth-Moon Zone, which would include other agencies like DOC, DoD Department of Homeland Security (DHS), not for their regulatory mission but for their promotion mission as they might be better positioned to ensure future infrastructure architectures are commercially viable and economically competitive, more so that if NASA were to plan them out alone.

***Saturation and Population Status.*** After four interviews the average population sample diversity is 36% military, 35% civil and 31% commercial so balance across the sample population appears acceptable. The codes derived from the Expert 4 transcript analysis are presented in Table 23. Of the 25 total codes, 13 were identified during the previous document analysis and 12 are new codes, one of which was not identified in previous interviews. The presence of one new code not identified in previous interviews indicates new information and a lack of theme saturation, so interviews continued in order to attain information power.

Table 23

*Expert 4 Transcript Codes*

| Directed Content | Derived Codes (and Code Counts) | New Not Previously Derived |
|---|---|---|
| Document Analysis Summary Tables 16-19 | Interagency effort (10)<br>Strategic communications and awareness (7)<br>Commercial utilization markets (7)<br>**Promote commercial space (6)**<br>**Sustained presence on Moon (4)**<br>Economic Zone Vision (4)<br>NASA roles and mission (4)<br>National priorities and purpose (3)<br>**Infrastructure competition (2)**<br>**Freedom of movement on the sea (2)**<br>**Shape trade by setting technology standards (2)**<br>**Stable environments benefit economy (2)**<br>**Space domain awareness (2)**<br>Unrestricted users for open trade (2)<br>Industry and private capital (2)<br>NASA acquisition and ownership model (2)<br>**Space competition (1)**<br>**Strengthen space capabilities (1)**<br>**Freedom of movement in space (1)**<br>**Maintain leadership in space (1)**<br>**Environmental management (1)**<br>**Land on Moon by 2024 (1)**<br>Architecting commercially viable infrastructures (1)<br>Future infrastructure needs and priorities (1)<br>NASA adoption of commercial services (1) | X |

*Note.* Transcript codes listed show the counts in parenthesis reflecting the number of times the code was found in the transcript. Codes are listed in order of code counts from highest to lowest. Codes in bold red font are identical to those found in the previous document analysis and black font are new codes. An X indicates a code not previously identified.

Expert 5 was interviewed on 24 March 2022 and has expertise spanning 33% in military space, 33% in civil space and 33% in commercial space. The tone and tenor of Expert 5 interview was dismay at the apathy of the U.S. when it comes to the strategic economic competition with China in space. There were numerous references to the U.S. of either thinking China not capable or even focusing on space in cold-war terms to foster prestige, completely

missing the economic challenge faced. The key insight afforded by Expert 5 was the goal of China's space industrialization to be largely economic, and the lack of a U.S. industrialization vision and plan to compete. There was also some concern on the lack of U.S. coalition building.

***Saturation and Population Status.*** After five interviews the average population sample diversity is 36% military, 35% civil and 32% commercial so balance across the sample population is still acceptable. The codes derived from the Expert 5 transcript analysis are presented in Table 24. Of the 16 total codes, 6 were identified during the previous document analysis, and 10 are new codes, one of which was not identified in previous interviews. The presence of one new code not identified in previous interviews indicates new information and a lack of theme saturation, so interviews continued in order to attain information power.

Table 24

*Expert 5 Transcript Codes*

| Directed Content | Derived Codes (and Code Counts) | New Not Previously Derived |
|---|---|---|
| Document Analysis Summary Tables 16-19 | Strategic communications and awareness (22)<br>National priorities and purpose (16)<br>**Space competition (12)**<br>Economic Zone Vision (8)<br>**Coalitions for investments (6)**<br>**Infrastructure competition (5)**<br>Interagency effort (3)<br>NASA roles and mission (3)<br>Industry and private capital (2)<br>**Strengthen space capabilities (1)**<br>**Freedom of movement in space (1)**<br>**China investments in infrastructures (1)**<br>National resourcing strategy (1)<br>Architecting commercially viable infrastructures (1)<br>Commercial utilization markets (1)<br>National industrialization plan (1) | <br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br>X |

*Note.* Transcript codes listed show the counts in parenthesis reflecting the number of times the code was found in the transcript. Codes are listed in order of code counts from highest to lowest. Codes in bold red font are identical to those found in the previous document analysis and black font are new codes. An X indicates a code not previously identified.

Expert 6 was interviewed on 28 March 2022 and has expertise spanning 40% in military space, 20% in civil space and 40% in commercial space. The tone and tenor of Expert 6 was to first challenge the premise that China is or should drive policy. Expert 6 also challenged a U.S.-only strategy and strongly supported a stronger coalition approach. Finally, Expert 6 appeared to strongly endorse DOC as a potential lead agency to at least plan for the future Earth-Moon Economic Zone, albeit including NASA to procure and provide seed money to build it out.

***Saturation and Population Status.*** After six interviews the average population sample diversity is 36% military, 32% civil and 33% commercial so balance across the sample population is still acceptable. The codes derived from the Expert 6 transcript analysis are presented in Table 25. Of the 10 total codes, 4 were identified during the previous document analysis and 6 were new codes. There were no new codes other than those identified in the previous interviews. No new codes indicate theme saturation, so interviews were ended.

Table 25

*Expert 6 Transcript Codes*

| Directed Content | Derived Codes (and Code Counts) | New Not Previously Derived |
|---|---|---|
| Document Analysis Summary Tables 16-19 | Interagency effort (8)<br>National priorities and purpose (5)<br>**Space domain awareness (3)**<br>**Coalitions for investments (3)**<br>NASA roles and mission (3)<br>**Space competition (2)**<br>**Infrastructure competition (2)**<br>Strategic communications and awareness (2)<br>Future infrastructure needs and priorities (2)<br>Congressional and constituency support (2) | |

*Note.* Transcript codes listed show the counts in parentheses reflecting the number of times the code was found in the transcript. Codes are listed in order of code counts from highest to lowest. Codes in bold red font are identical to those found in the previous document analysis and black font are new codes. An X indicates a code not previously identified.

**Comparing Previous Document Themes**

Interview codes identical to those found during the previous document analysis phase will be used to corroborate the document analysis. Codes were counted and listed in order from most code counts to least under each previous document theme and policy element. Table 26 shows the codes and themes from the previous document analysis, and the changes resulting from the expert transcript coding. Of the interview codes identical to the document analysis, roughly 38% were related to space competition, 35% were related to infrastructure competition, 15% were related to establishing human presence, and 13% were related to promoting commercial space. Combining infrastructure and space competition results in 73% of the coding, compared to the remaining 27% for establishing human presence and promoting space combined indicating 2.7 times the amount of interest in infrastructure and space competition themes over establishing a human presence and promoting commercial space themes.

Table 26

*Trump and Biden Document Codes with Interview Analysis Code Counts*

| Previous Document Analysis Themes and Codes | Document Analysis | Interview Analysis |
|---|---|---|
| **Space Competition** | **42** | **35** |
| Maintain leadership in space | 9 | 1 |
| Stable environments benefit economy | 9 | 2 |
| Freedom of movement in space | 9 | 3 |
| Strengthen space capabilities | 7 | 3 |
| Maintain leadership in space exploration | 5 | 0 |
| Lost leadership | 2 | 0 |
| Space domain awareness | 1 | 7 |
| NASA PBR for Earth-Moon Programs | n/a | n/a |
| **Infrastructure Competition** | **37** | **32** |
| U.S. investments in infrastructures | 13 | 0 |
| China investments in infrastructures | 5 | 3 |
| Coalitions for investments | 5 | 11 |
| Deter Chinese investments | 3 | 0 |
| Shape trade by setting technology standards | 4 | 3 |
| Freedom of movement on the sea | 4 | 2 |

| | | |
|---|---|---|
| Freedom of movement on the ground | 2 | 0 |
| Freedom of movement in the air | 1 | **0** |
| **Promote Commercial Space** | **36** | **12** |
| Promote space commerce | 18 | 0 |
| Space commerce regulations | 4 | 0 |
| Commercialize routine government functions | 3 | 0 |
| Commercial space nuclear power and propulsion | 3 | 0 |
| Purchase commercial products and services | 2 | 0 |
| Commercial Crew transportation | 2 | 0 |
| Commercial Resource recovery | 2 | 0 |
| Commercial Space vehicle servicing | 1 | 1 |
| Commercial In-space manufacturing | 1 | 0 |
| Commercial Scientific data gathering | 1 | 0 |
| NASA PBR for Commercially Aligned Programs | n/a | n/a |
| **Establishing Human Presence** | **35** | **14** |
| Land on Moon | 11 | 0 |
| Land on Moon by 2024 | 23 | 2 |
| Sustained presence on Moon | 11 | 8 |
| Environmental management | 7 | 1 |
| Human exploration | 5 | 1 |
| NASA PBR for Human Landing by 2024 | n/a | n/a |

*Note.* The table show the major themes, codes and code counts from the document analysis and changes from the transcript coding. Codes are listed in order of code counts from highest to lowest. Codes in bold red font are identical to those found in the previous document analysis.

**Corroborating Previous Document Analysis**

The first interview analysis involves corroboration of the document analysis themes and policy elements for the previous four themes; space competition, infrastructure competition, promote commercial space and establishing human presence. Of 347 total codes generated across the six expert interview transcripts, 92 or 27% were codes related to the four themes developed during the previous document analysis phase. Since only a little over one-quarter of the total codes were related to the previous themes, this indicates the experts were more interested in talking about new themes and new policy not in the documents or document analysis. The transcripts from each expert were analyzed to find supporting phrases and passages as exemplars and descriptive evidence to substantiate and corroborate the document analysis results. Corroboration was categorized as no changes needed to existing policy, or

changes needed to existing policy for each of the four themes. If there was a lack of a specific phrase or passage for an area, the document analysis finding remained the same.

For the space competition theme, no changes were needed to existing policy in three areas and changes were needed to policy in one area. For the infrastructure competition theme, no changes were needed to existing policy in two areas and changes were needed in one area. For the promoting commercial space, no changes were needed to existing policy in one area and changes were needed to policy in three areas. For the establishing human presence theme, changes were needed in three areas.

***Corroboration of Space Competition Theme.*** Of the 92 codes identical to those used in the previous document analysis, 38% were related to the space competition theme. For the first policy element, the document analysis found that both Trump and Biden policies commit to a safe, stable, secure space environment and this will be needed to attract future private investment. Expert 4 explicitly concurred stating, "You're right on. I think you will continue a commitment to a safe, secure and stable space environment, that's just right on what you said there. Both policies said the same thing. I think that in that case, it's fine the way it is" (Full Interview Transcript at Appendix E). The analysis concludes no changes are needed to existing policy related to committing to a safe, stable and secure environment. The U.S. should continue to commit to safe, secure, stable environment to attract U.S. private capital investment to the Earth-Moon Economic Zone.

For the policy element on SSA, the document analysis found Trump extended SSA to deep space which includes Earth-Moon Zone, but Biden appears limited to Earth orbit debris. SSA is a core competency of the U.S. and should be extended beyond LEO as a critical infrastructure for the future Earth-Moon economy. Expert 4 concurred with ensuring SSA covers at least the Earth-Moon Zone by saying, "Now, SSA is what I had there was basically concurring with what you

had… because if you want to operate freely in that environment, if anybody wants to operate freely, they have to know the environment that they're in." Expert 1 acknowledged, "No country in the world has a space surveillance network like the U.S. does. That's part of our infrastructure" (Full Interview Transcript at Appendix B). When asked which might be the most important infrastructure for the future Earth-Moon Economic Zone, Expert 5 said, "I would say most broadly, one is space situational awareness, right?" Expert 5 goes on to say, "And so as there's more stuff going to lunar orbit and in cislunar space, there's going to be a need for better SSA to support everything going on there" (Full Interview Transcript at Appendix F). The analysis concludes no changes needed to the Trump policy to extend SSA to deep space, or at least to the Earth-Moon Zone. The U.S. should continue the Trump policy that extended SSA to deep space and consider SSA as a U.S. infrastructure for the Earth-Moon Economic Zone.

Trump had a strengthen leadership policy for all space which would address first-to-market development of new infrastructures in Earth-Moon Zone, Biden has a maintain leadership strategy and seemed to limit it to only exploration and science which may not be appropriate for creating new infrastructures where none exist in the Earth-Moon Zone. Expert 4 stated, "… you use the word first-to-market. I think that's great. You know, let's get there before the Chinese gets there." On first-to-market Expert 5 states, "And so once China and Russia establish a permanent presence, how will you ever ask them to leave because they'll be there first." Expert 5 articulates the distinction between maintaining U.S. leadership and strengthening U.S. leadership by stating, "I think that when the U.S. articulates maintain leadership, I think they are thinking about the leadership…with regard to low-Earth orbit or terrestrial mission support…It just goes beyond just looking at how low-Earth orbit competition is going to play out because this is deep space articulation." The analysis concludes no changes needed to the Trump policy of strengthening and expanding U.S. leadership, with the caveat it be focused on developing the Earth-Moon

Economic Zone. U.S. continue the Trump policy to strengthen U.S. space leadership but focus it on developing U.S. infrastructures in the Earth-Moon Zone.

The document analysis found the Biden budget request to be 28% less than Trump budget request for the same Earth-Moon programs. Expert 4 stated, "We need the policy to have the specific dates, the funding, and the elements for the NASA's cislunar investment. We need all three dates, funding and what it's made up of in order to be clear about what the NASA's cislunar investment should be and to ensure what we do in that zone." While the decrease in funding is debatable, the focus should be on the dates in policy, and then ensuring the budget necessary to support. A budget with no dates will not ensure the U.S. will develop Earth-Moon Economic Zone infrastructures before 2049. The analysis concludes that changes are needed to existing policy in the area of budget to identify dates for specific Earth-Moon programs. The U.S. should continue the Trump policy of including dates in policy for initial landing and sustained presence but include dates for specific Earth-Moon Economic Zone infrastructures as well, then ensure budgets are adequate to support these dates.

Table 27 is a summary of the corroboration analysis for the space competition theme. Based on the analysis, no changes are needed to existing policy for three elements, and changes are needed to existing policy for one element.

Table 27

*Results of Corroboration Analysis for Space Competition Theme*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| **Space Competition** | Both Trump and Biden commit to a safe, stable, secure space environment. | No changes needed to existing policy. | The U.S. should continue commitment to safe, secure, stable environment to attract U.S. private capital and investment to the Earth-Moon Economic Zone. |

| | | | |
|---|---|---|---|
| | Trump extended SSA to deep space which includes EM Zone, Biden appears limited to Earth orbit debris. | No changes needed to existing policy. According to experts, the U.S. is currently the global leader in SSA and represents a significant infrastructure need for the Earth-Moon Zone. | The U.S. should continue the Trump policy and extend SSA to deep space and consider SSA as a U.S. infrastructure for the Earth-Moon Economic Zone. |
| | Trump had an expansionist strategy for all space which would address new infrastructures in EM Zone, Biden has a maintenance strategy and only for exploration and science which may not be appropriate for creating new infrastructures where none exist. | No changes needed to existing policy. According to experts, the U.S. needs to establish infrastructures before others because it will be hard to remove them if they get there first. | The U.S. should continue the Trump policy to strengthen U.S. space leadership but focus it on developing U.S. infrastructures in the Earth-Moon Zone before others. |
| | Biden budget request is 28% less than Trump budget request for the same Earth-Moon programs. | Changes needed to existing policy. According to experts, dates are needed in policy for specific infrastructures in order to assess the appropriate level of funding needed. Without dates, the funding levels are irrelevant. | The U.S. should continue the Trump policy of including dates in policy for initial landing and sustained presence but include dates for specific Earth-Moon Economic Zone infrastructures. as well, then ensure budgets are adequate to support these dates. |

*Note.* The table shows the document analysis from phase one, the interview analysis from phase two, and the corroborated or revised recommendations after triangulation between the document and interview analysis.

***Corroboration of Infrastructure Competition Theme***. Of the 92 codes identical to those used in the previous document analysis, 35% were related to the infrastructure competition theme. For the policy element acknowledging China infrastructure competition in both infrastructures and creating coalitions to counter them, the document analysis found that both Trump and Biden acknowledge China's strategy to displace U.S. leadership terrestrially and had

identified international coalitions to address it, however neither extend the infrastructure competition awareness and coalitions needed to space. To illustrate the consensus building that is required on this subject, two different opinions were expressed during the interviews. While in the minority from the discourse, the first is from Expert 6 who is skeptical of China's ambitions to include space into their BRI by stating, "I am skeptical that that there's a lot of buy in within China on this. This is a huge national initiative. I think it's more a reflection of the same sort of space advocates within the Chinese government selling this to the non-space political leadership, or at least trying to sell it to them. We saw similar things happening in the U.S. during the Apollo Program" (Full Interview Transcript at Appendix G). Expert 5 appeared to echo the majority of the discourse found on China's ambitions stating, "When it comes to looking at the Earth-Moon infrastructure, China is already starting to include cislunar space as part of their Belt and Road Initiative. They are talking about a spatial information corridor, including building partnership 132 member nations of the BRI. Is the U.S. doing something similar or is it trying to build that kind of infrastructure?" Expert 5 went on to explain that space infrastructure has been identified as a priority investment by one of the highest-level policy making bodies in China. When asked specifically if China was to be taken serious Expert 5 said, "Yes, they are. Because one way you know they're serious is not just their stating through their speeches, …but also putting it through the highest-level policy making body in China, the China National and Development Reform Commission. So that's the commission that actually identifies areas for priority investment." Despite the discourse and Expert 5 views, there remains a clear separation in the U.S. infrastructure policies regarding terrestrial and space infrastructure awareness and actions, to which Expert 4 states, "So with respect to the infrastructure competition…I do agree that we need to extend the terrestrial infrastructure into the space domain and it can either be through Biden's B3W addition, to the International Artemis Accords, or there might be other applicable

international agreements that are out there as well." On the related matter of coalition-building to counter China's BRI, Expert 5 noted the 132 member nations that China has assembled adding, "Nigeria is going to become the 14th economy in the world, according to Price Waterhouse Cooper, and Nigeria is investing heavily in its space program in collaboration with China. So, building those partnership structures for looking at cislunar space with countries outside of, say, the Artemis Accord signatories is very critical." Expert 5 goes on to say, "The U.S. also needs to have a bilateral relationship with countries outside of their allied partners. So very important to build partnership with Africa, for example. The U.S., I don't think is even thinking about how Africa is going to become so critical in the next 30 years," adding "…but then the conversation in the Quadrilateral Security Dialogue was about climate change and data sharing. It wasn't about this with Japan. I mean, if you look at Japan space ambition, they want to establish also a presence on the Moon by 2040. Right. They are a great country to push. India has a Moon program. Australia wants to take advantage of the commercial space sector and look beyond. And yet the U.S. ambition was missing even from the Quadrilateral Security Dialogue Joint statement." When discussing foreign control of infrastructures in general, Expert 1 emphasizes the importance of U.S. controlled infrastructures versus competitor-controlled infrastructures by stating, "So this goes directly to the heart of your question, which is we can't allow China to control that infrastructure because we need to be able to go ahead and rely on it for ourselves." Where China treats infrastructure competition as a seamless unified initiative across all domains, the U.S. appears to have a policy of recognizing the terrestrial infrastructure challenge but not the space infrastructure challenge, which affects coalition strategies. The analysis concludes that changes are needed to existing policy in the area of infrastructure competition awareness and coalitions to address it. The U.S. should develop a unified and

seamless infrastructure competition strategy and awareness policy across all infrastructure domains that China seeks to lead through their BRI.

The document analysis found both Trump and Biden state freedom of movement in the global commons as vital interest, which is a hallmark policy needed to ensure free movement of goods and services in the future Earth-Moon Economic Zone. That said, word selection is important to ensure the policy does not infer only the terrestrial domains such as air, land and sea, but includes the space domain. The phrase global commons should be changed in favor of common domains. Expert 4 agrees with ensuring freedom of movement to have a broad definition to capture all domains by stating, "Again, the idea there is to extend the global domain definition to include space and that will ensure the freedom of movement through space for all, for scientific purposes, for commerce." The analysis concludes no changes are needed to existing policy regarding freedom of movement in the global commons as being of vital interest, however common domains vice global commons might be a better choice of words. U.S. continue policy to ensure freedom of movement in the future Earth-Moon Economic Zone to ensure the free movement of goods and services on Earth and in space.

For U.S. leadership of global technology standards, the document analysis found both Trump and Biden commit to U.S. leading global technical standards. This will be vital to establishing U.S. technology standards for the infrastructures in the Earth-Moon Zone. Expert 4 agreed with the U.S. continuing to lead technical standards by stating, "I concur we should take the lead to develop global technology and safety standards." Expert 4 adds, "The idea is if you're going from Earth to the Moon, anybody on the Earth could get access to something, something going from the Earth to the Moon. Right. So, you'd want to make sure that those standards allow us to be in leadership to make it for global commerce, not just for us U.S. commerce." Just like

terrestrial infrastructures, the nation that sets the technical standard for others to use not only wields national power but reaps economic rewards as well. The analysis concludes no changes are needed to existing policy related to the U.S. commitment to lead global technical standards development. U.S. continue policy to lead technology standards to ensure future Earth-Moon infrastructure standards are U.S. based.

Table 28 is a summary of the corroboration analysis for the infrastructure competition theme. Based on the analysis, no changes are needed to existing policy for two elements, and changes are needed to existing policy for one element.

Table 28

*Results of Corroboration Analysis for Infrastructure Competition Theme*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| **Infrastructure Competition** | Both Trump and Biden acknowledge China strategy to displace U.S. leadership terrestrially and international coalitions to address it, however neither extend the infrastructure competition awareness and coalitions to space. | Changes needed to existing policy. According to experts, the U.S. needs a seamless Earth and space infrastructure competition strategy like China, as well as a better coalition strategy for space infrastructures. | The U.S. should develop a unified and seamless infrastructure competition strategy and awareness policy across all infrastructure domains that China seeks to lead. |
| | Both Trump and Biden state freedom of movement in the global commons as vital interest. | No changes needed to existing policy. However, a strategic communication issue using global which infers terrestrial. | The U.S. should continue policy to ensure freedom of movement in the future Earth-Moon Economic Zone to ensure the free movement of goods and services on Earth and in space. |
| | Both Trump and Biden commit to U.S. leading global technical standards. | No changes needed to existing policy. However, need to ensure standards are open and unrestricted. | The U.S. should continue policy to lead technology standards to ensure future Earth-Moon infrastructure standards are U.S. based. |

*Note.* The table shows the document analysis from phase one, the interview analysis from phase two, and the corroborated or revised recommendations after triangulation between the document and interview analysis.

***Corroboration of Promote Commercial Space Theme.*** Of the 92 codes identical to those used in the previous document analysis, 13% were related to the promote commercial space theme. As such, there was not as strong a corroboration but there were some significant statements by some experts. For overall promotion of commercial space, the document analysis found that both Trump and Biden promote growth of commercial space but lack specifics on the Earth-Moon Zone. Expert 4 stated, "…expand the commercial space promotion, the government promotion to the EM Zone. Right. So, expand it to that. And that will challenge industry to complete the infrastructure before 2049." The analysis concludes no changes were needed to existing policy that promotes overall growth of commercial space, however an expert felt it necessary to put more focus on the Earth-Moon Economic Zone. The U.S. should continue to promote growth of commercial space but focus more on development of the Earth-Moon Economic Zone.

The document analysis found that while Trump explicitly identifies several commercial markets in his policy, Biden only addresses one of them implying an oversight or shift in priorities. Expert 4 believes that government has to be specific in promoting commercial space out to include the Earth-Moon Zone and be specific on the markets to include users by stating, "But then there's another category called the commercial utilization folks, the folks that are going to utilize the infrastructure who will probably enter into agreements with the companies building out the infrastructure or may just be utilizing that infrastructure." Expert 2 wanted to see more explicit policy on public-private partnerships to create in-space logistics infrastructures that support sets of missions or other infrastructures with, "recommendation number two is the public-private partnership to create an in-space logistics infrastructure" (Full Interview Transcript at Appendix C). The analysis concludes changes are needed to existing policy that

explicitly identifies commercial markets. The U.S. policy should identify priority commercial infrastructures and users in the Earth-Moon Zone, target dates for both industry and government seed funding, and promote public-private partnership opportunities.

As with the budget for space competition, the document analysis found the Biden budget request to be 25% less than Trump request for the same commercial markets listed by Trump. While Trump explicitly identifies markets, neither identify dates. Expert 4's earlier comments apply to this area as well. To restate, Expert 4 states, "We need the policy to have the specific dates, the funding, and the elements for the NASA's cislunar investment. We need all three dates, funding and what it's made up of in order to be clear about what the NASA's cislunar investment should be and to ensure what we do in that zone." However, Expert 4 adds that commercial markets be delineated as original equipment manufacturers (OEMs) who build the infrastructures, and commercial users of the infrastructures stating, "So when I talk about industry in this context, it's the ones building it out to support the commercial utilization market. And NASA would provide the funding to go build that out." The analysis concludes changes are needed to existing policy in the area of budget and dates for commercially aligned programs in the budget. The U.S. should continue the Trump policy of identifying priority commercial markets, but dates and those commercial priorities should be reflected in commercially aligned in budgets.

On regulations, the document analysis found Trump's policy was an on-going regulation review to ensure responsiveness to industry, where Biden is currently directing a review of regulations with no end date identified. Again, this is supported by Expert 4 who states, "I was concurring with what you said, pretty much establish dates for competition or regulatory regulation reviews and ensure the regulatory environment supports commercial investment in commercial Original Equipment Manufacturers (OEM) infrastructures by 2049. The only little nuance I had maybe was, again, it's the term by 2049. So, what you really are looking for is

commercial investment to complete it, to complete the infrastructures by 2049." The analysis found changes are needed to existing policy regarding government review of commercial space regulations. The U.S. should continue the Trump policy to continually ensure responsiveness regulatory review and establish a date to complete the Biden regulatory reviews so as not to impact the development of Earth-Moon Zone infrastructures.

Table 29 is a summary of the corroboration analysis for the promote commercial space theme. Based on the analysis, no changes are needed to existing policy for one element, and changes are needed to existing policy for three elements.

Table 29

*Results of Corroboration Analysis for Promote Commercial Space Theme*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| **Promote Commercial Space** | Both Trump and Biden promote growth of commercial space but lack specific on Earth-Moon Zone. | No changes needed to existing policy. However, should be more specific on the Earth-Moon Zone and dates. | The U.S. should continue to promote growth of commercial space but focus more on development of the Earth-Moon Economic Zone. |
| | While Trump explicitly identifies several commercial markets, Biden only addresses one of them implying a shift in priorities and focus. | Changes needed to existing policy. According to experts, commercial priority infrastructures need target dates, need to be broken out by infrastructure builders and users, and needed to be seeded through public-private partnerships. | The U.S. policy should identify priority commercial infrastructures and users in the Earth-Moon Zone, target dates for both industry and government seed funding, and promote public-private partnership opportunities. |
| | Biden budget request is 25% less than Trump request for the same commercial markets listed by Trump. While Trump explicitly identifies markets, neither identify dates. | Changes needed to existing policy. According to experts, dates are needed in policy for specific infrastructures in order to assess the appropriate level of government-aligned seed funding needed. Without dates, the funding levels are irrelevant. | The U.S. should continue the Trump policy of identifying priority commercial markets, but dates and those commercial priorities should be reflected as commercially aligned in budgets. |
| | Trump's policy was on-going regulation review | Changes needed to existing policy. According to experts, a | The U.S. should continue the Trump policy to continually |

| | | | |
|---|---|---|---|
| | to ensure responsiveness to industry where Biden is currently silent and directs a review of regulations with no end date. | date should be included in the policy to complete the regulatory review. | ensure responsiveness regulatory review and establish a date to complete the Biden regulatory reviews so as not to impact the development of Earth-Moon Zone infrastructures. |

*Note.* The table shows the document analysis from phase one, the interview analysis from phase two, and the corroborated or revised recommendations after triangulation between the document and interview analysis.

***Corroboration of Establishing Human Presence Theme.*** Of the 92 codes identical to those used in the previous document analysis, 15% were related to the establish human presence theme. Again, there was not as strong a corroboration but there were some significant statements. For the first element, while both Trump and Biden address planetary contamination, neither address contamination of the Moon as an externality of sustained human presence. Human presence on the Moon will likely create the need for an environmental infrastructure on the lunar surface and in lunar orbit. Expert 4 stated, "So the notion of planetary contamination I think is too limiting. Both policies had it in there. So anyway, from my perspective, we got to expand the environmental infrastructure. Beyond Earth to the EM zone, including Moon activity. So, I agree." The analysis concludes changes are needed to existing policy in the area of planetary contamination. The U.S. should include the Moon in planetary contamination policy and consider it a future Earth-Moon Economic Zone environmental infrastructure to support all sustained human presence on the lunar surface or in lunar orbit.

Trump set dates for an initial landing and sustained presence, however Biden has no dates in his interim and space policy framework. Dates are critical to budgets in order to build the infrastructures needed to meet a 2049 deadline. There are several issues, the first being the initial dates are meaningful for prestige but somewhat meaningless for sustained economic competition and the sustained presence definition used by NASA does not include 24x7 human

presence rather long periods of no human presence. The other issue is that specific dates individual infrastructures need to be established in order to complete them by 2049. Again Expert 4 appeared adamant about getting not only initial landing and sustained presence dates but adding dates for the future infrastructures. Expert 4 states, "Establish the dates for initial landing, sustain presence, and infrastructures. Do them all. In other words, initial landing is kind of go out, you know, you land and then you go out and you develop infrastructure on the Moon." In also addressing the budget decrease from Trump to Biden, Expert 4 adds, "Establish the dates for those capabilities and then you can determine what kind of funding you need." When asked for a number one policy priority, Expert 1 stated, "You have to tell people, you know what…we are going to go ahead and move the date to 2035." The analysis concludes changes are needed to existing policy related to the establishment of initial landing and sustained presence dates. The U.S. should establish initial landing dates, define and establish sustained presence dates, and identify and establish dates for enabling Earth-Moon Economic Zone infrastructures.

Again, the document analysis found the Biden budget request was 18% less than Trump request, and the landing and sustained presence dates have been removed in the Biden request. Again, while it would appear the Biden request is 18% less than the Trump request, what is important are the dates for the activities that drive the appropriate budget to support them. While the previous statements on budgets and dates apply here as well, Expert 1 elaborated on a sustained presence date by saying, "It's going to be a long, long time in the future until humans are on the Moon 24 hours a day, seven days a week, 365 days a year. Right now, NASA's plan is to visit the Moon for one month every two years." In reference to Trump's dates in policy, Expert 2 states, "I'm a firm believer that establishing the dates is essential to get people off the dime, you know, because NASA was just poking along and didn't really have a program and that sort of thing. And all of a sudden, they've got marching orders." The analysis concludes changes

are needed to existing policy related to the budget request. Similar to the space competition theme change, The U.S. should continue the Trump policy of including dates in policy for initial landing and sustained presence but include dates for specific Earth-Moon Economic Zone infrastructures as well, then ensure budgets are adequate to support these dates.

Table 30 is a summary of the corroboration analysis for the establish human presence theme. Based on the analysis, changes are needed to existing policy for three elements.

Table 30

*Results of Corroboration Analysis for Establishing Human Presence Theme*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| **Establishing Human Presence** | While both Trump and Biden address planetary contamination, neither address contamination of the Moon as an externality of sustained human presence. | Changes needed to existing policy. According to experts, like an emerging market for orbital debris management and clean-up, there could be an infrastructure market for lunar environmental management from a sustained presence. | The U.S. should include the Moon in planetary contamination policy and consider it a future Earth-Moon Economic Zone environmental infrastructure to support all sustained human presence on the lunar surface or in lunar orbit. |
| | Trump set date for initial landing and sustained presence, however Biden has no dates in policy. | Changes needed to existing policy. According to experts, dates for both initial landing and sustained presence should be established, as well sustained presence should be defined and supporting infrastructures articulated. | The U.S. should establish initial landing dates, define and establish sustained presence dates, and identify and establish dates for enabling Earth-Moon Economic Zone infrastructures. |
| | Biden budget request was 18% less than Trump request, and the landing and sustained presence dates have been removed in the Biden request. | Changes needed to existing policy. According to experts, dates for both initial landing and sustained presence should be established, as well sustained presence should | U.S. policy should establish date for initial landing and sustained presence and define sustained human presence and supporting infrastructures. |

| | | | |
|---|---|---|---|
| | | be defined and supporting infrastructures articulated. | |

*Note.* The table shows the document analysis from phase one, the interview analysis from phase two, and the corroborated or revised recommendations after triangulation between the document and interview analysis.

**Developing New Interview Themes**

New codes not previously identified from the document analysis were used to uncover themes that were absent from the policy documents reviewed. All new codes from the expert interviews were consolidated. New codes that were the same as other new codes were combined and their word counts added to each other and listed in order from most code counts to least. Then, the combined codes were grouped into new themes not previously identified during the document analysis.

The first major theme to emerge was industrialization of the Earth-Moon Zone, the word "plan" was added to the theme based on Expert 5 who stated, "The U.S. really needs to create a vision or plan of space industrialization." National or sector industrialization plans appear to be common for emerging or developing nations that have no, or desire a specific industrial capability, to which the argument would be strong for the U.S. creating a similar plan to industrialize the Earth-Moon Economic Zone where no U.S. industrial capability exists currently. The codes architecting commercially viable infrastructures to be developed, interagency effort in devising the plan from a whole-of-government approach, prioritizing which infrastructures to pursue, involving industry both as infrastructure builders and utilization markets, and ensuring the development of the infrastructures supports free and unrestricted trade appear to fit nicely under an Earth-Moon industrialization plan theme.

The second theme was developed around interview codes related to an economic vision for the Earth-Moon Zone, priority setting on what to invest in, and national resourcing which goes well beyond NASA budgets. Clearly the theme needed to capture a U.S. economic vision

for the Earth-Moon Zone. In researching an appropriate theme category it was found that the codes derived fit nicely under Bruce Scott's, *The Concept of National Economic Strategy,* in which the author argues that "A national economic strategy comprises a vision of a desired future state to be achieved, a timeframe within which that state is to be achieved, and a set of policies and institutions influencing the mobilization and allocation of resources for promoting their efficient utilization" adding, "As with firm strategy, the vision provides the frame of reference for establishing priorities for the mobilization of resources as well as the fractions to be allocated across various product markets. Also, like firm strategy, national economic strategies are articulated and implemented through institutions" (Scott, 1997, p. 239). The interview codes related to economic vision, priorities-setting, and national resourcing all align perfectly under Scott's concept for a national economic strategy and while national for sure, it would focus on the U.S. economic strategy for the Earth-Moon Economic Zone only, just as the industrialization plan would focus on the development of the Zone. An economic strategy would also be an ideal way to capture and convey the space infrastructure competition with China and convey this to U.S. citizens and government, as well as to coalition partners.

The third theme reflects several codes largely grouped under a NASA issues theme. Codes included roles and mission, acquisition and ownership models, adoption of commercial services and standards, budget and the associated issues related to the cost of legacy infrastructures. Table 31 shows the combined codes and codes grouped by these three major policy themes.

Table 31

*New Codes and New Themes from Interview Analysis*

| Combined Codes (and Code Counts) | Grouped Codes (and Code Counts) by Theme |
|---|---|
| National priorities and purpose (33) | **Earth-Moon Industrialization Plan (107)** |
| Strategic communications and awareness (32) | Architecting commercially viable infrastructures (27) |
| Architecting commercially viable infrastructures (27) | Interagency effort (25) |
| NASA roles and mission (26) | Future infrastructure needs and priorities (18) |
| Interagency effort (25) | Industry and private capital (13) |
| Future infrastructure needs and priorities (18) | Unrestricted users for open trade (12) |
| Economic Zone Vision (17) | Commercial utilization markets (8) |
| Industry and private capital (13) | Congressional and constituency support (4) |
| Unrestricted users for open trade (12) | |
| NASA acquisition and ownership model (12) | **Earth-Moon Economic Strategy (89)** |
| NASA adoption of commercial services (10) | National priorities and purpose (33) |
| NASA legacy infrastructures (11) | Strategic communications and awareness (32) |
| National resourcing strategy (8) | Economic Zone Vision (16) |
| Commercial utilization markets (8) | National resourcing strategy (8) |
| NASA adoption of commercial standards (6) | |
| Congressional and constituency support (4) | **NASA Issues (58)** |
| NASA budget (2) | NASA roles and mission (26) |
| National industrialization plan (1) | NASA acquisition and ownership model (12) |
| | NASA adoption of commercial services (10) |
| | NASA adoption of commercial standards (6) |
| | NASA budget (2) |
| | NASA legacy infrastructures (2) |

*Note.* The table shows the combined codes ranked in order by most code count to least code count, and the same codes grouped by major policy theme.

**Summary of Document and Interview Codes by Themes**

A high-level visual generated by the MAXQDA software showing all document and interview coding by theme is presented at Appendix A. Rather than numerical counts of codes, the graphic only shows the intersection or "touch point" where there is at least one code between a document or transcript reviewed and corresponding theme produced. Within the document analysis area shaded in red, the six coded policy documents are listed at the top and the four derived themes are listed on the left. The intersection represented by a blue square indicates at

least one code linking the document to the theme. Likewise, within the interview analysis area shaded in green, the six coded interview transcripts are listed at the top and the seven corresponding themes listed on the left, the top four representing at least one identical code derived from both the document and interview analysis, and the remaining three at the bottom reflecting new codes derived from the interview analysis alone.

Appendix A visually shows the first four document analysis themes on the top left corroborated by the interview analysis by virtue of identical codes, and the three new interview analysis themes on the bottom left reflecting new codes not previously identified in the document analysis. The remaining analysis for the remainder of the report uses the codes and code counts from the tables contained herein, since they reflect code and code count data underlying the high-level visual generated by the MAXQDA software.

**Analyzing New Interview Themes**

The second interview analysis involves the analysis of interview themes and policy elements for the three new themes: Earth-Moon Zone industrialization plan, Earth-Moon economic strategy, and NASA issues. Of 347 total codes generated across the six expert interview transcripts, 255 or 73% were new codes not previously used during the document analysis phase. Almost three-quarters of the total interview codes were new, indicating supplemental information such as new themes not in the documents reviewed or analyzed. The transcripts from each expert were analyzed to find supporting phrases and passages as exemplars and descriptive evidence to substantiate the interview analysis. Since the themes are new, conclusions to the analysis were categorized as new policy needed, as opposed to the document analysis whose categories were no changes or changes needed to existing policy.

For the Earth-Moon Zone industrialization plan theme, five new policies were identified. For the Earth-Moon Zone economic strategy theme, four new policies were identified. For the NASA issues theme, two new policies were identified.

***New Earth-Moon Industrialization Plan Theme***. Of 255 new codes, 42% (nearly half) were related to the industrialization theme. The document analysis found no reference to industrialization or elements of an industrialization vision or plan in the documents reviewed. Industrialization plans are interagency, communicate vision, identify needs and priorities, put forth architectures and involve commercial industry, all of which are needed to develop infrastructures in the Earth-Moon Economic Zone by 2049. The most prescient and direct testament to the need for an industrialization plan was from Expert 5 who stated, "the U.S. really needs to create a vision or plan of space industrialization." Expert 5 is not alone in the thought of space industrialization, but the concept of a plan that would be focused on the Earth-Moon Zone might be. At a conference in 2019, then NASA Administrator Bridenstine discussed the industrialization of the LEO market by saying, "We want to prove capabilities and prove technologies, prove markets, that ultimately enable us to do more in space and have more people in space, more projects in space, commercialize space, industrialize space and, of course, have this be a major driver for the United States of America economically when it comes to the balance of payments and exports. That's the ultimate objective of the United States of America leading in space" (Foust, 2019). Unfortunately, Bridenstine's vision of industrialization was limited to LEO and an industrialization plan was never produced. When asked if the Earth-Moon Economic Zone was about prestige, Expert 5 stated, "And really as a return to the lunar program, the economics of it, I think we tend to continuously see China through the Cold War framework of prestige and space exploration, when they are insisting again and again that this is

about space utilization, development and industrialization." While the major theme was an industrialization plan at the national-level, all codes are essentially characteristics or elements of an industrialization plan to include; architecting infrastructures for commercial viability, using a whole-of-government approach beyond just NASA, identifying future infrastructure opportunities and prioritizing those of importance for U.S. to develop and own, ensuring infrastructures are developed for all users to ensure free and unrestricted flow of trade, identifying the commercial utilization market in addition to the commercial infrastructure developers, and ensuring congressional and constituency support to industrialize those of the most importance to the U.S. Clearly a national-level plan would be helpful in addressing another of the interview codes, that of garnering Congressional and constituency support to which Expert 1 addressed the issue as, "But we also need to recognize in other things, existing infrastructure is also a political hot potato because a politician will know that if he invests in existing infrastructure, he knows that that money will end up in the district where the infrastructure is and whether that district is in Southern California or Johnson Space Center in the space station. He knows that new infrastructure is an unknown. Where is that going to go? So, there's a political impetus to maintaining and funding old infrastructure, which leads to jobs in a district rather than new infrastructure, which leads to people don't understand where." Expert 2 went on to state, "I mean, one of the big problems, of course, is getting the Congress in sync with the administration." A U.S. industrialization plan for the Earth-Moon Economic Zone would help foster communication and support across Congress and government agencies. The analysis concludes new policy is needed to create a national-level Earth-Moon industrialization plan. The U.S. should create an Earth-Moon industrialization plan to develop Earth-Moon Economic Zone infrastructures by 2049.

The document analysis found no reference to an interagency approach to industrialization. Any future Earth-Moon industrialization effort will need to be interagency to leverage not only NASA, but infrastructure and economic competitiveness expertise from other agencies such as DOC, DOT, DHS, DoD, etc. There was significant commentary from experts about tapping the core competencies of U.S. agencies that not only have a history of developing infrastructures, but architecting economically competitive infrastructures to bring economic value to the U.S. Expert 5 states, "If there is this competition in Earth-Moon infrastructure building … how do you promote commercialization of that? I think NASA plays a role, but it does not play a leading role." Expert 4 concurs by stating NASA needs to, "…bring in the interagency expertise to ensure that they are addressing this, not just from their interests, you know the R&D and the scientific side got it." Expert 4 goes on to state, "The Commerce Department could work the commercial utilization folks. Right. They could go out. I mean, they've got the Bureau of Industry and Security, right. They do industrial base kinds of research all the time." Furthermore Expert 4 states, "So what's interesting is that the Department of Transportation, through their ASD organization, they're both kind of charged with promotion and regulation, right. So, they do that balancing act. So, if you look at it from the top Commerce Department perspective, much like the top DOT perspective, there's both regulatory and promotional roles" and, "So then the interagency representatives can take into consideration all the different parts of the government and come up with a balanced approach." Expert 6 elaborates on the DOC role stating, "So I mean, the one obvious one that stands out is the Department of Commerce, right. Because since 2017, 2018, they've been slated to play a much bigger role in sort of U.S. space activities in general. And if you I think we all sort of envision industry and private sector playing a much bigger role in all space activities, including Earth-

Moon and lunar stuff, then yeah, I think they would have to play a role there. They may even be a candidate for the lead because they can bridge sort of the government side and the private sector side." When asked if NASA is the right agency to develop commercially viable infrastructures in the Earth-Moon Economic Zone, Expert 3 stated, "I think we're in trouble if NASA, with its exploration mentality is charged to do all of this" (Full Interview Transcript at Appendix D). The analysis concludes new policy is needed to direct an interagency approach to plan the industrialization of the Earth-Moon Economic Zone. The U.S. should direct an interagency approach, specifying members to develop an Earth-Moon Industrialization Plan.

The document analysis found no reference to identification and prioritization of Earth-Moon Zone infrastructures to develop by 2049. Not only are their technical and logistical reasons to prioritize, but there are competition and national resourcing reasons to prioritize. Other than infrastructures implied from human exploration, there is no explicit needs or priorities identified to develop infrastructures needed by 2049. Expert 5 states, "I think there is still an inability I mean, correct me if I'm wrong, but when I listen to the conversations, I think there is still an inability to articulate across administrations what those infrastructures are and which are critical," and "Because everything is infrastructure, but what is critical for national power and grand strategy, what is critical to take up leadership, say, 20 years from now." Expert 5 goes on to state, "…the U.S. also needs to identify, first of all, goals that are clear in terms of space industrialization, Earth-Moon industrial policy and what are the goals that they want to do in the next 10-15 years. And it really is important to identify timelines." Expert 1 amplifies this and the imperative to industry by stating, "If you haven't defined an infrastructure idea that underpins the way you're going to define that cislunar superhighway, then the commercial world is not going to invest in it in a way that it does for other places where they know the outcome." Expert

5 adds, “but there is no clear direction from a high level as to what that U.S. investment should be, at least that is what I have seen…” To illustrate the difficulty and need to be well thought out, Expert 3 provided a practical example prioritizing infrastructures during the Bush era vision to return to the Moon stating, “And we did something very simple at the time, we took a Visio program and we just illustrated graphically, starting from where we were today in 2002 or whenever it was, what it would take to get given the confines of the NASA budget and inflationary growth, only what it would take to implant the infrastructure to get to Mars. And what you saw on the wall in a sort of a logic net fashion was each year you needed $1B to get these things.” Just within the interviews there were varying opinions on the infrastructure priorities and order of precedent in building them to include communications, Position, Navigation and Timing (PNT), fuel depots, in-space shuttles or ferries, SSA and others. If the experts are a microcosm of the issue, the infrastructure needs and priorities currently has no analytical underpinning and need to be articulated for national consensus. Underscoring this, Expert 1 said, “but let's talk about that infrastructure. What is it that you need to own? What is it that we need to maintain this system cislunar?” The analysis concludes new policy is needed to identify and prioritize Earth-Moon infrastructures that the U.S. needs to develop by 2049. The U.S. should direct the identification and prioritization of Earth-Moon Zone infrastructures to complete by 2049 and include it in Earth-Moon Industrialization Plan.

The document analysis found no reference to developing infrastructure architectures that are commercially viable, nationally competitive, or characterized as open for unrestricted for free trade. In fact, the interviews provided ample evidence of infrastructures being developed by NASA that are not commercially viable nor have characteristics needed for commercially viable unrestricted use and trade. To establish the premise that an overarching architecture governing

the development of multiple infrastructures is needed, Expert 1 states, “So the next point you need to remember is that infrastructure needs to be married to architecture. Infrastructure is very architecture dependent on how you do these things. But when you get out to space, which is what I started to talk about the architecture, what's the architecture going to be for the cislunar corridor?” Expert 3 stated it with an analogy, “That was the whole raison d'etre for that architecture, for this architecture that you're talking about. It really is more like a public works, It's like the metro. You've got to put in the Washington Metro, but you've got to leave open the possibility they're going to have a silver line eventually and you're going to have a whatever color line that you need to add on to it to make.” There were several criticisms of NASA of not architecting commercially viable infrastructures. The arguments center on the current NASA Artemis plans for SLS and other systems that are simply not economically viable if commercialized. When asked for an example of an infrastructure that is not commercially viable Expert 1 stated, “…as long as a government program like SLS exists, there can be no infrastructure investment by the commercial world or even by the government because not only does it eat all the money, it eats all the ideas.” Expert 1 goes on to say, “No nation can afford to build a replica of the SLS. But many nations could afford to go ahead and buy a seat from Space X or from Dream Chaser or from Boeing and if they could, those nations could buy a seat from those guys.” When discussing an alternative architecture to SLS involving a commercial in-space ferry between Earth orbit and lunar orbit to shuttle passengers of all countries, Expert 1 stated, “If you built that infrastructure just for the Moon, just for the manned lunar missions for NASA, you would save a ton of money over the current SLS and Orion architecture, but you would also now have an infrastructure that any other nation could use to do the same thing at a much lower cost.” To further Expert 1’s architecture, Expert 2 adds, “…suppose you're an

entrepreneur that wants to harvest resources from the Moon for example, or you're DoD that wants to go investigate objects in cislunar space that you can't identify from the ground. Those need logistical support in order to make those things happen. And it would be advantageous to both parties to be able to leverage some existing in-space infrastructure, rather than having to develop their own  If every little entrepreneur that wanted to bring, you know, titanium back from the Moon had to develop their own transportation infrastructure it would be unaffordable, right. So there needs to be a common infrastructure."  To amplify the explorer mission and culture mentality of NASA that appears to be inhibiting the development of economically competitive architectures, Expert 3 states, "When NASA thinks of infrastructure, my sense is that they think of it on a roadmap to a mission execution…So Gateway is to allow, when it's crewed, to allow operations between the crazy orbit that it's in and the surface. Maybe they say it's a waypoint on an architecture to get from here to there, but I don't think they have the cash to create that type of Gateway."  There were comments across several experts discussing the characteristics of future infrastructures to support unrestricted free trade and open use of commercially viable infrastructures, not only for economic reasons but for national security reasons.  Expert 2 says that China will likely follow that approach even if the U.S. doesn't stating, "So if China was to create an in-space infrastructure, and I don't see them being as forward leaning as the United States, they would probably welcome American companies taking advantage of their infrastructure unless there was something about it that was revealing of military capabilities or something like that."  Expert 4 states, "When you build this out, you want it to be global. You want other people to be able to access it."  Expert 1 used the analogy of a McDonalds in Russia, "…the policy position must be that if the commercial world comes in and provides infrastructure, they need to be able to utilize that with whomever they want you now.

You know, we can talk about, well, what if we get involved with Russia and those kinds of things? Well, that's no different than closing McDonald's in Moscow, right?" Clearly Expert 1 was referring to the national power a country has when another is reliant on their infrastructure, to which closing it represents a form of diplomatic sanction. The analysis concludes new policy is needed to architect infrastructures that are commercially viable and unrestricted for open use for the U.S. to compete and lead in the future Earth-Moon Economic Zone. The U.S. should direct the development of an architecture for commercially viable infrastructures in the Earth-Moon Economic Zone to ensure the U.S. can compete, ideally making it a part of an industrialization vision and plan.

The document analysis found no reference to involving both OEM and commercial utilization markets in an Earth-Moon industrialization plan. Involving both OEMs and commercial users in an Earth-Moon industrialization plan would provide competition expertise and help attract private capital. Expert 5 states, "I think the private space sector is going to play a critical role in the U.S." Expert 2 adds, "This whole issue in the United States point of view, China is different, but in terms of in-space infrastructure, that will not come to pass unless we leverage primarily private capital. So, one of the policies has to be that our approach to it must attract private capital." But which private industry? Expert 4 refines the definition of private sector to distinguish between OEMs and the utilization markets stating, "But then there's another category called the commercial utilization folks, the folks that are going to utilize the infrastructure who will probably enter into agreements with the companies building out the infrastructure or may just be utilizing that infrastructure." Expert 4 goes on to explain the reason to include in an Earth-Moon industrialization plan would be, "But you want to get the commercial utilization market needs in there up front to make sure it's got that commercial

utilization market application so that the taxpayers' money can then be leveraged later, and then NASA and the DoD and everybody else can buy services from it." The benefit of an industrialization plan that is open and available to industry is underscored by Expert 1 who states, "If you haven't defined an infrastructure idea that underpins the way you're going to define that cislunar superhighway, then the commercial world is not going to invest in it in a way that it does for other places where they know the outcome." Expert 3 states, "So it's not just the architecture as we would think of it. It's also the business model or the business plan. And, you know, industries got to see where they can cash in." The analysis concludes new policy is needed to distinguish the markets between OEMs and users and involve them in the industrialization planning in an effort to attract private capital. Direct an interagency process, to include industry OEM and utilization markets, as a whole-of-nation approach to plan the industrialization of the Earth-Moon Economic Zone.

Table 32 is a summary of the interview analysis for the Earth-Moon industrialization plan theme. Based on the analysis, new policy is needed for five elements.

Table 32

*Results of Interview Analysis for National Industrialization Plan Theme*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| **Earth-Moon Industrialization Plan** | Not in documents reviewed. | New policy needed. According to experts, an Earth-Moon Industrialization Plan is needed for Earth-Moon Zone development. | The U.S. should create an Earth-Moon industrialization plan to develop Earth-Moon Economic Zone infrastructures by 2049. |
| | Not in documents reviewed. | New policy needed. According to experts, there does not appear to be a whole-of-government or interagency (DOC, DOT, DHS, DoD, etc.) approach to plan for the industrialization of the Earth-Moon Zone. | The U.S. should direct an interagency approach, specifying members, to develop an Earth-Moon Industrialization Plan. |

| | | | |
|---|---|---|---|
| | Not in documents reviewed. | New policy needed. According to experts, future infrastructure needs and prioritization have not been identified for the Earth-Moon Zone. | The U.S. should direct the identification and prioritization of Earth-Moon Zone infrastructures to complete by 2049 and include it in Earth-Moon Industrialization Plan. |
| | Not in documents reviewed. | New policy needed. According to experts, NASA is not developing infrastructure architectures that are commercially viable, economically competitive, and open and unrestricted for free trade. | The U.S. should direct the development of an architecture for commercially viable infrastructures in the Earth-Moon Economic Zone to ensure the U.S. can compete, ideally making it a part of an industrialization vision and plan. |
| | Not in documents reviewed. | New policy needed. According to experts, there needs to be extensive industry involvement, to include not only the OEMs who build the infrastructure but the commercial utilization markets to attract private capital. | The U.S. should direct an interagency process, to include industry OEM and utilization markets, as a whole-of-nation approach to plan the industrialization of the Earth-Moon Economic Zone. |

*Note.* The table shows the interview analysis from phase two for the national industrialization plan theme.

***New Earth-Moon Economic Strategy Theme.*** Of 255 new codes, 35% were related to the Earth-Moon economic strategy theme. The document analysis found no reference to economic vision or strategy in the documents reviewed. Ideally an Earth-Moon economic strategy would come before an industrialization plan (i.e., strategy before plan) laying out the business case to develop the Earth-Moon Economic Zone. An Earth-Moon economic strategy would also help with strategic communications and awareness by communicating the business case to the American Public and Congress. There were a multitude of expert comments implying the U.S. does not understand that we are in an economic competition with China for Earth-Moon Economic Zone infrastructures, versus a prestige competition to win hearts and minds as was the case during the 1960s space race, or a military competition to protect U.S. assets in Earth orbit. Expert 5 states, “the U.S. doesn't seem to be able to understand that space is no more about

national prestige, it's an economic competition," adding, "My conclusion after nearly six, seven years of studies is that I don't think so and so my point is that I think there is a continuation of understanding space from an exploration, prestige perspective in the U.S." Expert 5 goes on to say, "I think we tend to continuously see them through the Cold War framework of prestige and space exploration when they [China] are insisting again and again that this is about space utilization and economic development." When asked if there was anything close to an economic strategy for the Earth-Moon Zone, Expert 5 stated, "Jim Bridenstine talked about it. As I said, there was sustainable presence, but there was a hesitation to articulate the economic returns and the fact that this is actually an economic competition. This is not a competition for ideological attractiveness." Expert 5 went on to state, "I think the U.S. needs to articulate a much more visionary leadership beyond just data sharing, and I think that they should include a clear articulation of why the U.S. is investing in Earth-Moon infrastructure, why it's particularly important for U.S. allies and partners, how they will benefit from this particular enterprise. I haven't found that in the U.S. There are several documents that talk about it in a roundabout manner, but there is no clear direction from a high level as to what that U.S. investment should be. At least that is what I have seen, and I have also seen a reticence to identify space as a critical infrastructure." To be fair, Expert 6 states, "But it's by no means guaranteed that there's going to be huge societal, economic, political, technological benefits from all this stuff." The contrary view indicates the need to articulate and communicate the economic risk and rewards in a national level economic strategy. In an off-camera comment by one expert after the interview, a remark was made to include the National Economic Council in the development of an economic strategy, if not lead it on behalf of the National Security and National Space Councils. Coupled with Scott's paper on the Concept of National Economic Strategy containing all the component

codes associated with this economic strategy theme, the analysis concludes new policy is needed to create a national-level Earth-Moon economic strategy. The U.S. should create an Earth-Moon economic strategy to articulate the vision, priorities, return on investment, and resourcing needed to ensure the U.S. will lead development of Earth-Moon Economic Zone infrastructures by 2049. Consideration should be given to the National Economic Council to lead its development.

The document analysis found no reference to an economic vision for the Earth-Moon Economic Zone in the documents reviewed. An economic vision to communicate and unify U.S. efforts around the economic competition with China over Earth-Moon Zone infrastructures versus a prestige or military competition would be helpful to convey the economic value to the U.S. if first-to-market, and the economic peril to the U.S. if they are not. When discussing the lack of economic strategy and vision, Expert 2 stated, "I think the next level down for this administration doesn't exist yet. As far as I can tell." On a national level vision of economic development, Expert 4 states, "So I do think that we should, you know, make sure that all of our instruments of national economic power are supported through the development of the cislunar infrastructure." In communicating outside the U.S., Expert 5 states, "So private companies and U.S. allied nations will look for economic clarity. BRI is offering them the economic clarity in terms of space infrastructure." Coupled with Scott's paper on the Concept of National Economic Strategy addressing an end-state economic vision, the analysis concludes new policy is needed to create a national-level Earth-Moon economic vision as part of the economic strategy. The U.S. should articulate an end-state economic vision for the U.S. in the future Earth-Moon economy, showing the benefits of being first and the pitfalls of being second to develop it.

The document analysis found no reference to an economic purpose or priorities for the Earth-Moon Economic Zone in the documents reviewed. Purpose would illustrate the economic

power to be gained and priorities would delineate which parts of the future Earth-Moon Economy the U.S. actually needs or can afford to invest. When asked if the White House is working on economic policy Expert 2 stated yes, "…but they haven't really thought about it yet in terms of the competition with China. They're just saying, well, here's these technologies and we do cool things with them, so what should we do?" A national level economic strategy could also provide a level of continuity between administrations. Expert 2 illustrates the consequences of changing U.S. priorities with the analogy, "A few months before 911, 911 happened and suddenly all the emphasis on space asset vulnerability went away because they were all about terrorism, so that allowed our adversaries years to catch up and develop assets and all those sorts of things. Today, obviously, things like the Ukraine conflict and even the pandemic and some other things once again seem to be distracting the administration from the importance of space." When asked if the U.S. had prioritized the resources to develop Earth-Moon infrastructures before China, Expert 3 stated, "You'd be hard pressed to get anything by 2049…you've got to give up some things or do some things very differently." Coupled with the Scott's paper on the Concept of National Economic Strategy addresses the need for national economic purpose and priorities, the analysis concludes new policy is needed to articulate the economic purpose and priorities as part of the economic strategy. The U.S. should articulate economic purpose and priorities for the U.S. in the future Earth-Moon economy, showing the benefits of being first and the pitfalls of being second.

The document analysis found no reference to a national resourcing strategy for the Earth-Moon Economic Zone in the documents reviewed. Resourcing the development of Earth-Moon Economic Zone infrastructures is likely outside the current NASA mission and budget. Articulating economic return in an Earth-Moon economic strategy will not be enough without a

national resourcing strategy to fund it over the long-term. When asked if resourcing was being discussed in the White House, Expert 2 stated, "So, you know, I think the discussion is going. And you know what everybody in the government is worried about is what's this going to cost us, right?" When discussing the need for a whole-of-government national resourcing strategy versus a NASA-only resourcing strategy, Expert 3 said, "But the money is going to come from someone else, not NASA." On the ability of NASA to fund this new area, Expert 1 said, "With a lot of the old infrastructure within NASA and the DoD and U.S. space in general, the old infrastructure acts as an ax, as an anchor on our ability to invest in the future, because it was not built to last that long, nor to go ahead and be cost effective." Expert 3 amplifies that statement with, "...and that's the problem NASA has, is the cost of salary and benefits and the buying power is just really eroding, although they have gotten a pretty healthy chunk of money of late, but that's been the problem." Expert 3 adds, "Space Force at least, I get the sense, they are on a mission. They're moving but they have no money yet, but they're going. And NASA's like, hey, wait a minute we have this Mars sample return thing that's going to suck every dollar for the next five years now that we've launched James Webb. So, what are you talking about infrastructure? Where is the money for that? Not clear." It could be that an Earth-Moon Zone infrastructure development spans several agencies, to include NASA, DoD, Commerce and perhaps others to seed and attract private investment. Coupled with the Scott's paper on the Concept of National Economic Strategy addressing the need for a national resourcing strategy, the analysis concludes new policy is needed to develop a national resourcing strategy to fund the priority investments identified in the economic strategy. The U.S. should include a national resourcing strategy as part of an Earth-Moon economic strategy.

Table 33 is a summary of the interview analysis for the Earth-Moon economic strategy theme. Based on the analysis, new policy is needed for four elements.

Table 33

*Results of Interview Analysis for National Economic Strategy Theme*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| Earth-Moon Economic Strategy | Not in documents reviewed. | New policy needed. According to experts, a national economic vision, priorities and purpose, and resourcing strategy is needed for Earth-Moon Zone development. Based on literature, these are elements that could be included in a National Economic Strategy. | The U.S. should create an Earth-Moon economic strategy to articulate the vision, priorities, return on investment, and resourcing needed to ensure the U.S. will lead development of Earth-Moon Economic Zone infrastructures by 2049 Consideration should be given to the National Economic Council to lead its development. |
| | Not in documents reviewed. | New policy needed. According to experts, there is no end-state economic vision for the U.S. role in the future Earth-Moon Economy of the future. | The U.S. should articulate an end-state economic vision for the U.S. in the future Earth-Moon economy, showing the benefits of being first and the pitfalls of being second. |
| | Not in documents reviewed. | New policy needed. According to experts, legacy belief in military and prestige priorities and purpose for the U.S. in space is overshadowing the economic priorities and purpose needed to win the strategic competition with China to develop the Earth-Moon Economic Zone. | The U.S. should articulate economic purpose and priorities for the U.S. in the future Earth-Moon economy, showing the benefits of being first and the pitfalls of being second. |
| | Not in documents reviewed. | New policy needed. According to experts, the expectation of commercial infrastructures being funded via the NASA budget is not practical and requires a larger national resourcing strategy. | The U.S. should include a national resourcing strategy as part of a national Earth-Moon economic strategy. |

*Note.* The table shows the interview analysis from phase two for the national economic strategy theme.

***New NASA Issues Theme.*** Of 255 new codes, 23% were related to the NASA issues theme. The major code was NASA roles and mission, which amounts to nearly 50% of all the code counts for this theme. The previous document analysis found references to NASA roles and mission, but all within the context of space exploration and science. There was no reference to NASA creating the Earth-Moon Economic Zone infrastructures needed meet economic goals or a strategic competition by 2049. In 1958, NASA was charted to be a civil space exploration agency. Among the goals were to expand human knowledge, develop space vehicles, preserve the leadership role of the U.S. in space science and technology, and during the Cold War, bring prestige to the U.S. to win hearts and minds of other countries. In NASA's words, "The Space Act has been amended several times since 1958, but these goals have been little changed" (NASA, 2008). So, one would ask that if we are in an economic competition with China to develop infrastructures on Earth and in space, does NASA have the role and mission to do that currently, it is not exploration or science. On the NASA mission to establish for prestige for the U.S., Expert 5 states, "the U.S. doesn't seem to be able to understand that space is no more about prestige." On the NASA mission to explore, an analogy was used during one interview to that of Lewis and Clark who explored the American Frontier. Like NASA, they were explorers and were not chartered to create an economically viable infrastructure to develops infrastructures (roads, telegraphs, mail delivery, etc.) to enable the new U.S. economy. Their mission was to explore and conduct scientific investigation. So, is the NASA exploration and science mission sufficient to develop infrastructures to enable the new U.S. Earth-Moon Zone economy? Expert 1 said, "If you went to NASA, they all thought they were explorers and it's like, you guys don't understand, you're not. You're building the means under which people will explore, you're not explorers yourselves, but you're approaching it as if you are. And that's exactly why we don't

have those kind of infrastructure discussions." Expert 3 said, "When NASA thinks of infrastructure, my sense is that they think of it on a roadmap to a mission execution" and, "If NASA were to sign up for this, for implanting this infrastructure, whatever it would be called in the Earth-Moon area, cislunar, you know, there would have to be very powerful people in charge of it because the tension between that element and the research element would be unbelievable." When asked if NASA was the best choice at building out the Earth-Moon Zone infrastructure, Expert 6 stated, "Yes because I think they're the best choice among what's available. And that's because I don't think this is appropriate for the DoD in general, this sort of Earth-Moon lunar infrastructure." In other words, Expert 6 says no, but it's all we got. Of course, one approach is to change NASA's mission to which Expert 6 says, "I'm a big organizational behavior, organizational culture or process kind of a guy…and it goes up against all the other things that they want to do, it drops off the table because it's not in their mission statement and it's not an existing constituency." Adding, "If Congress gives them the mission, it gives them some money." Expert 3 tempers this with, "So you know how you're going to not only architect the infrastructure itself, but how you're going to architect the NASA people infrastructure to do that successfully, it's not obvious," and "I find myself wondering if, let's say there was an SPD, something or other that wanted to lay in this infrastructure on the timeline that you're talking about. Would NASA raise their hand to do it? I don't know. Not obvious." As an alternative to NASA, Expert 6 argues, "…a lot of us are making the same case for the Office of Space Commerce that's tucked down underneath this office, underneath the National Oceanographic and Atmospheric Administration (NOAA). It's being stifled by the broader bureaucracy. And NOAA that doesn't care about any of the stuff that commerce does. He's got to pull it out and make it a separate Bureau of Space Commerce." A likely model might be Commerce is the lead

to plan the economic zone, and NASA provides the money and engineering expertise to oversee its development and commercialization. The analysis concludes new policy is needed to either amend the NASA mission to include planning and developing Earth-Moon Economic Zone infrastructures or designating another lead agency such as Commerce to lead the planning and use NASA to execute development. The U.S. should identify lead and supporting agencies to plan and develop Earth-Moon Economic Zone infrastructures by 2049 and adjust their roles and mission appropriately.

The next largest code count was NASA's acquisition and ownership model. The document analysis found references to NASA government developed and government owned infrastructures (like SLS, Orion, etc.) while simultaneously promoting commercially developed and commercially owned infrastructures (like COTS, CLPS, etc.). The issue is that the government owned and operated infrastructure uses resources needed for commercial owned and operated infrastructures, and in most cases the government owned and operated infrastructures are not designed as commercially viable infrastructures when it's time to transition them. There does not appear to be a good explanation for the co-existence of the two models, nor the applicability of the government owned and operated model as economically viable for the future Earth-Moon Zone. Expert 1 adds, "In the past, all that infrastructure we talked about is all government owned, every bit of it is government owned and that was okay because that's where the nation was in the sixties and seventies when we built it all. But now you have to think about infrastructure as, do I need to own the infrastructure or do I need to make sure it's there because there's a big difference between the two." Expert 1 states, "And by the way, we want all those infrastructure elements to be owned by the commercial world and we (NASA) will be your customer." Expert 2 highlighted the commercial viability of the Artemis Program elements

stating, "…the NASA Inspector General (IG) has just said you can't afford the Artemis Program. I mean, you can't afford the SLS part of it. So, figure out a way to do it with commercial launch vehicles. "When asked if NASA can or will use a different acquisition and ownership approach for Earth-Moon Zone infrastructures, Expert 3 referenced COTS, CLD and CLPS by stating, "Well, again, I think much to the chagrin of the old timers, NASA has pivoted in that direction, I think as evidenced by the CLPS Program, where you basically engage a commercial service to get your payload down on the on the surface." However, despite stating NASA has pivoted, when asked why NASA does not use the commercial services approach to replace the elements of Artemis Expert 3 stated, "So I don't have the answer. But one of the things observed is…the previous Office of Safety and Mission Assurance (OSMA) Director who was an astronaut, the NASA Director at the time, and the whole approach was to have a government solution and a commercial solution. So, the SLS is part of the government solution, but that's not sustainable. It's just not sustainable. It's smart, but it's not sustainable. You've got to break that mold because you don't have enough cash under the under the curve. The sand chart doesn't work here. Or let's put it this way. You'd be hard pressed to get anything by 2049 given the current, you've got to give up some things or do some things very differently." To further support for COTS-like strategy for Earth-Moon infrastructure, Expert 4 stated, "… they should not use what I would consider classic procurement methods. I still think they should go in and use other acquisition strategies that are commercial kinds of strategies." Expert 2 added, "So, if you can shape a program that attracts and doesn't drive [industry] away with excessive requirements and excessive government involvement and that sort of thing, that's the path to success for space infrastructure. And the policy folks need to understand what happened with COTS. They need to understand what's happening. The CLPS, the commercial lunar payload services program,

propose programs like that to attract private capital and don't drive it away." Coupled with the commercially viable architecture theme comments questioning the applicability of these large expensive government owned and operated infrastructures there appears to be a need for policy specific to the Earth-Moon Zone economic challenge that directs the use of more commercially owned and operated programs (i.e., commercial services contracts) that have a higher likelihood of being commercially viable and attracting private investment. The analysis concludes new policy is needed to direct an assessment on the appropriate acquisition and ownership model to develop and operate economically competitive infrastructures in the Earth-Moon Economic Zone by 2049. The U.S. should direct NASA or an independent body to perform an assessment on the appropriate acquisition and ownership model for to ensure U.S. Earth-Moon Economic Zone infrastructures are economically competitive by 2049.

While adoption of commercial standards was a code, it was largely positive in that NASA is beginning to adopt commercial standards that they develop with industry. And while there were budget and legacy infrastructure codes, they were related in that legacy infrastructures are driving budget inflexibility at NASA. If a national resourcing strategy is created for the Earth-Moon Zone, this makes NASA's budget inflexibilities moot. Table 34 is a summary of the interview analysis for the NASA issues theme. Based on the analysis, new policy is needed for two elements.

Table 34

*Results of Interview Analysis for NASA Issues Theme*

| | Document Analysis | Interview Analysis | Recommendation |
|---|---|---|---|
| NASA Issues | Not in documents reviewed | New policy needed. According to experts, NASA role and mission is one of space explorer is not appropriate to plan and develop commercially viable infrastructures for the Earth-Moon Economic Zone. Roles and mission of NASA and others may need to be addressed. | The U.S. should identify lead and supporting agencies to plan and develop Earth-Moon Economic Zone infrastructures by 2049 and adjust their roles and mission appropriately. |
| | Not in documents reviewed | New policy needed. According to experts, NASA acquisition and ownership model of government owned and operated may not be the appropriate model to ensure the U.S. is economically competitive int eh future Earth-Moon Economic Zone. | The U.S. should direct NASA or an independent body to perform an assessment on the appropriate acquisition and ownership model for to ensure U.S. Earth-Moon Economic Zone infrastructures are economically competitive by 2049. |

*Note.* The table shows the interview analysis from phase two for the NASA issues theme.

**Discussion of Results**

***Results "by Theme."*** There was a total of seven themes generated, four were developed during the initial document analysis and corroborated through interview analysis and three were developed during the interview analysis that were not identified during the initial document analysis. Of the four themes developed and corroborated from the document analysis, there were 14 separate policy elements identified. Of the 14 policy elements, six indicate no changes to existing policy and eight indicate changes to existing policy. Of the three new themes developed during the interview analysis, there were 11 separate policy elements identified during the analysis implying a need for 11 new policies. Table 35 shows summary results by theme.

Table 35

*Summary of Results by Theme*

| Themes (and Number of Policy Elements) | Corroborated No Changes | Corroborated Changes | New Policy Identified | Changes from Interviews |
|---|---|---|---|---|
| Space Competition (4) | 3 | 1 | 0 | Corroborated |
| Infrastructure Competition (3) | 2 | 1 | 0 | Corroborated |
| Promote Commercial Space (4) | 1 | 3 | 0 | Corroborated |
| Establishing Human Presence (3) | 0 | 3 | 0 | Corroborated |
| Earth-Moon Industrialization Plan (5) | 0 | 0 | 5 | New Information |
| Earth-Moon Economic Strategy (4) | 0 | 0 | 4 | New Information |
| NASA Issues (2) | 0 | 0 | 2 | New Information |
| | **6** | **8** | **11** | |

*Note.* The table shows the themes developed by the document analysis and corroborated by the interview analysis, and the new themes developed from the interview analysis. Total policy elements for each theme are in parenthesis and the columns show the breakout of no changes, changes or new policy needed for each theme.

***Results "by Recommendation."*** Upon inspection of the recommendation narratives across all themes, there is an artificiality in the number of changes and number of new policies needed when tabulating by theme. In some instances, recommendations appear similar in other themes, such as the recommendations to establish dates in both the promote commercial and establish human presence themes. In other instances, some recommendations appear to be subordinated or sub-recommendations to another recommendation within a theme such as the various vision, priorities, commercially viable architecture, etc. components of the industrialization plan. While the themes provided a useful analytical tool, the recommendations and tabulated results are best presented in terms no change, change or new policy recommendations. This provides a more actionable taxonomy to the target audience.

Upon reviewing the recommendations in the no changes to existing policy category, there does not appear to be any redundant or subordinated recommendations. As a result, there are

still six recommendations involving no changes to existing policy. Table 36 presents a summary of the no changes category before and after reconciliation review.

Table 36

*Reconciliation Results for No Changes Category*

| Recommended No Change Before Reconciliation | Recommended No Change After Reconciliation |
|---|---|
| U.S. continue commitment to safe, secure, stable environment to attract U.S. private capital and investment to the Earth-Moon Economic Zone. (Space Competition) | The U.S. should continue commitment to safe, secure, stable environment to attract U.S. private capital and investment to the Earth-Moon Economic Zone. (Space Competition) |
| U.S. continue the Trump policy and extend SSA to deep space and consider SSA as a U.S. infrastructure for the Earth-Moon Economic Zone. (Space Competition) | The U.S. should continue the Trump policy and extend SSA to deep space and consider SSA as a U.S. infrastructure for the Earth-Moon Economic Zone. (Space Competition) |
| U.S. continue the Trump policy to strengthen U.S. space leadership but focus it on developing U.S. infrastructures in the Earth-Moon Zone before others. (Space Competition) | The U.S. should continue the Trump policy to strengthen U.S. space leadership but focus it on developing U.S. infrastructures in the Earth-Moon Zone before others. (Space Competition) |
| U.S. continue policy to ensure freedom of movement in the future Earth-Moon Economic Zone to ensure the free movement of goods and services on Earth and in space. (Infrastructure Competition) | The U.S. should continue policy to ensure freedom of movement in the future Earth-Moon Economic Zone to ensure the free movement of goods and services on Earth and in space. (Infrastructure Competition) |
| U.S. continue policy to lead technology standards to ensure future Earth-Moon infrastructure standards are U.S. based. (Infrastructure Competition) | The U.S. should continue policy to lead technology standards to ensure future Earth-Moon infrastructure standards are U.S. based. (Infrastructure Competition) |
| U.S. continue to promote growth of commercial space but focus more on development of the Earth-Moon Economic Zone. (Promote Commercial) | The U.S. should continue to promote growth of commercial space but focus more on development of the Earth-Moon Economic Zone. (Promote Commercial) |

*Note.* The Table shows the six recommended no changes before the reconciliation review in the left column, and the same six recommended no changes after the reconciliation review in the right column. The theme for each is abbreviated in parenthesis.

Reviewing the recommended changes needed to existing policy category, there appears to be a need to consolidate some recommendations. Upon inspection, the following are not related and can stand alone: development of a unified seamless infrastructure competition strategy, policy to continually review regulation and set a deadline for completion of review, extend planetary contamination efforts to include the Moon.

However, there were a number of date-related recommendations for policy that could benefit from consolidation into a single recommendation such as: The U.S. should include initial and sustained operational dates for government and commercially aligned programs in policy for specific Earth-Moon infrastructures to be operational before 2049. This would cover several date-related policy recommendations from space competition, promotion of commercial space and the human presence themes. These same five date-related recommendations for policy are also related separately to budget recommendations across the themes and could benefit from consolidation into a single recommendation such as: The U.S. should include initial and sustained presence dates for government and commercially aligned programs in budgets for specific Earth-Moon infrastructures to be operational before 2049. Proposed budgets should support policy dates and enacted budgets should update and reflect new dates.

As a result of reconciliation, there are now five recommendations involving changes. Table 37 shows changes to the existing policy category before and after reconciliation review.

Table 37

*Reconciliation Results for Changes to Existing Policy Category*

| Recommended Changes to Existing Policy Before Reconciliation | Recommended Changes to Existing Policy After Reconciliation |
|---|---|
| The U.S. should develop a unified and seamless infrastructure competition strategy and awareness policy across all infrastructure domains that China seeks to lead. (Infrastructure Competition) | The U.S. should develop a unified and seamless infrastructure competition strategy and awareness policy across all infrastructure domains that China seeks to lead. (Infrastructure Competition) |
| The U.S. should continue the Trump policy to continually ensure responsiveness regulatory review and establish a date to complete the Biden regulatory reviews so as not to impact the development of Earth-Moon Zone infrastructures. (Promote Commercial) | The U.S. should continue the Trump policy to continually ensure responsive regulatory review and establish a date to complete the Biden regulatory reviews so as not to impact the development of Earth-Moon Zone infrastructures. (Promote Commercial) |
| The U.S. should include the Moon in planetary contamination policy and consider it a future Earth-Moon Economic Zone environmental infrastructure to support all sustained human presence on the lunar surface or in lunar orbit. (Human Presence) | The U.S. should include the Moon in planetary contamination policy and consider it a future Earth-Moon Economic Zone environmental infrastructure to support all sustained human presence on the lunar surface or in lunar orbit. (Human Presence) |
| The U.S. should continue the Trump policy of including dates in policy for initial landing and sustained presence but include dates for specific Earth-Moon Economic Zone infrastructures. as well, then ensure budgets are adequate to support these dates. (Space Competition)<br><br>U.S. policy should identify priority commercial infrastructures and users in the Earth-Moon Zone, target dates for both industry and government seed funding, and promote public-private partnership opportunities. (Promote Commercial) | **Consolidated.** The U.S. should include initial and sustained operational dates for government and commercially aligned programs in **policy** for specific Earth-Moon infrastructures to be operational before 2049. Policy should include:<br>• A definition of sustained as human, robotic, and provide operational availability (Space Competition, Promote Commercial),<br>• Priority infrastructures for the U.S. to develop (Infrastructure Competition)<br>• Public-private partnership infrastructure opportunities (Promote Commercial) |
| U.S. should continue the Trump policy of identifying priority commercial markets, but dates and those commercial priorities should be reflected as commercially aligned in budgets. (Promote Commercial) | **Consolidated.** The U.S. should include initial and sustained presence dates for government and commercially aligned programs in **budgets** for specific Earth-Moon infrastructures to be operational before |

| | |
|---|---|
| The U.S. should establish initial landing dates, define and establish sustained presence dates, and identify and establish dates for enabling Earth-Moon Economic Zone infrastructures. (Human Presence)<br><br>U.S. policy should establish date for initial landing and sustained presence and define sustained human presence and supporting infrastructures. (Human Presence) | 2049. Budget requests should support policy dates and enacted budgets should update and reflect the new dates. (Space Competition, Promote Commercial, Human Presence) |

*Note.* The Table shows the eight recommended changes to existing policy before the reconciliation review in the left column, and five recommended changes to existing policy after the reconciliation review in the right column.

After reviewing the new policy needed category, there appears to be a need to subordinate some recommendations. Upon inspection, the recommendation to direct NASA or an independent body to assess the appropriate acquisition and ownership model is not related to any other recommendations and can stand alone:

However, the following are components of both the industrialization plan and economic strategy theme that can be subordinated to each respectively. The industrialization plan could include the interagency approach, identification of priorities, and development of commercially viable architectures. The economic strategy could also include an interagency approach, as well as the economic end-state vision, economic purpose and priorities, and a national resourcing strategy.

As a result of reconciliation, there are now three recommendations involving new policy. Table 38 shows a summary of the new policy category before and after reconciliation review.

Table 38

*Reconciliation Results for New Policy Category*

| Recommended Changes to Existing Policy Before Reconciliation | Recommended Changes to Existing Policy After Reconciliation |
|---|---|
| The U.S. should direct NASA or an independent body to perform an assessment on the appropriate acquisition and ownership model to ensure U.S. Earth-Moon Economic Zone infrastructures are commercially viable and economically competitive by 2049. (NASA Issues)<br><br>The U.S. should create an Earth-Moon industrialization plan to develop Earth-Moon Economic Zone infrastructures by 2049. (Industrialization)<br><br>The U.S. should direct an interagency approach, specifying members, to develop an Earth-Moon Industrialization Plan. (Industrialization)<br><br>The U.S. should direct the identification and prioritization of Earth-Moon Zone infrastructures to complete by 2049 and include it in Earth-Moon Industrialization Plan. (Industrialization)<br><br>The U.S. should direct the development of an architecture for commercially viable infrastructures in the Earth-Moon Economic Zone to ensure the U.S. can compete, ideally making it a part of an industrialization vision and plan. (Industrialization)<br><br>Direct an interagency process, to include industry OEM and utilization markets, as a whole-of-nation approach to plan the industrialization of the Earth-Moon Economic Zone. (Industrialization)<br><br>The U.S. should create an Earth-Moon economic strategy to articulate the vision, priorities, return on investment, and resourcing needed to ensure the U.S. will lead development of Earth-Moon Economic Zone infrastructures by 2049 Consideration should be given to the National Economic Council to lead its development. (Economic Strategy) | The U.S. should direct NASA or an independent body to perform an assessment on the appropriate acquisition and ownership model to ensure U.S. Earth-Moon Economic Zone infrastructures are commercially viable and economically competitive by 2049. (NASA Issues)<br><br>**Consolidated.** The U.S. should create an industrialization plan to develop Earth-Moon Economic Zone infrastructures by 2049. The plan should include:<br>• An interagency approach, identifying lead and supporting agencies to include industry for a whole-of-nation approach. (Industrialization, NASA Issues)<br>• Identification and prioritization of Earth-Moon Zone infrastructures to complete by 2049. (Industrialization)<br>• An architecture for commercially viable infrastructures. (Industrialization)<br><br>**Consolidated**. The U.S. should create an economic strategy to articulate the vision, priorities, return on investment, and resourcing needed to ensure the U.S. can develop Earth-Moon Economic Zone infrastructures by 2049. Consideration should be given to the National Economic Council to lead |

| | |
|---|---|
| The U.S. should articulate an end-state economic vision for the U.S. in the future Earth-Moon economy, showing the benefits of being first and the pitfalls of being second. (Economic Strategy)<br><br>The U.S. should articulate economic purpose and priorities for the U.S. in the future Earth-Moon economy, showing the benefits of being first and the pitfalls of being second. (Economic Strategy)<br><br>The U.S. should include a national resourcing strategy as part of a national Earth-Moon economic strategy. (Economic Strategy)<br><br>The U.S. should identify lead and supporting agencies to plan and develop Earth-Moon Economic Zone infrastructures by 2049 and adjust their roles and mission appropriately. (NASA Issues) | its development. The strategy should include:<br>• An interagency approach. (Industrialization, NASA Issues)<br>• An end-state economic vision for the U.S. (Economic Strategy)<br>• Economic purpose and priorities for the U.S. (Economic Strategy)<br>• A national resourcing strategy. (Economic Strategy) |

*Note.* The Table shows the eleven recommended new policies before the reconciliation review in the left column, and three recommended new policies after the reconciliation review in the right column.

The reconciliation provides both a more accurate tabulation of the results needed to answer the research question, and a more cogent set of recommendation narratives for the target audience. The tabulated results from Tables 36-38 are consolidated in Appendix H and are: 1) six recommendations involve no changes to existing policy, 2) five recommendations involve changes to existing policy, and 3) three recommendations involve new policies.

***Research Question***. The research question is, "*Is U.S. policy sufficient to develop Earth-Moon Economic Zone infrastructures by 2049?"* As judged through a document analysis and interviews with experts, if there is no new policy or changes to existing policy identified, then U.S. policy is sufficient. If new policy or changes to existing policy are identified, then U.S. policy will be deemed not sufficient. Since there were five recommended changes to existing policy and three recommendations for new policy, the answer to the research question is, "*U.S. policy is not sufficient to develop Earth-Moon infrastructures by 2049."*

## CONCLUSIONS

The nation first-to-develop infrastructures in the future Earth-Moon Economic Zone will set the standards that shape and govern use by others, increasing both economic and national power. China has a goal to supplant U.S. infrastructure leadership on Earth and establish leadership before the U.S. in the Earth-Moon Economic Zone by 2049. Despite China incorporating their infrastructure goals into their constitution in 2017, this study found that U.S. National Security Strategy, National Space Policy and select NASA Presidential Budget Requests since 2017 are not sufficient for the U.S. to develop infrastructures in the Earth-Moon Economic Zone by 2049, implying China could be first to develop these infrastructures and set the standards that will shape and govern use by the U.S. and others.

The purpose of this study was to assess the sufficiency of U.S. policy by analyzing documents and interviewing experts to identify new policies and changes to existing policy. While recommendations were developed to answer the research question and start the discourse on this topic, it is left to future studies to analyze the recommendations in more detail. The interview analysis corroborated five recommended changes from the document analysis and identified three new policies not found during the document analysis, so current U.S. policy was deemed not sufficient to develop infrastructures in the Earth-Moon Economic Zone by 2049. Appendix H is the summary of reconciled results.

While analysis of the individual recommendations was not in the scope of this study, four appear to be critical to the Researcher. The first is to develop a unified and seamless U.S. infrastructure competition strategy and awareness policy across all infrastructure domains that China seeks to lead. This includes space, specifically the future Earth-Moon Economic Zone. Current U.S. policy recognizes terrestrial infrastructure competition as an economic challenge to the U.S., but space infrastructure competition is not acknowledged as an economic challenge, it

is seen as either a military challenge in Earth orbit or a prestige challenge to establish a human presence on the Moon. The second is to include initial and sustained operational dates for both government and commercially aligned programs in both policy and budget, for specific Earth-Moon Economic Zone infrastructures. This includes a definition of sustained and operational availability, a priority for the infrastructures, and public-private partnership opportunities for industry. Current U.S. policy and budget lacks specific dates and specific infrastructures needed to compete in the Earth-Moon Economic Zone by 2049. The third is the development of a national-level economic strategy for Earth-Moon Economic Zone investment. The economic strategy should articulate an end-state vision, purpose and priorities, return on investment, and a national resourcing plan. Consideration should be given to the National Economic Council to lead, supported by an interagency approach to develop the strategy and components. At present, there does not appear to be an economic vision or strategy to compete with China or others in the Earth-Moon Economic Zone. And the fourth is the development of a whole-of-government industrialization plan to develop Earth-Moon Economic Zone infrastructures. The industrialization plan should identify and prioritize those infrastructures important to the U.S. for national economic and national security, and architectures for commercially viable infrastructures that will make the U.S. economically competitive among nations in this zone. Fortunately, there is an opportunity to address these recommendations since the Biden Administration has only issued interim national security guidance and an initial set of space priorities.

In addition to an in-depth analysis of each of the eight recommendations from the analysis, there are a few observations from this report to consider for future study as well. The study assumed that China had the will and capacity to implement their infrastructure plans for

the Earth-Moon Economic Zone by 2049. This requires a validation likely done by U.S. intelligence organizations through a formal National Intelligence Estimate (NIE) or other means. Similarly, this study also assumed that the U.S. would continue the policy as articulated under Title 51 USC to be the leader in space. As the U.S. expands beyond Earth orbit and national resourcing becomes stressed by a policy to lead everything from LEO to deep space, priorities will need to be established and coalitions expanded. Given some of the vagaries in the U.S. policy reviewed, it sometimes appears the U.S. is focused on everything and nothing in space at the same time. Meanwhile China quietly builds the Earth-Moon economy of the future, and the U.S. may have another Sputnik moment in 2049. Attention to the more critical recommendations now, might help avoid this in the future.

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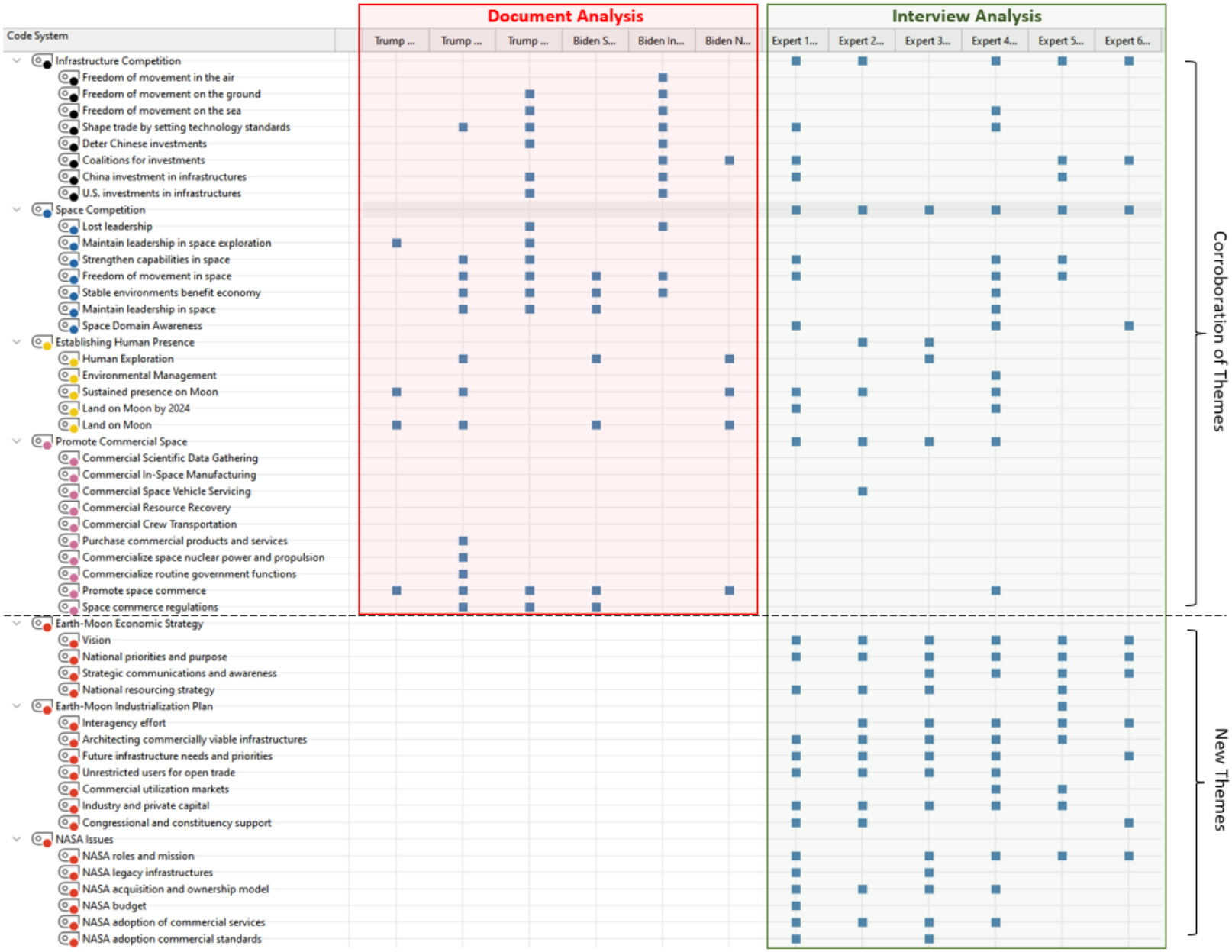
# Appendix A

Code Summary Visual from MAXQDA



## Appendix B

Expert 1 Transcript

Interview 15 March 2022

**Researcher:** [00:00:02] Ok. It's recording. Yeah. And so, feel free to wander on this thing. You know, you got the basic premise of this book, but I'll just at least start it off here. I've got these four themes, right? And I don't know if you had a chance to look at them or not, but it doesn't really matter because you can freewheel on this. But I looked at the documents, came up with these four themes, and the one that came out first was infrastructure competition. And to be honest with you, most of the documentation was centered on terrestrial infrastructure competition. There was clearly a recognition of terrestrial competition. However, it didn't seem like that competition extended into space. But I'll leave that for you to comment if you want to chat about that one first.

**Expert 1:** [00:00:55] So, you know, it's very interesting when you look at what infrastructure currently exists amongst all of the nations, obviously the two we're talking about is the U.S. and China specifically, but it's interesting to look at what infrastructure already exists, what infrastructure needs to exist, and what infrastructure people are working on for the future. And the dichotomy there is pretty large. If you, let's take the U.S. side of this for example, most of the U.S. space infrastructure, and I'll define what that means in a second, was built between 70 and 30 years ago. In other words, the most modern infrastructure we have is 30 years old, and it's when you start to scratch that. So, so you know, and I always I asked the folks, I said, why are we keeping these tests stands open when nobody's used them for 20 years? Well, we might need too.

**Expert 1:** [00:02:27] Okay. So, and that's not to suggest that all the infrastructure that's old isn't being used. In fact, most of the old infrastructure is being used. Everything that's in the Air Force satellite control network therefore everything that's in the massive deep space communications network, all of the test facilities, all of all of these other kinds of things. You know, you might count the Neutral Buoyancy Lab that Johnson Space Center as part of infrastructure. If you're going to do exploration, you need a place to train astronauts in a neutral buoyancy lab. I used to even, when I was at NASA, I used to tell people that the space station was a piece of infrastructure because it costs us about three and a half billion dollars a year to maintain the space station to basically keep it in space. And we did about 300 million dollars' worth of experiments on it. In other words, 90 percent of what we spent on the space station was keeping it in space. And the 10 percent we spent on it was actually doing experiments on it.

**Researcher:** [00:03:38] And ISS is a laboratory infrastructure?

**Expert 1:** [00:03:42] Exactly. That's exactly what it was. Yes, people, they couldn't get over that. It's like, what are you talking about? It's a marvel of engineering. It's a spacecraft. Yes, yes, yes, that's true. But it's a piece of infrastructure. And what you need and what you need to care about is that piece of infrastructure is robbing you of your R&D budget because of how much it costs to maintain that piece of infrastructure. And that's the story. With a lot of the old infrastructure within NASA and the DoD and U.S. space in general, the old infrastructure acts as an ax, as an anchor on our ability to invest in the future, because it was not built to last that long, nor to go ahead and be cost effective. It was built for whatever purpose it was originally built to operate for and the lifecycle cost of it over an extended period of time was not the consideration that went into the design. Everybody knows we could fly a space station for one third the cost of what we're flying the space station for. But the one we have right now already exists and the

government owns it. So, it's a piece of infrastructure that's in some ways an albatross around our neck, and it's an albatross around our necks from preventing us from building more modern infrastructure.

**Expert 1:** [00:05:10] Now everything I just said. If you took the words space away from it, you can make the same explanation about highways, bridges and telecommunication systems. Everything I've just said is equally applies to all of that. And if you then contrast that in China, almost all of their infrastructure is less than 20 years old, and most of it is less than 10 years old because they didn't have it beforehand. They didn't have any of that. So when they build their infrastructure, and let's ignore the corruption that probably cost them 50 percent on every dime they spend, but they are able to now build modern infrastructures, which by their very nature, are more software driven, less hardware driven and by their very nature are less expensive than our old, or our older infrastructure that we built. So, we have a lot of infrastructure between the two nations. The U.S. still has more outer space surveillance network infrastructure. No country in the world has a space surveillance network like the U.S. does. That's part of our infrastructure. All of those things are infrastructure. They cost, they cost an awful lot to maintain.

**Expert 1:** [00:06:32] Even some people would even throw many of the ground control stations for our modern space missions. It's that infrastructure and you might be right you might be wrong. If you were watching the news within the last day or two, you saw that NASA is beginning to move to a crawl to take the shuttle transporter that was built in the days of Saturn V adapted for the shuttle and now has been re-adapted for the SLS, and they've started to move that towards the SLS to go pick up the SLS. That one piece of marvelous engineering that that can hold that can carry 6000 tons on its back at point eight miles per hour is a piece of infrastructure and a very expensive piece of infrastructure. But you don't see Elon Musk building a starship that

requires a space transporter that goes at 28 miles an hour to go ahead and move around his Starship and super heavy launcher, which is equally as big as the SLS. He's instead created a modern infrastructure meant to be cost effective. So, so we have a lot of infrastructure. The U.S. is loaded with infrastructure, and it's not necessarily an advantage to us in this contest we find ourselves in between nations. Let me pause there for your reaction.

**Researcher:** [00:08:00] Yeah, I understand and agree. And you had three areas you were going to talk about, the what exists, the needs to exist, and the future. I should caveat the study by saying the Chinese said that they wanted to own the Earth-moon Zone, and that's a different way of looking at infrastructures. What I've pieced together is not necessarily ground, not necessarily LEO, but somewhere in this cislunar or translunar to lunar surface of the Moon area. But not Mars and asteroids. I don't even want to go there.

**Expert 1:** [00:08:55] Yeah. Yep. Yep. Got it. So perfect segue way.

**Researcher:** [00:08:58] Yeah, I get where you're going and kind of know what you are getting to, but it's lunar surface, lunar orbit and getting it to an Earth orbit, right? You bring up a great point about getting saddled with existing infrastructure. But now I'm very interested in your points that are perfectly in alignment with my study, which is this future infrastructure that is the beyond LEO and beyond the space station. We're talking about Gateway and getting to Gateway and getting to the Moon. What are you doing on the Moon infrastructure?

**Expert 1:** [00:09:46] Exactly, exactly. So that's the perfect segue way to the next portion of this. So, we need to, first of all, recognize that existing infrastructure, as I said earlier, is an anchor. But we also need to recognize in other things, existing infrastructure is also a political hot potato because a politician will know that if he invests in existing infrastructure, he knows that that money will end up in the district where the infrastructure is and whether that district is in

Southern California or Johnson Space Center in the space station. He knows that new infrastructure is an unknown. Where is that going to go? So, there's a political impetus to maintaining and funding old infrastructure, which leads to jobs in a district rather than new infrastructure, which leads to people don't understand where. All right, that's point number one. Point number two is when you think about future infrastructure and new infrastructure, you have to ask yourself who needs to own the infrastructure. In the past, all that infrastructure we talked about is all government owned, every bit of it is government owned and that was okay because that's where the nation was in the sixties and seventies when we built it all. But now you have to think about infrastructure as, do I need to own the infrastructure or do I need to make sure it's there because there's a big difference between the two.

**Expert 1:** [00:11:25] Now some people will tell you, we're going to have these private investments that are going to build our infrastructure for us, and we'll just be one user. And that's good as long as we are just one of many users, but if we're one of one then we're still the owner. Ok, so as you think about future infrastructure and how are you going to go ahead and make it less government owned, you have to also think about how it's going to be less than a hundred percent government occupied because it was a government owned and occupied. The commercial world still maintains they do a better job at building a cost-effective piece of infrastructure, but you need to figure out if the interest charges and the financing charges that the commercial world is going to charge you to get that is going to save you money over the inefficiency of the government. That's not a foregone conclusion, by the way. So that's a big thought as you move to the future, but let's talk about that infrastructure. What is it that you need to own? What is it that we need to maintain this system cislunar? I mean, some people will call it

a cislunar superhighway. I'm not sure it's a system of superhighway. It's more like a two-lane blacktop.

**Researcher:** [00:12:41] Okay, that's a rough road.

**Expert 1:** [00:12:44] But you know this very much plays into the question of what is your architecture looks like for getting from the Earth to the Moon? Because if your architecture looks like an SLS, you don't need much infrastructure. You don't really need much in the way. In fact, even Gateway is secondary to getting to the moon and back. You don't need it at all in that. But if you're architecture is different than SLS, then it may require a different kind of infrastructure. So, the next point you need to remember is that infrastructure needs to be married to architecture. Infrastructure is very architecture dependent on how you do these things. The Chinese, by the way, have placed the first piece of space-based infrastructure in the cislunar system. It's the Quanchang spacecraft, which it's using right now as a relay spacecraft relaying communications from the far side of the Moon. That is a piece, a piece of space infrastructure that can be now used by many missions. The next time the Chinese launch a mission to the Moon, they don't need to worry about landing on a side of the moon that will always be in communication with the Earth or comm outages because they now have a relay satellite as a part of their infrastructure, which allows them to go ahead and make their next mission to the Moon that much more efficient because they have the comm infrastructure already there.

**Researcher:** [00:14:23] I'd like to make a comment here that drives the point home and the raison d'etre for the study. And that is, let's say, Elon or some person says, OK, I'm going to go mine the surface on the far side of the Moon, but I don't want to pay for my own relay satellite. I'll just use China's. Elon says, OK, I'm just going to pay China for some bandwidth. Does the United States of America care about that?

**Expert 1:** [00:14:59] Well, you know, the United States of America never cared about it as long as we were the one you were asking. Right. And think about it, the entire world has relied on the United States of America to do space surveillance and space tracking. The entire world has relied on the United States of America to do the Deep Space Network. You know, when Japan and the United Arab Emirates (UAE) and all these other nations send out their deep space probes, they, for the most part, rely on our worldwide network. Most of them have an in-country antenna so that when Japan happens to be facing Mars, they can communicate to Mars, or when the UAE happens to be facing Mars to communicate. But if you want to be able to contact your satellite 24 hours a day, no matter where in the sky it is, there's only one agency in the world that can do that for you. And that is the United States of America. So, people have always come to the U.S. for that service. Certainly, in some not-too-distant future, there will be a choice at where you could go for that service. So, there is definitely a competition for infrastructure now.

**Researcher:** [00:16:21] I don't think you'd want it if there's two choices and the other provider can decide to turn it off at any point in time, then that becomes a national security issue.

**Expert 1:** [00:16:35] Oh, absolutely, absolutely. And by the way, one piece of infrastructure that I didn't talk about, but it's clearly a piece of infrastructure as well from a space perspective, it's all the launch bases, whether that's Cape Canaveral, Cape Kennedy, Vandenberg Air Force Base, Wallops Island, the mid-Atlantic Regional Center, or Kodiak. All of those are pieces of infrastructure as well. Now here's what's interesting when you think about those pieces of infrastructure and how that might guide us towards the future. If you go to Cape Canaveral, yes, Cape Canaveral is a piece of U.S. government owned and operated infrastructure. But if you go to the Space X launch pad anywhere inside that fence, Space X owns it and it's as modern a launch infrastructure as you can find. If you go to Wallops Island and you go look at where

Northrop Grumman launches their Cygnus cargo vehicles from, this is as modern a piece of space infrastructure as you can find. And obviously, if Elon ends up launching from Brownsville, Texas, or if he moves to Florida for environmental concerns when he builds the Starship capability that he's going to build, that will be a very modern piece of infrastructure. So, what we find is that we when we allow private entities who have a profit motive to go ahead and construct their own infrastructure and in fact, encourage them to do so by giving them a very favorable lease terms on the land and very favorable exclusivity terms on how you support them. And all of those are the kind of things when you when you create rules that encourage capital investment by private concerns in areas where they can make their own money, they will build you a new infrastructure without a dime of cost to the government.

**Expert 1:** [00:18:43] Now, let's be fair, it's not always without a dime across the government. I'm sure that somewhere in space X's books, the cost of the launch pad of Cape Canaveral is amortized, and it's sold with every rocket they sell. But you know they sell rockets to the commercial world as well, not just to the government. So, it's not like the government is even paying all that amortized cost. It's being split amongst all of the other customers. And again, therein lies that situation. If you can get other people to be customers to the space capabilities that you're using, then all of those costs for renewed infrastructure get spread around and you don't have to pay all the carrying charge and all of that work has worked really well in the launch area because launch is one of those, regardless of your architecture, I know you're going to need launch kind of things. And so, the commercial world can build that kind of infrastructure with high assurance that both its government customer and its commercial customer will end up helping to pay them back on it because it's so clearly the part of anybody's space infrastructure. But when you get out to space, which is what I started to talk about, it’s what is the architecture

going to be for the cislunar corridor? If you haven't defined an infrastructure idea that underpins the way you're going to define that cislunar superhighway, then the commercial world is not going to invest in it in a way that it does for other places where they know the outcome. And this is one thing we have failed to do is to define what such a superhighway might look like.

**Researcher:** [00:20:36] You bring up an interesting point, and I'd like to tailgate on that a little bit. The U.S. mindset on space, and I'll use your launch facilities at Cape Canaveral analogy, is we'll set the standard for the launch interface or let SpaceX set the standard on their own pad and the U.S. mindset, I don't know if it's policy explicit policy, but the mindset is we're doing it to make our own U.S. industry more competitive. So, the users of this infrastructure is quite frankly limited to U.S. government and U.S. industry. However, when you get out this cislunar superhighway corridor and you try that protectionist strategy of, you know, we'll have a cargo ship, but let's use Elon again. Ok, we'll have a SpaceX cargo ship going back and forth, hauling helium three back and forth between the Earth and Moon. But then some European Union member or Germany says, we've started mining too and we're not going to build our own cargo ship, we're just going to pay Elon to haul it. And the U.S. government says, no, no, no, no, no, that's our U.S. thing. My opinion is that will defeat the opportunity that exists in space, which is if you're going to create a cargo transportation infrastructure, just like rail or shipping would be the better analogy like international shipping, if you're going to create an architecture, an infrastructure like that, then you probably shouldn't say that it's for U.S. only shipping and standards. You want to get the rest of the world hooked on your stuff, right?

**Expert 1:** [00:22:28] Well, yeah, right. Interestingly, you know, the U.S. launch bases that are being used by SpaceX. Obviously, SpaceX is the most successful of any of them, but Rocket Lab is coming on strong. They're not U.S. only they've been launching satellites from other nations.

They've been most competitive in the U.S., but they've been launching satellites from other nations. I think they just launched an Arab sat just a couple of weeks ago on a Falcon 9 from Cape Canaveral. So, we have been launching them, But you're right, the policy position has to be that if the commercial world comes in and provides infrastructure, they need to be able to utilize that with whomever they want you now. You know, we can talk about, well, what if we get involved with Russia and those kinds of things? Well, that's no different than closing down McDonald's in Moscow, right? That's the same. That's the same argument. So, it doesn't matter that it's space or not. That's the conclusion.

**Researcher:** [00:23:27] By the way, we want Russians hooked on Big Macs. Why, because when you take it away, it's painful and you get leverage.

**Expert 1:** [00:23:37] Exactly right. Well, and look at this, let's make that topsy-turvy argument. For over a decade, the U.S. was hooked on the Russian built architecture of RD-180s and Soyuz and Soyuz capsules. And look where that put us from a national security perspective. So this goes directly to the heart of your question, which is we can't allow China to control that infrastructure because we need to be able to go ahead and rely on it for ourselves in the same way during the pandemic we found out we needed infrastructures to sew masks, we need infrastructure to maintain our own, our own presence to space, our own technological presence, our military presence, our own human exploration presence. So, we have to if we expect that to be the case, we have to do it ourselves.

**Researcher:** [00:24:31] And you didn't you don't see a lot of the words behind what I've written in the report, but I agree completely. And the more people you can get hooked on the U.S. standard as a user base, the more national power comes to the U.S. in terms of not only economic but military and diplomatic got it right because they're using your infrastructure.

**Expert 1:** [00:24:53] And in fact…

**Researcher:** [00:24:57] The whole raison d'etre here is if you are bought into that philosophy as the policy, then it's appropriate to make that philosophy a reality in this Earth-Moon zone thing, right?

**Expert 1:** [00:25:12] And I would tell you right now the tech standards policy is mixed, from different perspectives. Number one, most of these U.S. standards are ITAR controlled. But like, for example, let's talk about docking mechanisms, just a small little thing like docking mechanisms. NASA had its own docking mechanism that it used on Apollo and Shuttle and then space station and now every piece of infrastructure they've built since then. Everybody's got the same docking mechanism, except Elon Musk, who said, you know, your docking mechanism is too damn expensive and it's not that good. I'm going to create a new docking mechanism. So, Elon's docking mechanism costs, I believe the cost was $5 million a copy versus the NASA's standard, which costs $20 million a copy. Docking by the way is a hard thing. Sometimes we think it's pretty easy, but it's a hard thing. But Elon made it one fourth as expensive. But today, when you ask NASA what the docking standard is, they'll give you that older, more, government owned docking standard than allowing an OEM standard, as we would see in the automobile industry, for example, allowing an OEM standard to lead the way, which of course, makes no sense because at the end of the day, NASA paid for the OEM standard under the COTS contract. But they didn't ask for necessarily data rights for it, but they basically paid for that to be developed. So now there's a better standard, but because they've got a whole bunch of contractual restrictions.

**Expert 1:** [00:27:24] Let's talk about other pieces of infrastructure you need, there's three. Did you lose me for a second?

**Researcher:** [00:27:30] You dropped out for about 10 seconds, and it was right in the conversation. Yeah, all's I was going to add is my two cents to that OEM conversation, is it's good that there's an OEM that stood up with a standard because you want to promulgate that through the whole world, and everybody uses Elon Musk's standard. It's unfortunate that our own government, a.k.a. NASA, does not use that standard.

**Expert 1:** [00:27:56] That's crazy,

**Researcher:** [00:27:59] Right? Maybe there needs to be policy making the U.S. government adopt the commercial standards.

**Expert 1:** [00:28:06] All right. I know, I know it's nuts. So, um okay, so let's talk about infrastructure of the future a little bit. And as I told you, it's architecturally dependent, but let me talk about the kinds of things that you'll need. And then let me talk about the actual. So, we've already talked about one of the kinds of things you need which is communications. You need communications and without communication, satellites are useless. And so, you have to decide what kind of communications you're going to put in place. I am happy to say that NASA is working on a future commercial communication architecture, mostly because I forced them to and that commercial infrastructure is being now pursued by a bunch of commercial customers, but they're only pursuing the ground based elements of it right now - I shouldn't say only the ground based geometry, they're only pursuing the LEO and near Earth elements of it right now because NASA hasn't said what they want the standard to be for the deep space portion of it, especially around the Moon and the cislunar region. And again, by not defining a standard that

describes what you want, the commercial world can't go out and pursue it. And the reason the commercial world can't go out and pursue it goes back to our number of customers discussion.

**Expert 1:** [00:29:47] So we might hope that in the future, there are 10 customers for commercial communication services to the Moon. But right now, from a commercial world perspective, there's only one customer. And so, unless they see a contract or a requirement from that one customer, they're going to have a hard time making the investment all on their own. So, communication is one part of the infrastructure, but fuel depots got to be part of the infrastructure, can't go to the moon and back without having fuel depots unless you choose to carry all the fuel with you when you leave the Earth, which costs a lot of money. Because if you have to bring all that fuel from the surface of the Earth all the way to the moon and then all the way back with you and go through trans lunar injection and trans earth injection all the way out there and all the way back costs you. I mean, I think at least ninety nine percent of that fuel is just to go ahead and go through all those transitions and get back as opposed to if you have fuel depots in deep space around the Moon, you don't need to bring any of that with you. How the fuel gets the fuel depot is one of those things where you have to decide architecturally, are you going to try to do that from the Moon surface, which, by the way, for the next hundred years isn't going to be practical? Or are you going to go ahead and do it by virtue of a supertanker, which might be called the Starship? That can be more cost effect to get the fuel to where you want it to be than if you try to carry it on your Orion spacecraft, for example.

**Expert 1:** [00:31:24] And the answer is, of course, today the cheapest way we know how to do that is to load up a Starship with fuel. Shoot it out to the lunar environs and either refuel our fueling station, or the Starship itself becomes a fueling station around the moon, and when it's empty, you bring it back. So that's another piece of the infrastructure. So, communications and

fueling stations, but also need a shuttle. I'm going to tell you what that means. Okay, so you I think you and I spoke about when we were on the phone the other day about the Inspector General (IG) report, where they basically said SLS cost $4.1B dollars, right? Yes. Okay. How much do you think it takes to get -- so there are four astronauts on an SLS. How much do you think it takes to get four astronauts to low Earth orbit right now in the cheapest way possible? How much do you think it costs? It costs Space X about $60 million a seat.

**Expert 1:** [00:32:28] It costs $240M dollars to get folks to low-Earth orbit on SLS, by the way. Think back to 2001 A Space Odyssey and you'll understand the infrastructure or the architecture here. You got folks to low-Earth orbit, then you go into a shuttlecraft or a shuttle lean craft, not a shuttle craft, (a.k.a. Star Trek or those kind of things), but a craft which is only designed to operate in space. It's never intended to land on Earth or land on the Moon. And it shuttles you back and forth from low-Earth orbit to low lunar orbit, and then you go ahead and board a landing system in lunar orbit. That architecture is incredibly inexpensive, and the reason why is incredibly inexpensive is because, number one, it already shares the mechanism you have in place to get to the station, to get to the space station with the architecture that we use to get to the Moon. It requires one intermediate product called the shuttle or an extra-terrestrial transfer vehicle or whatever you want to call it, and it will shuttle you back and forth to the moon. And then it hooks up to a human lander, which will land you on the moon. The human lander, part of that's already part of the equation, part of the NASA budget.

**Expert 1:** [00:33:58] But instead of using that shuttle, that shuttle method, they're trying to throw the entire weight of the entire mission at once from the surface of the Earth to the Moon. And as a result, rather than each seat costing $60 million per astronaut, it’s $4.2 billion, divided by four, which is something north of $1.05B billion dollars per seat. So, $1.05B dollars versus

$60 million per seat is the kind of leverage you get when you build an architecture that is more in tune with how you want to move forward, and because that architecture requires a changing point in LEO orbit that becomes part of your infrastructure as well. What is the transfer station in LEO orbit look like? We know what the transfer station in lunar orbit looks like, it looks like the Gateway. So, imagine, if you will, a Gateway on both sides of that interface. That Gateway is the transfer point you bring somebody from Earth on a capability that you've already developed and paid for, you put them into a shuttling spacecraft that only is designed to go from point A in space to point B in space between the Earth-Moon system, and then you land them on the moon using an HLS you had originally. So that approach to an architecture demands those infrastructure pieces of a transfer point in low-Earth orbit or in some sort of medium orbit doesn't have to be low Earth orbit, but some sort of medium orbit, intermediate orbit.

**Expert 1:** [00:35:45] It demands a transfer point in lunar orbit, it demands cargo, and it demands fueling stations so that you can fuel the shuttle. And if you if you built that infrastructure just for the Moon, just for the manned lunar missions for NASA, you would save a ton of money over the current architecture, but you would also now have an infrastructure that any other nation could use to do the same thing at a much lower cost. You know, right now, no nation can afford to build a replica of the SLS. But many nations could afford to go ahead and buy a seat from Space X or from Dream Chaser or from Boeing and if they could, those nations could buy a seat from those guys, bringing the transfer point, then by a seat on the shuttle and then buy a seat on the lander and they could go ahead and get through a purely commercial services at a very low cost, then they could enter that market, but they can't do it today when the cost per mission, just for the SLS is over a billion dollars. And once you add in, the human lander system it drives you

nearer to one and a half billion dollars for every butt you want to send to the Moon. Nobody else can afford to do it.

**Researcher:** [00:37:07] Yeah, I agree. If I was Hilton or Marriott and I wanted to put a hotel in lunar orbit or on the surface for tourism, I don't think I'd hire NASA to get my people there.

**Expert 1:** [00:37:21] Exactly, exactly right.

**Researcher:** [00:37:25] And my biggest fear is if we're not thinking about this and other people are, the U.S. won't do anything unless there's something there that challenges the U.S. to go do something different. So right into this loop of, well, it's not a priority because there's nothing there, but when somebody puts something there, then it becomes a priority, and you get in to do it. By the way, I'll throw these words out Expert 1, because you got me thinking, you know, everything you're describing and I know you've got a few more to talk about, about future infrastructures. But the person that lays all that out, that architect, that's really a city planner. It is not an explorer, right?

**Expert 1:** [00:38:08] Exactly right.

**Researcher:** [00:38:09] Ok.

**Expert 1:** [00:38:10] And Researcher, your point there is prescient because or I should really say insightful, because if you went to NASA, they all thought they were explorers and it's like, you guys don't understand, you're not. You're building the means under which people will explore, you're not explorers yourselves, but you're approaching it as if you are. And that's exactly why we don't have those kind of infrastructure discussions. It's a topsy turvy look at how this works as opposed to Elon who's an explorer, but he's also an infrastructure guy. He says, look, I know how to do this in a way that I think it makes sense to me. Elon, by the way, has an architecture

somewhat like this. Not exactly the same in his mind. He's a little bit off on it, but nonetheless, he's much closer than NASA is on this right now.

**Researcher:** [00:39:09] So what worries me, is if I was the governor of a state and I wanted to bring economic development to my city, would I hire a city planner to come up with a lean, mean infrastructure that's competitive in the world or would I hire an explorer to come up with my lean mean infrastructure? Obviously, we know what the answer to that is. My fear is when I ask people, who's coming up with this future architecture for this infrastructure in the cislunar world, the answer tends to come back as OSTP. And then I'm like, I know who OSTP is. There's two people or maybe one and their workhorse is NASA, which is the explorer. So still getting the explorer to lay out the architecture of the city. So. Exactly. I don't think you'll ever get the policy you need as a nation for this vision of beating China to lay out the city architecture and city infrastructure.

**Expert 1:** [00:40:04] Right, you're exactly right. Well, and now you know, let's talk about the last piece of this infrastructure because you've got the telecommunications. Well, I and by the way, I, you know, I never bet against Elon, and I never bet against China. Okay. So, let's talk about the last piece of infrastructure because we got the telecommunications piece, we got the fuel piece, we got the transfer mechanism ferry which I call the shuttle piece, so we've got the transfer points that we've got right now but you need some place to go. And by the way, as you said, those places might just be in orbit around the Earth or orbit around the Moon. But at some point, you want to go ahead and land on -- I won't call it terra firma because I guess terra in Greek means Earth, so what would it be -- lunar firma?

**Researcher:** [00:40:53] You need to trademark, that one.

**Expert 1:** [00:40:58] And so to do that, you need to set up a facility on the Moon. Let me let me tell you the most interesting thing about a lunar facility ...who runs it when there's nobody there. Because as you know space is a harsh, a harsh place the radiation that hits the lunar surface, not just heat radiation and light radiation but all of the particles that hit there, all the things that have to be done. So, if you want to keep an environment, a habitation environment going on the moon, it's going to require tending. So not only do you need the habitation environment there to be able to survive, but you need something to tend it because let's face it, it's going to be a long, long time in the future until humans are on the moon 24 hours a day, seven days a week, 365 days a year. Right now, NASA's plan is to visit the Moon for one month every two years. Well, who's going to make sure that all that stuff is ready for them and working when they get there two years from now, the way it was last time?

**Researcher:** [00:42:15] By the way on my study, rather than focusing too much on the 2024 landing date, I was deferring more to the 2028 sustained presence date, whether it's real or not. I know, by the way, what does sustained mean? It's got to be more than two months, right? Attending or attending?

**Expert 1:** [00:42:36] Yeah, right. So, the sustained presence part of it is some sort of robotic maintenance capability. And in fact, I had begun while I was at NASA, to talk about task independent robots that you would have on the surface of the Moon. By the way, I thought it was interesting that about six months ago, Elon unveiled his task independent robots, they would be just shells basically. Because that's what a human being is a task independent robot, basically, except we're not robots. But you need testing independent robots that when the cruiserweights break, they can go do that and when they need to go do something else, they can go, do that. And in general, by the way, beginning with human capabilities isn't bad, but you've seen

them…Boston Dynamics has these robots that are basically multipurpose, right? They're task independent robots. And in fact, that's what I told my folks to do. I said, look, let's go hire Boston Dynamics to go ahead and start thinking about this, because what you want to be able to do is not just maintain the facility, not just to operate the facility, but actually to go ahead and get useful work out of the facility when human beings aren't there.

**Expert 1:** [00:44:02] And you can do that if you have robots who are interacting with the same tools that the human beings that are going to be there one month a year or two months a year, if you're interacting with the same tools, that means you can be nearly as effective between the times that it's human occupied and non-human occupied. So, I view a very big piece of the infrastructure as the automation and robotics that will be left behind in order to go ahead and do those tasks, whether that's maintenance or actual mining or whatever else kind of operation needs to get done. And by the way, it's not too impossible to even think of some of these as being avatars. You know, the time flight for a signal from the Earth to the Moon is just only under two seconds. So, it's not perfect, not perfect timing, but it's still OK to be avatars to the Moon rather than Mars. They have to be fully automated, but at least on the Moon they only need to be semi-automated in order to do that because you could go ahead and operate those. There are quite a few things that could be done if you establish an infrastructure like that.

**Expert 1:** [00:45:15] And part of it is actually getting the structures to the surface, which my answer to that is, you know, you basically need to go ahead and just and send them to the surface well ahead of when they're needed and actually and actually provide them as don't try to build something on the surface. It's easier than if you try to build something on the surface of the Moon, it's much more expensive than building something on the surface of the Earth and sending it to the Moon by orders of magnitude, because if you try to build it on the surface of the Moon

you got to send the equipment there to build it at some point in the future and that leverage point will change. It will shift to where you have enough stuff on the Moon now, where it's actually cheaper to manufacture on the Moon than manufacturing on the Earth and send it to the Moon. But for right now, probably for the next decade and a half to two decades, that infrastructure is best built on the Earth and sent to the Moon so robotics are waiting for humans to come occupy it.

**Researcher:** [00:46:25] So your time frame is interesting because if you believe China that they want to own the Earth-Moon infrastructure by 2049, and you said theoretically, you could do this in the next 10 to 20 years. Now you're talking 2044. So, the U.S. actually has an opportunity to lead, at least in this area, this is just one probable opportunity to lead in several of these areas at a fraction of the cost of the way they're pursuing it right now and ultimately beat China. But I'm worried that our city planners, whoever that is, is not doing this well.

**Expert 1:** [00:47:14] They're not. And by the way, you know that now because I told you to go read the NASA budget and you told me you did. And if you actually read the NASA budget and you figure out how much is being spent on anything other than SLS and HLS, it's almost nothing. There's no money being spent on rovers, there's no money being spent on structures on the surface of the Moon, there's no money being spent on any of those things because SLS and that architecture is the program that ate this future infrastructure. And the space station is the program that ate the future infrastructure most, those things prevent the U.S. from making those kinds of investments which can keep us in the lead.

**Researcher:** [00:47:57] So you must segue into another thought here. I did, I looked at that budget because it was a good data point. Just the ground trawler and all that comes right. But then I looked at a comparison. I looked at Trump's last PBR and Biden's first PBR. And my gosh,

I don't know if you saw what I said in the document analysis, but first of all Biden took out all the dates, so there's no dates. Now, whether Biden was right or wrong who knows, right? The dates are all the dates are gone, not just landing, but sustained presence out of everything. And just in the Earth-Moon, because I came up with a definition in which I did some analysis to figure out what programs met that definition of Earth-Moon kind of the right budget. The Biden's budget request compared to Trump's is 28 percent.

**Expert 1:** [00:49:17] But the NASA budget was higher under the Biden's first budget than Trump so where did it all go?

**Researcher:** [00:49:27] The budget request actually was a little lower than Trump's last one. I only looked at the total budget request, but it's a little misleading for what I'm looking at, right? Because it's got planetary, aeronautics and other stuff stuck in there. I'm only looking in this little Earth-Moon Zone thing.

**Expert 1:** [00:49:47] Right, right, right, right.

**Researcher:** [00:49:48] And Trump's request for these Earth-Moon programs, by the way, and I'm fairly confident I got it right because Bridenstine carved out which of those programs were Earth-Moon in the last budget.

**Expert 1:** [00:50:30] Yeah, yeah, you know.

**Researcher:** [00:50:34] Now I associate that with the turmoil of with Trump's budget wasn't real anyway?

**Expert 1:** [00:50:43] Yeah, that very well, that very well could be just because Trump's budget wasn't real, because I think if you went back the year before, a better comparison would be to look at the 2020 budget. You probably find it's more or less more or less the same level because Trump's budget was way inflated. He knew he'd never get it, but they asked for it anyway.

**Researcher:** [00:51:08] But nonetheless, it was about priorities and not necessarily the actual money. You could argue that it was inflated, but the fact is that Biden's request was lower, and all the landing dates are gone.

**Expert 1:** [00:51:39] Yeah, they're gone. They're gone.

**Researcher:** [00:51:41] I did a search for Earth, science or climate and you get quite a bit more. So that was one data point, and for the commercial stuff, I actually carved it out too. So not just the Earth-Moon programs, I also carved within that Earth-Moon program, the human presence piece, and then there was some other stuff that was kind of a cross between human presence and what I would call commercial resource excavation, you know it wasn't necessarily needed for human exploration, but that was in there, too. And that was quite a bit less too...twenty five percent less. Actually, what I found interesting was of all the things that Biden kept, he actually kept Gateway.

**Expert 1:** [00:52:40] You know why Gateway stays, because Gateway is an international cooperation. Gateway is nothing but wasted money the way they were doing it.

**Researcher:** [00:52:58] Ok. All the all the other, because that reflects a priority of the administration, right, is to get in there and rebuild that international right.

**Expert 1:** [00:53:06] Exactly which I can't argue with it. I mean, you know, I always told folks, I said, well…why don't we just make landing on the Moon the international cooperation? But the problem is it had been sold for so many years as Gateway that nobody wanted to change their priority.

**Researcher:** [00:53:23] Well, that's a pity. So, you know, they pumped up the budget a bit in other areas, there's a couple of rovers looking for volatiles on a lunar surface. They kept that and they actually pumped up a lot of the lunar instrumentation.

**Expert 1:** [00:53:40] It's in the science piece, but hopefully exploration that kind of thing. Well, you know what, what Biden did in his budget, and I haven't looked in the 22 to budget for a while now because it was submitted so many so long ago. Is he kind of kind of right-sized the lunar exploration stuff down to what the Congress could possibly pass? But he also took the focus off of 2024. Now I was all in on 2024. I just didn't think NASA needed as much money as the administration wanted to throw at it. I think they needed a better idea, not a bigger wallet. But it wasn't a matter of ideas, everybody thought it was a matter of money. It's like, no you just need to be smarter about how you're spending your money. You're spending your money poorly. But that's a whole different discussion. Okay, so look, that's sort of the infrastructure piece. I'm sure we could spend more time on it, but we've actually been on the phone for a little over an hour here and I do need to do a couple of other things.

**Researcher:** [00:54:53] Yeah, I'll let you go. But before we get off the phone, if you were going to give the top one, or top two, or three or whatever recommendations for how to get out of this bind and actually put some infrastructure in this Earth-Moon zone before China does, with the thought that the first one there sets the standard for all others, what would that that policy be? I mean, what would those big hitter things be? It's a little bit money, but it's also words, right?

**Expert 1:** [00:55:29] No, it's worse, it's worse in policy, let me tell you what it is. As long as a government program like SLS exists, there can be no infrastructure investment by the commercial world or even by the government because it not only does it eat all the money, it eats all the ideas. You must tell people, you know what…we are going to go ahead and move the date

to 2035 that will no longer be the means we get to the Moon. Look, I'm all about the fact that we're going to get to the Moon before the end of this decade. We're going to have to use SLS. There's no question about it, but we should have a vision that says we are going to move away from that. And the architecture we're going to move to is closer to the one that I described to you with those kinds of elements. And by the way, we want all those infrastructure elements to be owned by the commercial world and we (NASA) will be your customer. And that policy...

**Researcher:** [00:56:32] We and the world will be your customer...

**Expert 1:** [00:56:35] Exactly, that policy change would go ahead and begin to change the dynamic. But NASA has not made that argument to Congress, and Congress is too interested in spending money against where the dollars are going today than against those future places that some dollars might end up, that circles back to how I began. And so, you can go ahead and have that discussion.

**Researcher:** [00:57:02] Yeah, that's fantastic. I think that's a perfect way to end the conversation, and I appreciate your time. Let me let me go to through this and if I have a need to follow up with you, I will, but you've given a lot to think about.

**Expert 1:** [00:57:17] Perfect. All right, always a pleasure.

**Researcher:** [00:57:20] Hey, thank you, Expert 1.

**Expert 1:** [00:57:21] All right. You have a great day. Bye.

## Appendix C

Expert 2 Transcript

Interview 15 March 2022

**Researcher:** [00:00:02] Ok, says we're recording, so of the four themes I came up with let's just get to the first one. The first one was infrastructure competition as a theme that ran across the National Security Policy, National Space Policy and into some of the budget documents across both the Trump and the Biden administration. I started this thought at the 2017 point when China got focused on infrastructures, or at least put it in their constitution. So, everything kind of starts at 2017. I came up with these 4 themes and subthemes, hopefully you had a chance to kind of glance at some of these. And even if not, I'd be interested in your thoughts on the sufficiency of where the policy is going, the current policy, and some recommendations that you might have on any of these. And don't feel to talk to all of them if you don't want to. You can pick out some that require some attention or not.

**Expert 2:** [00:01:03] So I actually did look at the 4 tables. I saw the one about infrastructure competition, but the other three for space competition, human presence and commercial space are all things that I'm familiar with. So that's cool.

**Researcher:** [00:01:35] Do you see all 4.

**Expert 2:** [00:01:42] I do now.

**Researcher:** [00:01:47] Which one would you want to start with?

**Expert 2:** [00:01:49] Well, it's up to you. Whatever.

**Researcher:** [00:01:53] We'll start with the first one, which was the infrastructure competition. What was your thoughts on the policy?

**Expert 2:** [00:02:05] So there's some actually current activity in infrastructure. At the policy level, OSTP is actually chairing an interagency working group on what's called OSAM which is on-orbit servicing, assembly and manufacturing. So, they are writing a strategy what the nation should do in order to create infrastructure that uses those capabilities, I mean, everybody's pretty convinced that those can really be transformative in terms of space operations, but I guess my observation would be that they haven't really thought about it yet and this is sort of inside baseball, but they haven't really thought about it yet in terms of the competition with China. Right. They're just saying, well, here's these technologies and we do cool things with them, so what should we do? But I think it's pretty obvious that the nation that creates a robust infrastructure is going to have more success overall in all of its activities, particularly in terms of leveraging lunar resources, but also, you know, maintaining capabilities in Earth orbit and also supporting human activities, whether those are in commercial space stations or at L1 or on the lunar surface or whatever.

**Expert 2:** [00:03:48] The logistics infrastructure is key to all of that. And it also unlocks value. This is a theme. So, like almost three years ago, my colleague and I wrote a paper, an article in Aviation Week. And the title was unlocking economic value in Earth orbit. So, it talked about this idea of a space superhighway, and we used Amazon as an example. You know, Jeff Bezos didn't have to create his own transportation network. He's doing it now. But even before that was really happening being able to leverage existing transportation infrastructures and digital communications, for one of the five biggest companies in the world is unlocking value, and there's the competition aspect. I don't think the OSTP really quite has, or the Interagency Working Group (IWG) quite has their hands around that yet. But since you don't have any visibility into the IWG, I would just say that, you know, nationally there are discussions about

how to leverage these technologies. But the connection to international competition hasn't quite been made among all these agencies.

**Researcher:** [00:05:27] That hits two themes. One is because they're separate in the policy, one is infrastructure competition, and one is space competition and I guess I'd like you to comment. What I found interesting was infrastructure tends to be terrestrial infrastructure discussions and then space competition is over here, but it tends not to talk about infrastructure. So, you have this kind of weird schism going on where there's terrestrial infrastructure stuff going on and then space competition stuff.

**Expert 2:** [00:06:05] But right?

**Researcher:** [00:06:06] So I think you hit it in your earlier comment is they might be missing the competition piece.

**Expert 2:** [00:06:13] Well, a couple of things. One of them is you're right that no one up until the last couple of years really thought about a space and in-space infrastructure. Right, it was just rockets and satellites were good. But then when you start looking at it and looking at all the things, some of which are aspirational, which are ongoing. Well, you know, suppose you're an entrepreneur that wants to harvest resources from the Moon for example, or you're DoD that wants to go investigate objects in cislunar space that you can't identify from the ground. Those need logistical support in order to make those things happen. And it would be advantageous to both parties to be able to leverage some existing in-space infrastructure, rather than having to develop their own right. If every little entrepreneur that wanted to bring, you know, titanium back from the Moon had to develop their own transportation infrastructure it would be unaffordable, right? So there needs to be a common infrastructure. Now I will make a comment that, you know, 80 percent of our terrestrial commerce is seaborne, right? That shipping is very

inexpensive in terms of getting things between continents and between nations and that sort of thing. And our companies leverage Chinese shipping lines all the time.

**Expert 2:** [00:07:55] Right, so the fact that there's a competition between nations is generally that we've been able to leverage their investments in shipping infrastructure. So, if China was to create an in-space infrastructure, and I don't see them being as forward leaning as the United States, they would probably welcome American companies taking advantage of their infrastructure unless there was something about it that was revealing of military capabilities or something like that. So yeah, I mean, I think the idea of combining these sorts of infrastructure and space is relatively new. I will actually take some credit for getting that dialogue going. People are now thinking seriously about that. That article that I sent you has 424 shares. I've never written an article that got that kind of distribution. So, you know, I think the discussion is going. And you know what everybody in the government is worried about is what's this going to cost us, right? Well, so that was a lot of discussion about your comment about the space and infrastructure being separate. I think there is a thought about in space infrastructure, we haven't seen the Bucks yet.

**Researcher:** [00:09:36] I appreciate those comments. The entanglement of money and national resources with policy has to be addressed because it gets expensive, very fast when nothing exists and it's a hard place to get to.

**Expert 2:** [00:09:49] Well, well, okay, so let me make a comment about that. This whole issue in the United States point of view, China is different, but in terms of in-space infrastructure, that will not come to pass unless we leverage primarily private capital. So, one of the policies has to be that our approach to it must attract private capital. We've had success for the past. You're of course, familiar with the COTS program, right? You know the way what made that attractive

was they said, you know…we're going to give you some non-dilutive capital and we're not going to be imposing many requirements on you. We're going to tell you what our needs are, and they received 21 credible proposals for the most part to build new rockets. We got the Falcon 9 and we got access to a half a billion dollars. I mean, how much should we spend on SLS, right? So that kind of thinking, you know, we want to attract investment, and I think that half a billion dollars probably represented a quarter of what the development of those launch vehicles cost. So, if you can shape a program that attracts and doesn't drive them away with excessive requirements and excessive government involvement and that sort of thing, that's the path to success for space infrastructure. And the policy folks need to understand what happened with COTS. They need to understand what's happening. The CLPS, the commercial lunar payload services program, propose programs like that to attract private capital and don't drive it away.

**Researcher:** [00:12:00] Oh, that's a great point. One thing that kind of runs through this is, you know, letting NASA's see programs like that with government investment and then trying to leverage concepts like COTS to privatize some of the services of the routine services even out to the Moon, even the all the logistics supply to the Gateway, right? And things like that.

**Expert 2:** [00:12:28] Well, absolutely right. And there are there are people in NASA that hated COTS because they didn't have the kind of control that they wanted to have. And so, public-private partnerships have that aspect. They bring in more capital, but the government has less control over the final product. And you just have to decide what you want. You know? That's a policy item right there is like, OK, what are the downsides of public-private partnerships? How do we create policies that encourage them but don't create too much risk for the government?

**Researcher:** [00:13:17] Are you seeing any, I don't know how much you're involved in the commercial regulation business, but any changes from Biden where he's going with all this, he's

got his interim policy that he put out and it said something like he's going to clarify a lot of these commercial space regulations, definitely for on-orbit servicing and manufacturing but basically anything that's going on in commercial space. It wasn't as freewheeling a regulatory environment, it's more of a let's pause and look at that for clarity.

**Expert 2:** [00:13:54] The one area that I pay attention to that kind of regulatory stuff is the in-space servicing so that the Outer Space Treaty is inadequate to say what government should do about one satellite coming close to another in order to provide it services. One could say that you don't need any regulation as long as the parties' consent to doing it then what's the deal? But then you think about, well, what if there's damage? What if the damage creates more debris or damages a third party? There are issues that ought to be dealt with there now. DARPA created a consortium, let's see where this would go in your…Well, yeah, promote commercial space. There's a consortium called Consortium for Execution of Rendezvous and Servicing Operations (CONFERES), have you heard about this?

**Researcher:** [00:14:59] I have. Yeah.

**Expert 2:** [00:14:59] It's okay. Yeah. So that has brought government entities together with commercial entities, and they're trying to sort out what makes sense in the specific area about servicing and that sort of thing. It's very capably run. It's does an annual servicing forum that's global. There's international participation.

**Researcher:** [00:16:02] But let me ask you, because this kind of segues into the previous discussion? Two things I want to chat before we end, do you think the U.S. is aggressive enough in establishing space infrastructure, and you could take that in two different ways. One could be aggressive enough in funding and aggressive enough in establishing dates. You know, Trump had some real hard dates out there, right, like 2024 or 2028. Biden has put forth any dates yet.

How important are dates to any of this? And then, you know, at least in my analysis, the Trump policy used words that some would find provocative, but they were what you probably would expect in a domain that is in need of expansion. So, you have words of strengthened expanding, you know. You know that forward leaning leadership kind of stuff. I think the point of the question is, do you think the U.S. is aggressive enough in their policy? Obviously, this is all related to taking China serious in this space infrastructure threat. I guess if you don't take them seriously, then you don't have to be aggressive so maybe that's the fundamental issue to the policy discussion. What are your thoughts on this?

**Expert 2:** [00:17:56] So one of the figures that was instrumental in creating this interagency working group on servicing and assembly and manufacturing space is Dr. Bhavia Lal, who is now the associate administrator for the Technology and Policy and Strategy

**Researcher:** [00:18:18] I know Bhavia.

**Expert 2:** [00:18:21] Bhavya gives a talk on how important our space activities are vis a vis the China competition. She'll even talk specifically about Artemis. Why is Artemis most important vis-a-vis the competition? She explained that very well. And so, the creation of this interagency working group, I would have thought that was years in the future that they hadn't gotten their heads around this, but I think that that it's a very positive step. There's always a lot of arm wrestling and competing interests and that sort of thing in an IWG. So, they're not. I don't think, quite ready to finish it up yet, but between Bhavia and the deputy administrator of NASA, Pam Melroy. The question is, given the new policy and technical initiatives that the Biden administration is pursuing, like this idea and like further research and on-orbit operations, and that sort of thing. Hmm, what implementation is going to emerge? So, I think we're being aggressive enough on the policy side. The question is when it gets down to the arm-wrestling

stage of resources and that sort of thing, what's actually going to come out of it? Did that answer the question?

**Researcher:** [00:20:42] I did. I think that's why I put the budget stuff in here. It's just so intertwined, right? You can be aggressive in your policy but if you don't back it up with the requests for the budget then it's a slippery slope. Budgets are dependent on dates because dates will drive budgets.

**Expert 2:** [00:20:59] And I'm a firm believer that establishing the dates is essential to get people off the dime, you know, because NASA was just poking along and didn't really have a program and that sort of thing. And all of a sudden, they've got marching orders. And unfortunately, I mean, one of the big problems, of course, is getting the Congress in sync with the administration. And that's a... I don't know whether you want to call it a policy issue or not, but if the Congress didn't support the 2024 date, then there was never the budget to make that happen. And you know, NASA has a problem because they work for the administration, but they get their money from the Congress and that synchronization was not there. I mean, for a variety of reasons. But I don't think that, you know, the current administration beyond the NASA people that I've mentioned is perhaps being aggressive enough, just as they have a lot of things going on well, if we go back to Rumsfeld, right, so he wrote this report, he chaired the commission, there was report, you gave a press conference after it became Secretary of Defense and he held the report in one hand and says I was the chairman of the commission that did this report on national security space. And then he passed the book into his other hand, and he says as the secretary of Defense, I will now implement this report. It was a very funny moment a few months before 911, then 911 happened and suddenly all the emphasis on space asset vulnerability went away because they were all about terrorism, so that allowed our adversaries years to catch up and develop assets and

all those sorts of things. Today, obviously, things like the Ukraine conflict and even the pandemic and some other things once again seem to be distracting the administration from the importance of space. And therefore, the messaging isn't as crisp and clear as it was in the Trump administration, I mean, 2024 didn't get much crisper than that.

**Researcher:** [00:23:50] Just so you know, in doing this document analysis, the 2024 initial and the 2028 sustained presence were peppered in Trump National Security Policy, National Space Policy and the NASA budgets. In the Biden, at least the initial Biden policies, there is no dates anymore, right? None, definitely not in the national security and space policy framework. And even in the first budget request he put in, all the dates are gone. There's a lot of reasons for that. Well, I mean, how important is it to get them back, I think is the big question.

**Expert 2:** [00:24:33] Space was an entire sentence in the Trump inaugural address. And of course, there was no such sentence in the Biden inaugural address so there's an overarching message there. The Vice President is over negotiating with the Russians, or not directly but working with the Europeans, and has to worry about the border crossings and so I think that, you know, whether or not the policies, you know, I read this space policy framework? It's got good stuff in it, but I think the next level down for this administration doesn't exist yet. As far as I can tell.

**Researcher:** [00:25:36] So great segue, so what would you recommend to this administration in the next level of their policy, with an eye towards competing with China to establish these space infrastructures?

**Expert 2:** [00:25:57] Right, so the number one recommendation. well one of them, is do whatever they have to do to get Artemis back on track. And I think really that means a shift to commercial launch vehicles, I mean, the NASA IG has just said you can't afford the Artemis

Program. I mean, you can't afford the SLS part of it. So, figure out a way to do it with commercial launch vehicles would be recommendation number one. And recommendation number two is the public-private partnership to create an in-space logistics infrastructure because that will be the foundation. Also, that makes a sustained presence, that makes permanently occupied habitat on the Moon feasible because without logistic support, you know, we're not going to be growing stuff on the Moon to eat anytime soon. That's hard, stuff is still going to have to come from the Earth. If you create the logistics infrastructure, so many other people can also use it. Right. The commercial space stations and the assembly of a huge telescope for, you know, that's the successor to James Webb and all this.

**Researcher:** [00:27:23] Other nations have to use this stuff too, right? You know, in an ideal world, right?

**Expert 2:** [00:27:30] Yeah, exactly. Like I said, I mean, if only China created infrastructure, there are probably some U.S. companies that want to use that, but an in-space logistics infrastructure is also a tool for creating international partnerships. Now we're going to get down in the weeds a little bit, but I'll just give you one example. Today, if Malawi wanted to launch a, you know, some kind of an Earth resources satellite or something like that, they'd have to build or buy an entire spacecraft. What if instead, they only had to build the payload, the sensor, and then somebody could take that and hang it on a platform somewhere in space. And provide it the power and the communications and the station keeping and all that kind of stuff. So it reduces the cost up to that new developing nation of getting things into space, so it helps them establish a space program and it creates this partnership, you know, to do that you need the pieces of infrastructure, you need a transfer vehicle or space, tug, if you will, to get the module out to the platform and you need the platform itself and you need fuel depots to make this all work. You've

got to get a lot of gas up there and the third thing is we need to maximize the use of low-cost transportation in space. And everything we do is for commercial and our civil so commercial is going to do it, but in both our civil and our national security.

**Expert 2:** [00:29:18] Planning and investments, we need to maximize the use of low-cost transportation, obviously, specifically think about Starship here, but I think that New Glenn and Vulcan will also have some opportunities for lower delivery costs to orbit. And if the infrastructure connects to these low-cost launch vehicles, it maximizes their value. The example that I always use is the container ships big container ships like the one that got stuck on the Suez. Those are extremely efficient and get moving things across oceans from port to port. But all those goods are not destined for that port. They're going to go hundreds or thousands of miles away from that port on trucks and trains. The trucks and trains maximize the value of the container ship, so you move a bunch of stuff cheaply 90 percent of the way, then the last 10 percent is done by these other vehicles. We need to think that way in space. So, if Starship delivers one hundred tons to LEO that there are things that can take those payloads and take them to their final orbits, whether they're free flying satellites or payloads that are going to be connected onto a persistent platform that's going to provide them the hosting. So those kind of things about maximizing investments and creating policies that maximize the value of low-cost transportation to orbit and to the Moon are needed. Right, because once again, the NASA IG has said you can't base a program on something as expensive. It's just not going to work.

**Researcher:** [00:31:10] Maybe one last question, but certainly open to other thoughts here, but who is the architect of this in-space logistics infrastructure policy? There's a difference between the programs and the policy. But who do you think? Who do you think is this architect for the President that should be thinking through this? Just exactly like you kind of laid it out.

**Expert 2:** [00:31:37] They have the talent there now, in conjunction with the National Space Council. I mean, Parikh is going to is thinking about these matters and has attracted the talent at OSTP, so they, you know, architecting the policy can be done by those two organizations working together as they are. They are definitely doing that.

**Researcher:** [00:32:06] Yeah, I'd love to see policy come out that uses really those three or four words in space logistics.

**Expert 2:** [00:32:20] I actually think that's imminent? Yeah, that's good. Yeah, it's not. It's not advertised. I mean, you know, IWG don't have websites and, you know, put out flyers and that sort of thing. But I actually think that policy is imminent.

**Researcher:** [00:32:37] Yeah. I think if they can get that into some future space policy with this administration or the next, it closes that gap that we talked about at the very beginning of the infrastructure discussion with SpaceX. And then there's a reason why you want it done in a certain time frame, the competition piece, it kind of closes that those gaps.

**Expert 2:** [00:33:01] Are you able to interview government people for this, your paper for you?

**Researcher:** [00:33:07] It's an academic paper, so sure.

**Expert 2:** [00:33:12] Would you like to talk to Bhavya?

**Researcher:** [00:33:15] I know Bhavia. Not sure she's going to have time to do this?

**Researcher:** [00:34:09] I think we just need some policy, right? The Space Force is going to have some piece-parts of this.

**Expert 2:** [00:34:15] Well, I mean, the Space Force is actually being more aggressive about refueling than NASA, they have determined. Are you familiar with the Space Power Capstone document?

**Researcher:** [00:34:36] Yes.

**Expert 2:** [00:34:39] So they have the five core competencies in there. And one of them is space, mobility, and logistics. So, it's not a question of where, I mean, they've said this is a core competency we must be able to master. And the current driver is refueling, but they know that, you know, modernization and technology upgrade are critical for their staying ahead of the adversary.

**Researcher:** [00:35:08] That was my thought that they were going to establish some sort of space domain awareness presence in the cislunar space. And I'm talking beyond LEO kind of presence with assets. I think in their mind, where their mind is going, is some sort of in-space logistics infrastructure to service those assets.

**Expert 2:** [00:35:28] It is, and they are at the working level. They're pursuing this vigorously. The four stars have already bought into it. They say we have to be able to do this, hence it's in the capstone document. And now the lower levels are figuring it out. What are the approaches? I mean, they're looking at, you know, standard interfaces for refueling and they want to leverage commercial, they really don't want to build their own infrastructure. NASA has some needs for logistics, but, really, if you could create this, this infrastructure, you unlock so much value. You know, you enable new businesses that we haven't even thought of yet.

**Researcher:** [00:36:29] So I'm sensitive of your time.

**Expert 2:** [00:36:34] Hold on one second.

**Researcher:** [00:36:50] And I'll let you get back to the business of business. Any last thoughts on any of this? Again, kind of the two central questions that I'm poking at right now is the sufficiency of the current policy, current meaning U.S. policy as an embodiment of both Trump

and Biden policies, and then recommendations for the future, whether it's Biden's next double down or the next administration, where are we going on this?

**Expert 2:** [00:37:21] I'd like to do is look over the policy themes again and send you an email on those further out thoughts because you want to talk out to 2049, the Chinese goal and we've really talked very near-term stuff here. So, I'll do that and then maybe if you want, we can talk some more later.

**Researcher:** [00:37:47] That'd be great.

**Expert 2:** [00:38:44] So, there's this independent think group piece called the smart think tank. As organized by a guy at JPL, like 40 folks, we're sitting here thinking about. So SMART stands for servicing, manufacturing, assembly, robotics and transport in space, it came up with a bunch of recommendations right around the time Bhavya and Pam Melroy were both on the think tank and got pulled into the transition team. But they heard all the conclusions and that sort of thing.

**Expert 2:** [00:39:36] Well, they briefed a lot of folks. I mean, they briefed a bunch at NASA, and they briefed the DoD Defense Innovation Unit (DIU) Director. He was very supportive instantly, and I know OSTP is as well.

**Researcher:** [00:40:03] Right? And that was my thought was I saw that I know the contents of it. It's very related and relevant to this. And then but then I see the Biden stuff come out and I'm like, well OK, now where's the meat? Where's the beef?

**Expert 2:** [00:40:17] There's some of it behind the scenes that I didn't see, so anyway, I've got to run, but it's been a real pleasure.

**Researcher:** [00:40:30] Yeah, we'll do. Please let me know when you're in town.

**Expert 2:** [00:40:35] Yeah, thanks.

**Researcher:** [00:40:37] Ok, bye. Thank you.

## Appendix D

Expert 3 Transcript

Interview 16 March 2022

**Researcher:** [00:00:00] So, like I said, I'll just kind of start it off with the big picture. Looking through these documents, I came up with four themes. The first theme was just infrastructure competition at large. But to be honest, what I found was when things like national security talk about infrastructure competition, they tend to gravitate to a terrestrial geopolitical discussion and not a space infrastructure discussion. So do you have any thoughts on how to connect or maybe how to get this point driven home, that maybe it should be connected a little bit. If China doesn't discriminate between Earth and space infrastructure development, maybe the U.S. shouldn't discriminate too much either.

**Expert 3:** [00:01:05] But yeah, hey more of a question. Do we do we still have a National Space Council under Biden or not?

**Researcher:** [00:01:15] Yeah. Yeah, I think they've met once formally with Harris sitting in the seat, I think.

**Expert 3:** [00:01:23] Yeah that's right. That's right. Vice President is chair of that. Yeah, so I would think a lot of this discussion would occur in that forum. Especially because, as you correctly inferred, I think we're in trouble if NASA with its exploration mentality is charged to do all of this. Now, admittedly, in today's environment, NASA will turn more and more to industry, which seems to be a definite thrust probably within the last five years, more than I've ever seen before, as witnessed by the commercial cargo and commercial crew and now the… I don't know if you're aware of the Commercial LEO Destinations (CLD) Program, but it is the third element of that triad. And that's what comes after space station gets mothballed in 2030. So,

NASA has led a couple of awards, actually three; one to a Nanoracks Voyager team, one to Northrop Grumman and one to Blue Origin. And each of them has a new space station concept. It's a commercially led, commercially financed with NASA's help, much like commercial cargo and crew was. So, for example, the Nanoracks Voyager team just won a $160 Million award to take it from a blank sheet of paper to Critical Design Review (CDR). And Lockheed is the vehicle provider. You can go on the Web and look at CLD and you'll be able to see those three. So those three elements may become part of this infrastructure by hook or crook and probably luckily the commercial thrust will help in some manner.

**Researcher:** [00:03:38] So I had one input provided to me that said if they were architecting what NASA has architected for SLS and Gateway and that vision of getting out there, and Orion and down to the surface, if they were architecting it with the eye towards it being commercialized and openly provided as a service, a commercial global service not just back to NASA as sole customer but open to Europeans and other space entities. Other commercials or China would be a better or more economical choice to get you to the Moon. Any thoughts on how the current architecture of this will either help or not help that vision of commercializing this Earth-Moon architecture where it could be used as a pay-as-you go thing, whether you're going to a hotel on the Moon, or you just want to bring dirt back from the Moon.

**Expert 3:** [00:04:56] Well, again, I think much to the chagrin of the old timers, NASA has pivoted in that direction, I think as evidenced by the CLPS Program, where you basically engage a commercial service to get your payload down on the on the surface. So, I mean, that's kind of a big step for NASA, right? And I don't know how much Gateway helps here, that remains to be seen. I think Gateway strikes me as more on the explorer side than on the providing infrastructure side, but NASA will get bored with it pretty quickly, so it might end up in some

way or another becoming part of the Earth-Moon infrastructure and maybe, you know, not least, but given to commercial entities to operate because I think once they put the Gateway in place, then everybody's going to start to get the Moon-Mars itch. And in order to get to Mars, you've got to devote some serious cash to some of these vehicles and whatnot. And that's the problem NASA has, is the cost of salary and benefits and the buying power is just really eroding, although they have gotten a pretty healthy chunk of money of late, but that's been the problem.

**Researcher:** [00:06:40] So when I talked about infrastructures to another person, what their comment back was similar, but they said, you know, NASA has these when you say infrastructure to an asset person, they gravitate to the comm systems around the world, the crawler, the Vertical Assembly Building (VAB) down the Cape. You know that person's thought was the cost of maintaining that infrastructure eats into building new infrastructures.

**Expert 3:** [00:07:21] Oh yeah.

**Researcher:** [00:07:22] So a little bit a different take on that. Not only salaries of people, but the cost of keeping that stuff up that.

**Expert 3:** [00:07:29] Yeah.

**Researcher:** [00:07:30] Maybe it could be done differently. Unfortunately, you've got this legacy cost.

**Expert 3:** [00:07:42] Yeah. No, it's a real thing. I mean, just keeping the ten centers healthy is a tremendous drain on the system, much less the Gateway and all that stuff. When NASA thinks of infrastructure, my sense is that they think of it on a roadmap to a mission execution. So, Gateway is to allow, when it's crewed, to allow operations between the, you know, the crazy orbit that it's in and the surface. Maybe they say it's a waypoint on an architecture to get from here to there,

but I don't think they have the cash to create that type of Gateway. I mean, if you look very closely, they don't have a, in the first instantiation, they don't have a crew or a human airlock.

**Researcher:** [00:09:22] Like an airlock kind of thing?

**Expert 3:** [00:09:26] Kind of an airlock. Yeah. And so, you know, so they're cobbling this thing together as they go, as they can afford it. And so, I think they may be thinking like a Nanoracks airlock for small things and then eventually some kind of a crew interface. But they're not thinking about this as a in any sense, a waypoint or a fueling depot or anything like a depot for a Mars sprint. But they are at least thinking about it in terms of tele operations with the surface and interaction, and with the astronauts at the surface. So, it's kind of a…it's a compromise. So, if they have to make a compromise on their prime mission, which is exploration, you know, it kind of reminds me of Code U, which was the U for utilization, and it was basically the outfit downtown that ran the space station and the biological and physical research on the station and everything. And it used to be a joke that Code U would come to the table and say, we have this payload that we want to put on station to do plant growth studies or whatever. And the head of the operations side of the house, basically had the keys to the kingdom. And he regulated how much utilization got up because you need food, you need things like a new toilet.

**Expert 3:** [00:11:25] High demands for up mass on these utilization flights so engaging Code U never got any traction at all because it was always the lowest on the priorities. So what I'm trying to paint a picture that if NASA were to sign up for this, for implanting this infrastructure, whatever it would be in the call it Earth-Moon area, cislunar, you know, there would have to be very powerful people in charge of it because the tension between that utilization element and the research element would be unbelievable. And NASA, it's kind of funny…originally, I thought it was an engineering outfit with a little bit of science here in there. But now where I am and what I

do, I see it's a science organization with a little engineering flavor. And so, it just depends on what center you operate out of. Goddard is the Science Center, Jet Propulsion Lab (JPL) is a Science Center, Johnson Space Center (JSC) not so much. So, you know how you're going to not only architect the infrastructure itself, but how you're going to architect the NASA people infrastructure to do that successfully, it's not obvious. Space Force at least I get the sense they are on a mission. They're moving but they have no money yet, but they're going. And NASA's like, hey, wait a minute we have this Mars sample return thing that's going to suck every dollar for the next five years now that we've launched James Webb. So, what are you talking about infrastructure? Where is the money for that? Not clear.

**Researcher:** [00:13:21] My analogy, is this is like Lewis and Clark building a raft. The purpose is to get Lewis and Clark down the river, and they're going to design the raft to get Lewis and Clark down the river. The infrastructure is the raft and if you said, well, you should be designing that to get future people down the river faster and cheaper, they'd be like, that's not our job, it's to get Lewis and Clark down the river. So, it begs the question of who, who, who. If the race is on to build a future raft to haul people up and down the river, do you leave it to the Lewis and Clark people, or do you have OSTP or somebody else step in there and say, we're just not going to do it like that anymore? Because we again, we have an economic race going on, not an exploration race like the space race and the Cold War, an economic race. I'm struggling to find the right policy folks, because my opinion is if you ask OSTP, they're going to call NASA and say, come up here and help me craft some policy. We know what the policy is going to be. So, I'm finding it's not necessarily what's written as the issue, it's what's not written.

**Expert 3:** [00:14:40] Yeah, it.

**Researcher:** [00:14:40] Seems to have an issue here.

**Expert 3:** [00:14:43] And it does matter at some level. You know, I'm watching the tug of war with Air Force handing off the civil space aspects of space domain awareness to either Commerce or NOAA or whoever. And, you know, all they have is this little SPD-3 or something that they hang their hat on. And there's nothing between that and getting it going. So, nothing's happening.

**Researcher:** [00:15:17] That's a good point on a similar thought and that is you got some high-level stuff policy, but you peel that back and there's not necessarily the policy below that to enable things to happen.

**Expert 3:** [00:15:34] Right. Let's put it this way. It's so fuzzy that everybody's jockeying for position and nothing gets done. So, you got that problem. And I don't know how that's going to play out. It's still not obvious. So, yeah, you know, I find myself wondering if, let's say there was an SPD, something or other that wanted to lay in this infrastructure on the timeline that you're talking about. Would NASA raise their hand to do it? I don't know. Not obvious. And if they got assigned to do it. Um. I find myself wondering what Centers would be assigned to that.

**Researcher:** [00:16:25] And now you're back to the commercial equation of getting that community energized. And you got to seed it. Right. I understand that.

**Expert 3:** [00:16:39] Yeah.

**Researcher:** [00:16:40] My fear is use SLS as an example. If the future architecture is to shuttle tourists back and forth between the Moon, to stay at the Hilton on the Moon. If China was going to do that, they're not going to build an SLS. But if you asked Elon Musk what his answer is, it might be something different.

**Expert 3:** [00:17:03] I mean, it is. What's his name? Branson thinks it's something else. And Blue Origin's one thing. It was kind of interesting when this CLD thing came out initially all three of the commercial competition had their artist's conception of their vehicle. And if you look at the three of them, you very quickly see that the Lockheed one and the Nanoracks Voyager one are very, what I would call classical glue…an inflatable module to a steel module, throw a couple of solar arrays on it and a couple of external attach points and an airlock and call it a day. If you look at the Blue Origin's one, it looks like something out of 2001 A Space Odyssey. It's inviting. It's classy looking, short sleeve environment, you know, nothing out of place, no wires all over the place. It looks like something you want to go to. And so, they at least think about it as this has to be a desirable thing, whereas the other two could care less, you know. So, it's yeah, commercial has to be, I don't think the word partner is appropriate, I think it's more than partner, I think they have to be the dominant player in it. And the government's just going to have to get out of the way and let them do it. And I find myself wondering if NASA's the right outfit to do it or not. I don't know.

**Researcher:** [00:19:35] So to get us out of this. You think the policies should be a little bit more? I mean, there's no question Trump's policy was very.

**Expert 3:** [00:19:47] Yeah. Going to the.

**Researcher:** [00:19:48] Moon. Here's the date.

**Expert 3:** [00:19:50] Yeah. Yeah.

**Researcher:** [00:19:51] Do or die. Yada, yada, yada. Biden's right now is not. But it's going off the initial set, so I don't know where that's going to go. But I'm wondering what's the flavor of the policy that we're going to need if you, again, buy into this competition set up by China. If

we're going to need to be a technocrat at the highest level to make this happen, or we just empower NASA and say, here you go, just go beat them.

**Expert 3:** [00:20:26] I don't I think the space race kind of model is the one, that only gets you so far with NASA. I think it works better with the DoD agencies. From my experience with NASA, the policy has to make sense and be well thought out. Incremental in nature because of the funding streams available. But you have a, you know, it has to be complete, and everybody has to see where it's going and by when it has to go. So, I'll tell you an experience I had early on back in the 2000, just after the Bush vision for Space Exploration, we got the nod at headquarters to put together an architecture team to achieve that vision. And we did something very simple at the time, we took a Visio program and we just illustrated graphically, starting from where we were today in 2002 or whenever it was, what it would take to get there given the confines of the NASA budget and inflationary growth, only what it would take to implant the infrastructure to get to Mars. And what you saw on the wall in a sort of a logic net fashion was each year you needed $1B to get these things.

**Expert 3:** [00:22:20] You got the landers, the aero accelerators, the crew modules, the nuclear thermal propulsion, the, you know, the whole infrastructure. And we just laid it out and we laid it out with budget in mind and real-world development times. And we blew out of 2030 so fast that we just all threw up our hands and said, we can't get there from here. And we all went home. And to this day, it's still the case. The team downtown, the White House, they still talk about Mars in 2030 but that is patently absurd when you look at what you have to do between now and then to get there from here. So, it has to be well thought out and it can't just be a toothless vision. You have to really lay in some experience with real money available and the interfaces and interconnections. It's a giant project. And you've got to show all the interdependencies, all the

long lead parts. I mean, it has to be well thought out in that sense. A real architecture team needs to do it.

**Researcher:** [00:23:42] When you did that, and I'm curious and poking around at this prioritization because you can't build everything and maybe you don't need to, right, at least initially. But there are certain things that take priority as far as an infrastructure. Com always pops up as a number one thing, right. Not much has changed since that vision because now you just got vision two going on and everybody's kind of scrambling to figure out what are these infrastructures that you need to enable all that. When you did that, were there any what I would call, enabling infrastructures that kind of popped out as the to make this whole thing work? This one is like number one; it's just got to happen. The number two is kind of got to be this.

**Expert 3:** [00:24:30] Well, the big bugaboo back then and it's still the case to this day is the space radiation effects on the human. So, in that time frame, we had to get the humans back and forth quickly. And that precipitated out the new nuclear rocket. And you very quickly put pen to paper and come up with a cost estimate for that and it's absolutely mind blowing. So, it was the space radiation affects that dominated everything back then. Not so much solar, but more the galactic cosmic rays. Because by the time the astronaut took the 6-to-8-month journey out and spend some time on the surface and came back, every strand of DNA was damaged with some kind of particle effects. So, you know, getting the human back and forth in a healthy manner was just not achievable at that point. So that was kind of the uber problem. And we were doing everything to try to skirt around it, like burn fast, get there quickly, put them underground, get it back quickly. That was the whole raison d'etre for that architecture, for this architecture that you're talking about, it’s really more like a public works, it's like the metro. You've got to put in the Washington Metro, but you've got to leave open the possibility they're going to have a silver

line eventually and you're going to have a whatever color line that you need to add on to it to make.

**Researcher:** [00:26:18] It just the landing on the Moon or the landing on Mars. It's in this case, it's the sustained presence would be the operative word. And what do you need for a sustained presence, by the way? There's a definition to a sustained presence. Somebody said, well, the asset might be to sustain presence. Somebody operates the facility on the lunar surface for two months and then they leave it in mothball for five months and then they come back and turn it back on for two months. Is that sustained presence?

**Expert 3:** [00:26:50] That's the Gateway model. Yeah. When you look at the Gateway, it's very sparsely populated with crew. Surprisingly so. Yeah. That's not going to cut it. So, the problem is the Gateway and what comes after it, the depot. And I mean, very quickly, you're going to have to make an architectural decision, unlike where we are today. You know, there's the commercial rocket assembly in space and depoting. Right. That's one architecture.

**Researcher:** [00:27:37] And I've heard that one is a big priority.

**Expert 3:** [00:27:40] Yeah. Yeah. Or the other alternative is Griffin's giant rocket, the SLS. And you take everything up and initial operating configurations good enough. So CLD, the new project actually is somewhere in between. We'll probably go up with commercial, will go up with an initial operating configuration that's very modest but right off the dime the architecture is going to have growth paths, airlocks, ability for other modules and sort of like the more like the space station assembly version.

**Researcher:** [00:28:31] Hypothetical question for you on that CLD is if you were doing it now for obviously a NASA mission purpose versus a putting it up as a public works utility that it's operated the whole thing every piece part of it is operated by various commercial entities and it's

open to anybody to use, U.S. governments, international agencies, etc., would you architect it differently?

**Expert 3:** [00:29:04] Just the way they are architecting it for the latter. So, it's a commercially owned, commercially operated available for sovereign astronauts from wherever they want to come. NASA is just a user. They have no territorial oversight or anything. NASA's there to help the commercial entity in an advisory role. But there's no Johnson Space Center or any of that. It's basically a Lockheed station with University Space Research Associates (USRA) managing the science operations in what we call Science Park on the vehicle. And, you know, the Nanoracks Voyager team will basically look to close the business model, they have to entertain international users from wherever they come. So that's the model they're using.

**Researcher:** [00:30:12] What's the challenges of getting NASA to kind of adopt that model for this whole Earth-Moon future economic zone as opposed to the getting the next human to put the flag again.

**Expert 3:** [00:30:30] Yeah, yeah, yeah. So, it's very much a build as you go. But the money is going to come from someone else, not NASA.

**Researcher:** [00:30:47] That's where they just… It's more that model of COTs. Yeah, crew cargo. Okay. Yeah.

**Expert 3:** [00:30:58] Yeah. So that.

**Researcher:** [00:31:02] So why not? Why didn't NASA adopt this kind of, say, CLD/COTS model for the whole Moon thing. The whole show, right? The Gateway, the Artemis Station? CLPS I get that, I really understand that one quite well, but I don't understand why they didn't take parts in CLPS and CLD just say let's apply it to the rocket, the crew vehicle, the station, the rovers, everything, the whole enchilada.

**Expert 3:** [00:31:41] So I don't have the answer. But one of the things I observed is, I'll call it the old guard. And I don't mean old in age sense, but, you know, the previous Office of Safety and Mission Assurance (OSMA) Director who was an astronaut, the NASA Director at the time, and his whole approach is to have a government solution and a commercial solution. So, the SLS is part of the government solution, but that's not sustainable. It's just not sustainable. It's smart, but it's not sustainable. You've got to break that mold because you don't have enough cash under the under the curve. The sand chart doesn't work here. Or let's put it this way. You'd be hard pressed to get anything by 2049 given the current, you've got to give up some things or do some things very differently. This crowd, and Phil McAlister, is really the I think, the bright light in this and is pivoting to commercial. Do you know him? No, no, no. If you ever wanted to talk to somebody about the questions you're asking me, I would refer you to Phil McAlister. He is in the Human Exploration and Operations Directorate, which they've changed the name. I don't know if you picked up on that yet, but they've gone back to the old name.

**Researcher:** [00:33:44] A few subtleties I noticed between the budgets. They also went from exploration technologies to space technologies. I caught that.

**Expert 3:** [00:33:52] One. Yeah. And then they bought Jim Freed back, he was previously a center director at Glenn. He's now in charge of building the equipment in this Moon-Mars caper. So, you've got Cathy Lures, Phil McAlister doing the operations, which includes Space Station, and you got Jim Freed who's doing the nuclear thermal rocket or whatever it's going to take to get there from here. So, but I think the one person that I would heartily recommend you talk to is Phil.

**Researcher:** [00:34:44] Thank you. I see the nuclear, I get it for Mars, that for the propulsion, as well as nuclear on the Moon and for the Moon stuff. How prominent do you think this all plays? Not only propulsion, but power?

**Expert 3:** [00:35:05] Well, power has to come first because surviving the lunar night. Doing anything at all seriously on the Moon is going to require a lot more power than they can generate with photovoltaics. So small modular reactors on the Moon, fission surface power is the NASA program. That's going to be first out, the nuclear thermal rocket, if you've been watching the budgets, it's in…it's out, but it's at least now talked about all the time. Whereas 10-15 years ago, when we were doing that Bush thing, it was an issue. They had made a stab at it with this Prometheus project back in the early 2000's and spent a lot of money and then came up with…they couldn't decide is it nuclear electric or nuclear thermal? Spent a lot of money doing trade studies and then it was abruptly canceled. So, like many NASA efforts and DoD efforts. This time around, I think everybody realizes we've got to have fission surface power quickly to do anything and you've got to at least lay the pipe for a nuclear thermal or nuclear electric. And so, NASA has contracts out for both right now. There are large study contracts with industry, PWXT in Southern Virginia, having the nuclear thermal and one of the nuclear thermal propulsion contracts, I think General Atomics has one and there may be one other. And NASA Glenn is doing the fission surface power. And people like PWXT and others are working on that, too. So, I have a feeling that's going to spring forth out of the noise.

**Researcher:** [00:37:11] And OSTP has got a working group and going on all this, and they've got the DOD as a part of it.

**Expert 3:** [00:38:59] So I didn't know there was a working group, but I did. I am somewhat aware of the Demonstration Rocket for Agile Cislunar Operations (DRACO) Project at DARPA.

**Researcher:** [00:39:16] So we're supposed to be a roadmap that they were this working group was putting together. So, you might want to ask. I have not seen the roadmap, but.

**Expert 3:** [00:39:25] Well, maybe OSTP will be up at the space symposium in a few weeks, and I can hunt them down and talk about it.

**Researcher:** [00:39:33] Yeah, I have to imagine NASA's got a roadmap, and I have to assume OSTP just adopted that roadmap.

**Expert 3:** [00:39:40] Yeah.

**Researcher:** [00:39:41] The other one is DRACO. What else could be on that?

**Expert 3:** [00:39:46] Yeah, I've seen the NASA, the Space Technology Mission Directorate Roadmap, and it does have DRACO on it, but it's a one. It's a very sparsely populated thing, but at least they have that. So yeah, that's good news.

**Researcher:** [00:40:02] Yeah. See if I got any other kind of big thoughts on this. You know, our discussion weaved the NASA's human exploration, architecture and culture in thinking of the big government systems with this ability to have this infrastructure up there for public use or private and public use. And this intersection of commercial kind of in the hub as enabling. And I'm just trying to figure out what kind of policy might exist someday and make that happen because I don't think it's NASA policy because NASA's not going to tell themselves to do it unless there's a change agent that comes in and takes it in that direction. And I don't know if there's a change agent there right now.

**Expert 3:** [00:40:58] Yeah, but the thing I mean, you know as well as I do, the thing that turns industry on is the ability to make money in doing this so.

**Researcher:** [00:41:13] It was a chicken and the egg thing here.

**Expert 3:** [00:41:15] Yeah. Yeah. So, it's not just the architecture as we would think of it. It's also the business model or the business plan. And, you know, industries got to see where they cash in.

**Researcher:** [00:41:31] Yeah, NASA's got to be an anchor tenant. It's got to be more right.

**Expert 3:** [00:41:36] Even if it's not, it's not 50-50. It's 20-80. I mean, industry has to be the dominant partner in this thing. Yeah. And let NASA play exploration.

**Researcher:** [00:42:01] So I'm toying with this a lot, and I don't know how to fix this with policy. Maybe it's a fix with budget, but Elon wants to do something, watch something. Goes around the back side of the Moon or doing something. He needs a relay system. He's not going to build it. He could build his own satellite as; I'll do it for myself and then I'll sell it to others later. But for the first initial case, he might just go to the Chinese and say, you got a relay satellite on the other side of the Moon, can I just buy some time? I don't know if that's great for the U.S. to get into that mode of operation buying those services from China. China for relay time on the far side because it's a slippery slope. What else are you going to buy from China when they start building their infrastructure so they would be building their customer base? I don't know what policy would shift that model.

**Expert 3:** [00:43:10] Yeah, I have a hard time imagining, given what's happening in the world, that China we would buy services that potentially have impact on human life or high value assets from the Chinese.

**Researcher:** [00:43:28] But what's to stop Elon from contracting with?

**Expert 3:** [00:43:34] And again, that.

**Researcher:** [00:43:35] Is commercial company.

**Expert 3:** [00:43:36] Yeah, that gets back to your policy directive. In some sense, what I was going to say and what is different today is that laser communications have now been used, at least by NASA and maybe others in space, on two occasions and it's been very successful. So, I think that technology is ready to be commercialized and utilized in a communications relay architecture. And I would dare say that industry is ready to do it. So, NASA doesn't have to do it anymore. And I think from an architecture technology point of view, I think laying in a communications relay system with maybe a wide-band link with laser and a backup x-band or whatever might be the way to go. And again, I think at this point, NASA or whoever the architect is of this infrastructure can actually write down requirements and industry can go off and build it. And it could be a strap on module to an existing comm satellite or it could be a new age satellite with a prime and a backup or whatever. But I think the communications architecture is now favorably disposed to using optical communications.

**Researcher:** [00:45:32] Let's put it that way. I'm conscientious of the time, so I'll let you go here in a minute. But I have one other question, and it's along this line. I've heard negative things about NASA in this regard, so I'd like to pose this to you.

**Expert 3:** [00:45:48] Excuse me. I'm good to 1030.

**Researcher:** [00:45:51] NASA builds or NASA seeds the laser com, whatever infrastructure turns it over to the contractor that built it and says, go commercialize it, privatize it, whatever. We'll be your customer. But feel free to sell it to anybody else that wants to come along, China don't care. I have been told that NASA has been reluctant to adopt the commercial company's technical standard. And I'm not picking on communications, it could be anything. So, they had Elon build something, and he's come up with a standard and for some reason, NASA doesn't like

the standard, but Elon came up with the standard and he wants to market that. But I've been told NASA tends to be reluctant in adopting the commercial standard that they themselves put on contract.

**Expert 3:** [00:46:53] So, you know, I don't I don't know.

**Researcher:** [00:50:19] Well, it's a micro issue of the bigger thing we're talking about earlier, where to put this infrastructure in place. NASA's going to have to rely on propping up commercial, but then switching over to become a user and not necessarily doing it themselves kind of thing all the time.

**Expert 3:** [00:50:41] Now, if you're on the NASA's science side of the house, what you just said is an obvious no brainer because they don't want to put their money into building hardware, nuts and bolts. If you're on the SMD or the JSC driven world, that might be a bitter pill to swallow. But it's going to happen, it's going that way, I have no doubt. And if the policy, if they put the policy in place and it's well thought out and it says that thou shalt divest themselves of this and commercialize it, and I think NASA will come along. I really do.

**Researcher:** [00:51:27] You know, I mean, there's traces of this in the LEO stuff, right, with the space station and COTS back and forth. So, there's precedent for changing that way. Of course, it existed first, and we did it. Now we're kind of still building the same time, thinking about commercializing.

**Expert 3:** [00:51:51] But, you know, when you when you look at NASA sometimes has to be kicked in the head. I'll give you an example in that architecture, way back when that we did for Vision for Space Exploration, we could not get NASA to decide between these large inflatable accelerators for bringing equipment down on the surface versus supersonic retro propulsion, which is basically landing and taking off. Elon said the answer will be supersonic retro

propulsion. And that's the way we're going. I'll be damned, but he's landing those boosters routinely now on the Earth after launch. And it's impressive as hell. And it would have taken NASA 20 years to get there from here because they couldn't get out from under the trade space analysis. Elon said, we're going this way so industry can make those kinds of calls. NASA has a hard time; the agency has a hard time doing that.

**Researcher:** [00:52:59] I think that with a big, broad government brush and as an Air Force guy working at Cape Canaveral, if you told me the rocket was coming back, I'd be jumping under the truck. I wouldn't be watching it.

**Expert 3:** [00:53:16] I know it looks surreal when you see it.

**Researcher:** [00:53:20] I'm done recording here, unless you have anything else?

## Appendix E

Expert 4 Transcript

Interview 22 March 2022

**Researcher:** [00:00:11] Okay. So, we're recording.

**Researcher:** [00:00:16] So hopefully you got these themes. So, did you have any thoughts on the first theme or of the four themes? The first one that I came up with going through the documents, was infrastructure competition.

**Researcher:** [00:00:32] They were called out in the policy with some words too big to send you all the quotes. So, this is kind of the summary highlights of all the citations of the policy. Did you have any thoughts on any of this?

**Expert 4:** [00:00:46] Sure. And, you know, first of all I guess I'll say that I think that current U.S. policies is not sufficient to address the strategic goal of making sure that our country has cislunar infrastructure, leadership and development by 2049 in response to China's BRI goals. And so based upon the fact that I don't think the current policy framework is sufficient. I had some thoughts, some ideas here. In some cases, it was pretty consistent. In some cases, there were some gaps I thought maybe could be brought to the discussion for future policy modifications and additions. So, with respect to the infrastructure competition, which was the first one, I do agree that we need to extend the terrestrial infrastructure into the space domain, and it can either be through Biden's B3W addition, to the International Artemis Accords, or there might be other applicable international agreements that are out there as well. Basically, the idea is to, as opposed to going in just looking at space and modifying space policies, is to look at the infrastructure and then extend the infrastructure into the Earth-Moon environment. So that was one item I thought could be supported. The second one. Freedom of movement. Again, the idea

there is to extend the global domain definition to include space and that will ensure the freedom of movement through space for all, for scientific purposes, for commerce.

**Expert 4:** [00:02:43] And, you know, and I do think that would be something that the DoD would have a role for, to ensure that freedom of movement, much like it does today in waterways around the world with the Navy. And I do think the way that the Space Force is organized with chief of space operations, they're already thinking in those terms to make sure that there's freedom of movement, at least within orbital the orbital space domain. But recommendation would be to expand that into the Earth to moon environment. The third item has to do with standards, and I concur we should take the lead to develop global technology and safety standards, because that way, you know, by setting up those standards, we can ensure that our interests are met in addition to our allies and even perhaps some of our near-peer adversaries perhaps may want to take advantage of some of that in the future. And if we set up with those standards for technology and safety, then we can be ensured that our interests are met in the earth to moon environment. Space competition was the next one. Did you want to stop at each or just go through the whole thing and then go back.

**Researcher:** [00:04:09] I'm just going to ask a question on the last one. I noticed in some policy, it was very specific freedom of movement on the seas and in space. And in other policy, it just says freedom of movement in the global commons. So, you think everybody understands what global commons is or do you think we've got to be specific in space?

**Expert 4:** [00:04:32] I think you've got to be specific because I think the word global commons will extend to orbit in some people's minds, but that's as far as it's going to go if you use the word global.

**Researcher:** [00:04:41] Well, that's another angle on this, too, because when people think space, they think of Earth. They don't think out to the moon.

**Expert 4:** [00:04:47] Right. Global could be the things that help contribute to our national power on earth. And some of those are orbiting satellites. But that's a very different environment than the Earth to moon environment. Again, this gets back to the lack of sufficiency of current policies that don't really address it.

**Researcher:** [00:05:08] It's funny you picked up on the same word. I did that word global. It implies earth.

**Expert 4:** [00:05:13] Yeah, well, and it does imply Earth and maybe we need a different term or at least extend the global aspect to, say, Earth to Moon activities could also have an impact on Earth activities, global activities. So that's why I thought that for that one, the way you define global technology and safety would include cislunar infrastructure.

**Researcher:** [00:05:38] Yeah. Space competition. This is the next thing.

**Expert 4:** [00:05:42] The space competition. This one, I think the first one right on. You're right on.  On this one, I think you will continue a commitment to a safe, secure, and stable space environment, that's just right on what you said there. Both policies said the same thing. I think that in that case, it's fine the way it is, right? It would be sufficient. Now, SSA is what I had there was basically concurring with what you had. Extend SSA requirements to include the cislunar zone. Again, space situational awareness tends to be near or earth. Kind of that seems to be the big thing these days is space debris. And that is not that is not a trivial matter. I mean, as you know, a lot of stuff up there. Right. But I do think that some of the technologies that they're looking at now could be extended and need to be extended into the earth to moon environment. Because if you want to operate freely in that environment, if anybody wants to operate freely,

they have to know the environment that they're in and say today, at least the civil part of it, is informing commercial entities that are flying birds, for example communications, letting them know that they may have a potential conjunction. They could have a conjunction happening and they might want to take action to avoid that from happening.

**Expert 4:** [00:07:19] So let's see for the U.S. global space leadership theme. I said expand global space leadership to include the creation of cislunar infrastructure to support exploration, science, national security and commerce. So, I do think that we should, you know, make sure that all of our instruments of national economic power are supported through the development of the cislunar infrastructure. You use the word first to market. I think that's great. You know, let's get there before the Chinese get there. But I do think that our space leadership should expand to our global space leadership should expand into the environment. And then the last one under space competition, identify dates of infrastructures. So, I said, you know, look, policies do not put in how many dollars are in there right? But we need the policy to have the specific dates, the funding and the elements for the NASA's cislunar investment. Right. We need all three dates, funding and what it's made up of in order to be clear about what the NASA's Cislunar investment should be and to ensure what we do in that zone extends or our global space leadership extends and extends into that cislunar zone.

**Researcher:** [00:09:02] So I appreciate that comment. Your gut tells you lower budgets are bad, but it's not necessarily without a date. You just don't know. You just don't know. And without not only without a date, but without a what are you going to do by that date?

**Expert 4:** [00:09:20] Right.

**Researcher:** [00:09:22] Yeah. When they took out the dates, that was a that was a critical thing. So maybe the budget is right who knows.

**Expert 4:** [00:09:30] Human presence. So, the notion of planetary contamination I think is too limiting. Both policies had it in there. So anyway, from my perspective, we got to expand the environmental infrastructure. Beyond Earth to the Earth-Moon (EM) zone, including moon activity. So, I agree. I agree with what your recommendation is there. You know, again, you want to make sure that people can operate in that zone without contaminating the space environment, the moon environment. Unfortunately, you know, a lot of people might look at spaces, for lack of a better term, is not something we should be concerned about here in terms of our environment on the Earth. But I would say that you do not want space contamination. I mean, you don't want stuff up there. It just could be a real problem. So, you have to figure out a way to control that environment that you're in. And so, I agree with what your recommendations are here. Then I basically said, I concur with your recommendation. Then I said establish the dates for initial landing, sustain presence and infrastructures. Do them all. In other words, initial landing is kind of go out, you know, you land and then you go out and you develop infrastructure on the moon.

**Expert 4:** [00:11:09] But I think that in parallel with that, you need to develop the EM zone infrastructures as well so that all three of those elements can be completed prior to 2049 or all three of those objectives can completed be completed by 2049. This is not just about exploration anymore, right? First to the moon anymore. This is different than the space race. This is about sustained, sustained capability. And that's what the infrastructure needs to provide. And it needs to provide it for all different aspects of national, foreign, national power. So, referring back to the one I just said, requests the funding to support the dates for the initial landing sustain presence at zone infrastructures to complete prior to 2049. To your point earlier, what are the elements of it?

Establish the dates for those capabilities and then you can determine what kind of funding you need, at least for NASA to get to kick it off. Right. To kick off the initial capability or there's a term enabling program. That's a good, great word. I'd like that word, use that term. So that's what I had for establishing human presence. So.

**Researcher:** [00:12:26] Through another interview. That that initial human the whole human presence thing is a discussion in itself. And then the initial and sustained human presence is another discussion. The sustained human presence has an implication that there's some person there all the time. And what I was told was maybe not so. Right now, I'm told NASA defines that as you have a lunar base, but it might be only occupied two months out of the year. And it just depends on the crew that's down there. It doesn't mean there's a person there all the time. And is that a sustained human presence or not? And maybe you could accomplish that. And then someone's got to do what I call just station keeping of this thing, not just the routine maintenance of it, but what if something goes wrong?

**Researcher:** [00:13:27] On this station that's down there and there's no person there to take action? You got any thoughts on what a sustained human presence is?

**Expert 4:** [00:13:37] My, my...

**Researcher:** [00:13:38] Maybe it's not just to sustain human presence. Maybe just sustain presence. I don't know.

**Expert 4:** [00:13:43] Yeah. Yeah, well, look. Well, first, I'm not sure I define a sustained human presence as somebody being there all the time. I'd say the way I would, that's the way I would define it. However, I'm not so sure it's necessary. Right. I mean, there are other ways to remotely monitor what's there. But that gets back to the infrastructure. I mean, you've got to build that into your EM infrastructure so that you can communicate remotely and get the instrumentation on

there. You get the telemetry back and figure out what you're dealing with. Because if you don't do that and you send a human down there, then how are they going to really obviously know what they're up against? Was there a meteor shower right where they are? Well, I got some other ideas, but we're being recorded. But yeah, like you never know, right? I mean, you got science fiction, right? Who knows, right? I mean, little green men, right?

**Researcher:** [00:14:42] So my house is monitored by Alexa right now.

**Expert 4:** [00:14:45] Yeah, sure.

**Researcher:** [00:14:46] I'm not sure I need a human there. In fact, if I was going to turn this into an infrastructure, maybe the economic powerhouse would be the Sensi thermostat with Alexa and not the person, because that's not really infrastructure.

**Expert 4:** [00:15:02] Right. Right. No, but I think that's another if you want the flexibility to make sure that it's maintained remotely, you'd have to build that into that infrastructure.

**Researcher:** [00:15:14] Right.

**Expert 4:** [00:15:14] Right. So, in addition to supporting people when there, you know, so yeah, that's a good point. All right. So that was a good.

**Researcher:** [00:15:24] That's a good segue way into the last one, which is to promote commercial space.

**Expert 4:** [00:15:29] So I guess before I get into the details of that one, I kind of came up with three main players here. So, we have NASA, which is going to get the enabling program funding. They're going to go out and for the infrastructure, they're going to build out that infrastructure with probably companies that have got some pretty good experience building complex space systems, right, based upon the things that are here, Gateway, Logistics, Crew and cargo. But then there's another category called the commercial utilization folks, the folks that are going to utilize

the infrastructure who will probably enter into agreements with the companies building out the infrastructure or may just be utilizing that infrastructure. So, it's kind of analogous to the Eisenhower Highway system in this country. The highways that were built for people to be able to move between the cities. Well, the people using it are different than the people that built it. And so, the idea here is that NASA would contract with folks that understand the space environment and more complex systems in the space environment. And then you have another what I was calling commercial utilization of that. So, I wanted to just let you know what like how I kind of some of the term because things like commercial I mean so many different terminologies when it comes to commercial space and private sector and private and all that. So, so let me go through them and you can ask questions, but I want to I want to kind of set that framework for how I divided these folks up.

**Researcher:** [00:17:20] I had a hard time going through these the commercial stuff to this because it just said stuff like we want to do in-space manufacturing. It's like, well. What does that mean? I mean, I get it. I know it visually. I understand it. But what? What do you mean, we?

**Researcher:** [00:17:38] Who, when? How? Where's the money? Who's leading it? It didn't really mean anything to me. And actually, a number of these commercial areas other than just the cheerleading things. But yeah, the Devil's in the details on some of this.

**Expert 4:** [00:17:58] Yeah, it is. It is. So, the first one I said expand the commercial space promotion, the government promotion to the EM zone. Right. So, expand it to that. And that will challenge industry to complete the infrastructure before 2049. So, promote, when you have commercial space activities include promoting commercial space, whether it's remote sensing or space transportation, include the EM zone is another area of government commercial space promotion. Okay. So, the next one talked about the commercial market priorities to give industry

guidance and to support enable the NASA enabling programs. So, this is where I brought in the term commercial utilization market. I said identify and promote all identified commercial utilization markets to support industry guidance and NASA's enabling program requirements. And then I added through commercial procurement acquisition strategies to meet the to complete the infrastructures before 2049. So, the idea of the end market, the operator or the end user is going to be this commercial utilization folks, which and I guess the most common ones are cargo transport by United Parcel Service (UPS) and Federal Express (FedEx). Versus maybe some of the larger space companies that would build out the infrastructure to support that and might even. You know, build the transport vehicles that those other companies would use. Right, to be able to transport that cargo. So, you know, just like today, I don't think UPS builds their trucks. They have a truck building company build them. But they put UPS inside and they drive it.

**Expert 4:** [00:19:59] They're using it right. Same with FedEx. So, it would be the same kind of thing where they have you know, they would have one of their folks driving from, you know, Rocket Man, right, going from the Earth to the Moon. But those infrastructures, that's part of it. Like the transport systems, that would be something that would probably be built by somebody else who understands, you know, in space propulsion and things like that. So anyway, but I thought it was important to identify the commercial utilization markets and that's where I just tweaked. When you said identify commercial market priorities, that was what I interpreted that to be. It wasn't the people building the infrastructure but the people utilizing it. So, then the next one, identify and promote all commercial utilization markets to support industry guidance for how to use it and or industry guidance on how to build it out. And then NASA's enabling program funding to complete OEM infrastructures before 2049. So, when I talk about industry in

this context, it's the ones building it out to support the commercial utilization market. And NASA would provide the funding to go build that out. And then the last one had to do with regulations.

**Expert 4:** [00:21:25] So I had established dates. Again, I was concurring with what you said, pretty much established dates for competition or regulatory regulation reviews and ensure the regulatory environment supports commercial investment in OEM infrastructures by 2049. Didn't really have much there. The only little nuance I had maybe was, again, it's the term by 2049. So, what you really are looking for is commercial investment to complete it, to complete the infrastructures by 2049. Now that commercial investment could be from through the well recommended acquisition strategies to build it out with things like OTA's and other commercial arrangements, right where industry comes in with some of their funding or you know, of the infrastructure build out or some of these commercial utilization folks, maybe they want to invest in some of this capability because they see their business case for their end business. Right. Supporting their investment in some of this capability. But in every case, though, NASA is in that leadership role because they're kind of the ones that understand that domain and they're the ones that are uniquely positioned to kick off the program. But I would say that, and this gets to some additional comments that I had outside this, but, you know, the idea there is nascent needs to use commercial best practices when they're out building out and they're out talking with people about what those commercial utilization markets would be.

**Researcher:** [00:23:17] You think whenever you talk Moon or space, whether it's near Earth or Moon, everybody just defaults to NASA. The whole conversation is NASA. You think they say it in a tongue in cheek way, do you think they got it in them to beat China at this economic game that we're in here?

**Expert 4:** [00:23:48] Well, one of the things I was going to add that isn't really addressed here, and it's something that you see in space policies, all the space policies, they talk about lead agencies, and they talk about contributing agencies or they have special terms. You may even have more than one lead agency. Right, like co-lead agencies. So, one of the things I think that should happen here is NASA should take the lead on the activity, but they need to bring in the interagency expertise to ensure that they are addressing this, not just from their interests, you know the R&D and the scientific side got it. But if you bring in as supporting agencies, DOT, they can handle the licensing and regulations for the transportation from the Earth to the moon. And what does that mean? And they've done it for commercial space from Earth to orbit. Right. And so, they can they've got some expertise there to talk about some of this stuff and to figure out what the right regime would be and go out with things like rule makings and stuff like that out to the industry to say, what would you like to see in this in this regime? So, the DOT could be part of it.

**Expert 4:** [00:25:05] The Commerce Department could work the commercial utilization folks. Right. They could go out. I mean, they've got the Bureau of Industry and Security, right. They do industrial base kinds of research all the time. So, they talk to industry a lot about stuff. And they could go out and talk to the commercial industry. And then maybe there's a little bit of a like an independent or a little bit of having the Commerce Department involved gives a little different focus. But, you know, NASA would still be the lead, but the Commerce Department could handle that. And they could also handle the SSA requirements as well for the commercial transport and the commercial transit from the Earth to the Moon because you know that's kind of their role. They're trying to do that right now, as you know, with the stuff in orbit. So that could be something they could also work on.

**Researcher:** [00:26:04] So I want to expand on this a little bit. Just for the record of the conversation here, we've got you got NASA, who has been set up, obviously to be an explorer, but also enable national prestige that we know why that lead in science and technology. But you talked about DOT and some of the other regulatory bodies.

**Expert 4:** [00:26:29] Right.

**Researcher:** [00:26:31] But by virtue of doing that, regulation, regulatory bodies, you know, they have some awareness on what makes things competitive. Right? Because you can't be overly regulatory because you won't be competitive. So, there is a balance between regulating yourself out of business and enabling business internationally. And then you brought in the third and I don't know you would know better. Is Department of Commerce a regulatory agency or are they a facilitator of economic? An economic engine in power. And so, you got this massive explorer with the technical knowledge, you got the regulators, you know, the competitiveness stuff, and then the Department of Commerce who brings in this industry, maybe I don't know what your thoughts on how all this intertwines.

**Expert 4:** [00:27:23] So what's interesting is that the Department of Transportation, through their ASD organization, they're both kind of charged with promotion and regulation, right. So, they do that balancing act. Today, the, the Department of Commerce actually has regulatory responsibilities as well for the commercial remote sensing industry within the department. Right. It's out of NOAA. So, they also have the Space Commerce Office, they really are a promotional organization only. They're only promotional. But the Bureau of Industry and Security, they do industrial based studies all the time and they interact with industry in terms of their supply chain and what capabilities are out there. So, if you look at it from the top Commerce Department perspective, much like the top DOT perspective, there's both regulatory and promotional roles.

And to your point, if they look at it from that perspective and if the people that are involved are high level people in the department, their role will be to get the right balance and they will understand what enables industry and what doesn't enable industry. So that's why I think it's important that we go with the Department of Transportation at that level and the Commerce Department at that level. So, then the interagency representatives can take into consideration all the different parts of the department and come up with a balanced approach.

**Researcher:** [00:28:54] I think you said two things. For all these agencies, they have a regulatory job, but they also have a promotion promoting job for the national economy, the national power. And maybe in this new area, it's a little light on the regulation, a little bit more on the promotion side to get it going.

**Expert 4:** [00:29:12] Right, right, right. Exactly. Exactly right. To get it kicked off first. And then when you start talking nuts and bolts, then you'd bring in some of the regulatory rules and things like that.

**Researcher:** [00:29:23] So there's this planning aspect of what this future infrastructure zone for commercial economic engine looks like. And you talked about involving these other agencies that bring to bear these other competencies in that area and industry would provide some perspectives. But industry, their major play is probably more in the implementing of this with NASA. But can you expand on your thoughts of how NASA maybe currently engages with industry to build stuff using an SLS model, versus a DARPA model that NASA could take. What are the different models that NASA could take with industry to get them more involved and make whatever gets built more of a competitive thing than a, you know, an SLS or a NASA government operated thing?

**Expert 4:** [00:30:33] The pieces that go into the enabling infrastructure, communications, you know, transport vehicles, I think things that are required to frankly, go to put the first man or put the people on the moon. NASA should still be in charge, but they should not use what I would consider classic procurement methods. I still think they should go in and use other acquisition strategies that are commercial kinds of strategies, and they should go to companies who will build out these capabilities and ask them for some kind of investment, some kind of joint investment, so that it's not just your classic taxpayer money paying for a system to be built, that there should be some skin in the game and investment from the companies that are building that infrastructure because those same companies then can turn around and be the ones to basically provide that infrastructure to commercial industry as well. It's kind of like a company builds a capability for NASA, but that operational capability of that system is actually paid for by the people that will buy that or the commercial utilization folks. So, you start out with the initial infrastructure and the standards and the rules and all that stuff. You start to build it out, but then it'll transition from NASA contracting to basically the commercial utilization people buying that, parts of that infrastructure for them to perform their commercial business.

**Expert 4:** [00:32:34] I know maybe I'm getting a little confusing, but it's, you know, the role of NASA needs to be to build one or two of these things, let's say the infrastructure with one or two of the transport systems, and then you'd bring in the commercial utilization guys that would use this in a services environment to transport the stuff, just like the COTS kind of situation, right? The COTS, guys. Right. So, I guess I'll change my tune a little. So, to build the first couple, it could be an SLS kind of model, but that better transition quickly over to more of a service model where NASA would pay for a service from a UPS or a FedEx to transport the stuff. So, NASA's builds it out to start with a classic Space contractor, but then they move quickly over to more of a

commercial relationship, a service relationship. So yeah, so I think initially they can build an SLS kind of thing just to get it, to get it started. So right. And then later on that same thing, they would pay they would pay for their stuff to be transported by FedEx spaceship. But the FedEx spaceship would also be transporting commercial goods as well. So, NASA would be a one of the customers, but not the only customer. The DOD would be another customer, paying somebody to transport stuff for us.

**Researcher:** [00:34:13] What you described was a classic DARPA model where DARPA invests in the first one just to buy down the technology, risk and proof of concept. Without it, that would never be the commercialized thing because it's just a proof of concept and getting rid of some technical risk. But then if it worked, then the DOD would contract for commercial entities. Well, first of all, if you go into the industrial base and the DOD could buy back that as a commercial product or service in the future. In other words, the DOD would never operate the DARPA thing as a user because it would just be too costly, probably, right? Not operationally sufficient.

**Researcher:** [00:35:08] And I don't know. There are pockets of NASA doing that in some areas like the commercial lunar payload services thing and the COTS thing.

**Expert 4:** [00:35:16] And the program back and forth.

**Researcher:** [00:35:20] They don't seem to be well. And maybe that's the grand strategy for SLS or Gateway.

**Expert 4:** [00:35:26] Yeah, yeah, maybe.

**Researcher:** [00:35:27] I don't know. It doesn't seem to look like that.

**Expert 4:** [00:35:29] But not yet. Anyway, it.

**Researcher:** [00:35:31] Looks to be. That might be a NASA operated.

**Expert 4:** [00:35:36] So I do think the three categories still kind of hold the idea. You know, NASA's kind of going to contract through a space prime, right, to develop one or two of these things because they're going to be complex systems, right? They're going to be complex. And so, but the folks using it, whether it's government or commercial, they're going to just operate it. But it's got to be operated in such a way that it's safe. Right. It's environmentally safe. It's safe from the environment of space and all that stuff. NASA and the NASA prime who is doing the build out, they've got that expertise to do that, and that's what they would do. But you want to get the commercial utilization market needs in there up front to make sure it's got that commercial utilization market application so that the taxpayer's money can then be leveraged later, and then NASA and the DOD and everybody else commercial can buy services from it.

**Researcher:** [00:36:40] Right. You can't build something that's not profitable as a commercial endeavor. Otherwise, it's not a viable infrastructure.

**Expert 4:** [00:36:50] Right? Right.

**Researcher:** [00:36:51] Exactly. Unless it's for a purpose of the public good.

**Expert 4:** [00:36:55] Well, yeah, right.

**Researcher:** [00:36:55] Government does that a lot or some areas. But defense is a classic government. Good.

**Expert 4:** [00:37:02] Well, Global Positioning System. Right. So, GPS is a free government is a free service that we provide for the world as part of the gold standard, as part of our leadership. And now that you bring that up, when you build this out, you want it to be global. You want other people also to be able to access it, probably not for free unless it's a government-to-government agreement. With an international coalition or whatever.

**Researcher:** [00:37:36] U.S. holds the standard and everybody else complies.

**Expert 4:** [00:37:39] Right, exactly. And we may want to provide the transport to make sure that it's all compliant, but then they would do other things. Other countries would do other things because it would be global. The idea is if you're going from Earth to the Moon, anybody on the Earth could get access to something, something going from the Earth to the Moon. Right. So, you'd want to make sure that those standards allow us to be in leadership to make it for global commerce, not just for us U.S. commerce. Right. So, the other organizations I had DHS down here too for the resiliency of the infrastructure. Yeah, I think that's another one now is whole Department of Homeland Security gets back to this whole thing about global and homeland. But you know, DHS, I, I think they talk in terms of infrastructure, right? And they talk in terms of infrastructure resiliency, and they provide guidelines to U.S. Industry within those critical infrastructures that are defined. I don't know if there's 12 or so, 13, I guess, but the idea there would be bring some of that experience to this to the architecture. Right. And things like cyber protection, things like that, where they are heavily involved right now and have the expertise.

**Researcher:** [00:39:08] I don’t mean to put words in your mouth, but it sounds like the policy is very clear. NASA go land a person on the moon, but there seems to be some missing policy in the upfront planning of the architecture that leverages all these other departments and agencies that probably could bring something to bear on an infrastructure architecture that's sure that's economically competitive with China, because that's what the challenge is. Right? It's economic.

**Expert 4:** [00:39:37] Competition. Yep, yep. That's right. And then the last one is DOD, the DOD. We talked about freedom of transport. And, you know, I think that for something like this, NASA is a good starting leader to get the thing kicked off. But in order to get it kicked off, you've got to have all these policy things kind of in place so that it covers all the different equities and elements of national power. And I do think that the DOD can play a key role in

making sure, just like we do today, you know, making sure that commerce and things can transit, right. For whatever they need to do and that's where they could be involved upfront. And for the architecture, how the space force could potentially protect that architecture. Right. So. Great.

**Researcher:** [00:40:40] Anything else to add on any of this? I don't want to take all your time.

**Expert 4:** [00:40:43] No, no, it's a very exciting thing. Again, I say I think that it's not sufficient as it is. I think with some of these changes in some of these adds, maybe they can be a little more comprehensive so that we can make sure that we can win that competition with China, you know, the BRI initiative. So anyway. Okay.

**Researcher:** [00:41:10] Thanks, let me turn off the recording here.

## Appendix F

Expert 5 Transcript

Interview 24 March 2022

**Researcher:** [00:00:02] Okay. What I did, as you saw, was I went through national security policy, the national space policy, and I limited budgets to the NASA budget request documents. There's a lot of other policies out there, and people are trying to talk me into looking at other policies…I thought they're informative, but probably the biggies that matter are national security, national space, and the budget...because we're talking about tangible things here, infrastructure, systems, and technology stuff with standards. So, it's really important to include that in the process of doing this. I was searching for what the grand strategy would be and the themes for that strategy? I identified four areas, that came across as document themes. That's just how it came out. And within in each one of those four, I guess I just call them policy elements or areas that seem to be repetitive between the Trump and the Biden administration. By the way, I'm not trying to say who was better. That's really definitely not the purpose of the study. What I'm really trying to do is find out which had good policy for this particular grand strategy challenge, and then acknowledge it and put it in as a recommendation that this just needs to either continue or this is just an area of weakness or it's going the wrong way and we need to change course and improve it.

**Researcher:** [00:01:48] What I would ask is the process here, is I would like to go through the four areas, and you could talk if you want about those. If not, feel free to go off in a different direction because quite frankly, I think it's more important to find out what's not in the policy documents than what's in there. The missing stuff seems more interesting than what is there. So, the first theme that came out and it was probably more prevalent in the national security strategy

than in the space strategy, was the infrastructure competition in the national security policy, both Trump and Biden. It was very clear that they both recognize the geopolitical aspirations of China and tied it to this infrastructure piece. Before I go into this more space specific, do you have any thoughts on any of the infrastructure competition pieces?

**Expert 5:** [00:03:09] Yes, because I think I agree with you because if you look at the even the context of the conversation, the Trump administration very early on identified China as a competitor, not just in terms of leadership, but also in terms of taking advantage of infrastructure across different domains. Not just space, but also innovation of futuristic technologies like quantum. So, there was a growing recognition that it's not just overall infrastructure, but space itself can be seen as a part of that particular infrastructure within the Trump administration thinking. And in some of the documents I saw that clearly reflected, including in former Vice President Mike Pence's speech to the Fifth National Space Council in 2019, where he recognized space as a part of that overall infrastructure. So, I think yes, I think there is a recognition that the U.S. needs to compete across infrastructures. And so, I would agree with that. Where I would diverge is that, when you talk about infrastructure, there is the overall idea of infrastructure, which could include anything that you would think as infrastructure. I think there is still an inability I mean, correct me if I'm wrong, but when I listen to the conversations, I think there is still an inability to articulate across administrations what those infrastructures are and which are critical.

**Expert 5:** [00:04:50] Because everything is infrastructure, but what is critical for national power and grand strategy, what is critical to take up leadership, say, 20 years from now? And so, I think that's where China diverges, especially under President Xi Jinping. So, when he became president and then subsequently, he gave a lot of direction, including his book that he published

on Chinese socialism under their special characteristics. And so, in that he identified 13 areas and one of the areas was the critical infrastructures of quantum, artificial intelligence, robotics and space. So, there is very clear direction as to what needs to be invested in. I haven't found that in the U.S. There are several documents that talk about it in a roundabout manner, but there is no clear direction from a high level as to what that U.S. investment should be. At least that is what I have seen, and I have also seen a reticent to identify space as a critical infrastructure.

**Researcher:** [00:06:00] The DoD has identified a number of these critical areas. They're working on 5G, artificial intelligence (AI), quantum and space as well. And when I talk about infrastructure. It's easier to relate the discussion and the definition of that when you talk 5G because that was a competitive issue that everybody really understood. In that example, it's a battle over the global 5G standard and who will control that worldwide. And I was like, yes. But then I would also tell them, but you know, that's going on in these other areas, too. And they're like, no, we didn't know that. This is completely almost irrelevant to this, but I found it helpful to use that 5G analogy to these other areas like space because I don't think people understand it is occurring in these other areas too.

**Expert 5:** [00:07:09] Yes. And I think the other thing which you might find useful just to inform your analysis of U.S. Documents as well, is to look at China's white paper. Because since they're comparing in terms of competition. But China publishes a lot of white papers on, for example, artificial intelligence, space, and quantum to their state council. And those are definitive statements of what they're going to do in the next five years. And so that tells you that their thinking is already crystallized into actual policy papers and they're thinking a lot into the future. And I think there's a recognition that technologies like space, artificial intelligence, and quantum will be critical as to which country will lead in terms of leadership and norms and regimes. And I

suppose for some interesting reason, they have come to the conclusion that leadership in this fields will result in them becoming a lead actor overall. And so, I think I'll finally end by saying that the 5G example is great. But I remember when there were early, early contention that China is investing in 5G and would become the leader one day but there was a lot of denial in the U.S. There was like they're not capable of. And for some reason most of the denial was not based on factual analysis, but just opinion. And I worry that a similar kind of denial in space infrastructures, because we are so much in our own bubble, that's a worry I have.

**Researcher:** [00:08:41] So I've done some of these interviews and that denial is still occurring in the space area. In fact, one just blatantly told me that there's no competition in this area, and I don't really understand that denial. But you think China is resolute in their incorporation of space in this infrastructure goal?

**Expert 5:** [00:09:21] Yes, they are. Because they are because one way, you know, they're serious is not just their stating through their speeches, but also putting it through the...let me back up. I say why I think it's important. So, one of the most serious and highest-level policy making body in China is the China National and Development Reform Commission. So that's the commission that actually identifies areas for priority investment. So, for their budget, I know they do not publish a military budget or a space budget, but from that you know that these are the areas that are critical. And so, in 2020 April, they put out a document in which space, satellite, internet, 5G, all interrelated technologies were identified as new infrastructure and critical infrastructure. So, by which it means that two years before now when we are talking, it's going to be April very soon, China actually already identified space as a critical infrastructure for priority. And you can see that happening in terms of some of the programs they have announced since then, including investment in space where solar power and planetary defense. So, the current

white paper which came out, identified planetary defense as a critical game changer in the world. If they become a leader in that by which you know what I mean, if an asteroid comes towards Earth, they'll have the capacity to either slow it down or be able to do some kind of maneuver. And so, I think I don't think I mean, this has happened two years ago and yet there is, and the denial is really something that I cannot understand, because once you put it in a policy document and you have support from the highest policymaking body.

**Expert 5:** [00:11:12] I don't know what the denial is based on then, because I look at facts and if China had come out and said, okay, no to what the China National Reform Commission said, but they haven't done that. And so, it's a bit puzzling to me. The same kind of denial happened with China's landing on the far side of the moon. So, when China announced in 2002 that they're going to have a mission to the far side of the moon by 2019, 2018 was the launch date. And that was like nearly 20 years before they actually did it. So, all those 20 years, there was complete denial that this will never happen. China will never land on the far side. Nobody's done it. It's the most difficult feat. And I actually remember presenting just a year before that, saying that this is what they intend to do. And the audience was in complete denial. This was in Huntsville, and they started getting upset with me saying it because they thought this is never going to happen. And then when it happens, there is complete strategic surprise. But my point is, they told you they're going to do that. You thought it's just propaganda, you know? I mean, seriously, you have to look at capacity and what they have achieved.

**Researcher:** [00:12:34] I have two thoughts on this matter. One is agree completely. It's a great cultural study of the U.S., especially the space community of the U.S., who have been taught and brainwashed to believe that they are the leader in space, and they always will be the leader of space. It just is what it is. The two things that I find surprising are the one you just mentioned,

which is not taking China seriously, despite another expert telling me they have hit every major milestone that they wanted to hit. They have said they were going to do it and they have accomplished. And that scared that person because he says that that means they're serious. You know, nobody says they're going to do something by a date, and they actually do it. So, he said that's evidence that they are serious. So, I agree. And I don't know why that's not sinking in about China and space. The other thing that I find interesting that's probably a subcategory of this whole discussion is we seem to be engaged in a. Space competition to. For prestige again. Let's just put a human on the moon again because we left, and we should be back. And I'm not sure that's what this war, this competition is about.

**Researcher:** [00:14:04] There's obviously a theme of prestige, both China and the U.S., but I think this is a different than the Soviet-U.S. Competition where it was about hearts and minds and national prestige. It seems very clear that China wants an economic dominance in whatever this future lunar earth-moon zone evolves to be. They have convinced themselves that they want to lead that that economic zone. And what concerns me is I don't I don't see evidence in the U.S. policy that what the competition is about. It's an economic competition in space and not a prestige competition. And the evidence is why would we why would we make a big deal about landing a person on the moon by 2024? Well, that's not an economic, goal, that's a prestige goal. Economic goal is putting infrastructures in space that can be commercialized that you have other users use as a public infrastructure, and you bring economic value to national power to the country. And I don't see that argument being made anything but that. That was my perception from the documents. But if you'd like to elaborate on any of that.

**Expert 5:** [00:15:32] Yeah, sure. I would love to because my work gets very vindicated by you finding it in the documents as well. It's always good to get more and more research and I like

your abstract a lot. Where you said, is this actually budget and policy substantial enough to actually build an Earth-Moon Economic Zone infrastructure in the U.S.? And I think my conclusion after nearly six, seven years of studies that I don't think so and so my point is that I think there is a continuation of understanding space from exploration, prestige perspective in the U.S. NASA is a very civilian, it has a lot of glory, rightly so, but it continues to see space from that particular perspective, right? What happens is that if you look at the Chinese articulation for their space ambitions, especially by those who lead their space programs, and they have given I mean, people say don't fund data. There's data everywhere. They have given interviews. They have written about it, especially Wang Xiji, she has written about it who is the head of their long March mission, Wu Werien who is the head designer of their China Lunar Exploration Program, and then Ouyang Ziyuan, who is actually the founding father, if I may, of their lunar program. So, in that contention, why is China going to the moon? It's not really about a human landing for them.

Expert 5: [00:16:57] They are not really prioritizing that. I think if you listen to Wu Werien, he points out that in this interview he gave in 2005 and subsequently several interviews, including Ouyang Ziyuan, who's the head designer. So, in that contention, they argue that there are several resources on the moon. One is water ice, which is really critical. And they actually show you charts as to why that is critical. And they're giving these interviews to their audiences who are their internal audience. And then the second important contention is that there are other resources on the moon, like silicon and iron ore. And then there is helium three. So, in that contention, their argument is that if we invest in capacity for resource prospecting today and reach a maturity stage by, say, 2040, the return of investment is about $50 trillion. And that's their calculation. And they've put it out. And so, despite them saying that, despite them insisting that this is about

economic prosperity, you know, Wang Xiji, who is there, as I said, founder of the Long March rocket program, clearly stating that China's investment in space is about ensuring that China benefits from it economically. And they always have an economic reason explaining their Beidou navigation system why they build it. The return from Beidou $9 billion investment in the beginning, $59 Billion annually as return from their lunar program.

**Expert 5:** [00:18:23] The economics of it, I think we tend to continuously see China through the Cold War framework of prestige and space exploration when they are insisting again and again that this is about space utilization, development and industrialization. And so, as you know, China and Russia signed a memorandum of understanding last year. Right. In which they have actually clearly put out their design as to what they want to achieve by 2040, the International Lunar Research Station, a permanent base on the moon. And so, they are not even talking about a human landing. I don't think they see a human landing, a temporary human landing as giving them strategic advantage. It could be for prestige purposes. They could showcase the technology and achieve some kind of global status. But I think they realize that the actual strategic advantages, if you can establish a permanent presence so that you can actually then lead cislunar space and that economy. And it's very clear in their documentation, in their argumentation, and also in their strategic thinking. I don't see that kind of argument in the U.S., the Trump administration talked about establishing sustainable presence by 2028, and the Artemis Accords actually talked about utilizing resources on the moon through international partnerships, but somehow that particular focus is not carried through in U.S. policy and purpose.

**Researcher:** [00:19:51] You know what your points are right on. I agree completely. One thing that I saw lacking or missing from the Trump arguments was understand, sustain human presence. But there was never and explanation for what purpose? For what purpose? And beyond

scientific right science of the human physiological state on an outer space or lunar soil, regolith, material, science data. But there was never this connection of we're doing it for some economic return. They seem to have two worlds of promote commercial space, but it all hovered in this near-Earth orbit kind of stuff with an occasional lunar resource extraction statement here and there, and then put the person on the moon. And I never saw the two kind of come together as a why do you want a person on the moon? I get it from a national prestige, but I don't. You know, what is the economic that's an expense and not a return on investment. So yeah, so.

**Expert 5:** [00:21:07] I wrote a piece in the space review where I said the U.S. lacks visionary leadership and exactly what your point is, especially with regard to the Moon. So, you talk a lot about the moon, Mars Moon to Mars program, for example, right, which Jim Bridenstine talked about. As I said, there were sustainable presence, but there was a hesitation to articulate the economic returns and the fact that this is actually an economic competition. This is not a competition for ideological attractiveness. Right. And China is actually diverging. So, and this is something that I point out. Let me elaborate on that. So if you look at the U.S. focus on the moon today, and the actual purpose of the U.S. Artemis Accords can be traced back to Mike Pence's speech, right, which I mentioned in 2019, April in Huntsville, actually, where they had a meeting of the National Space Council where he pointed out that China has landed on the far side of the moon that's why the U.S. needs to have a similar kind of kind of response that leadership is not taken right.

**Expert 5:** [00:22:15] But if you look at China's focus, the focus was not to land on the far side of the moon as an end in itself, the focus was to build the capacity to understand how to land in difficult missions, including resource prospecting on the far side, to then use that understanding to build a permanent presence for economic purposes. The goal and so there was a

misunderstanding that the goal was just landing on the far side to show off some capability. It was not really that the longer-term vision was clearly articulated by their chief scientist. These were just missions that they were accomplishing. And as we saw the former interview, they are very good about meeting goals on time. They were very, very good about meeting time. But in the U.S., I think and that's again a concern of mine because there is a lack of understanding that this is not a race for prestige and exploration or showing off some capability. I think the U.S. might actually miss the bus because there are such divergent views. Both are going to the moon, but both are going for different reasons.

**Researcher:** [00:23:19] I gave an example to somebody, and they were shocked, and I said, okay, so China has a relay satellite on the far side. So, Elon Musk wants to do something on the moon, let's say Bezos or early on wants to do something on the far side of moon. And instead of putting up their own satellite for relay, they just decide to buy some bandwidth from China that that hopefully would shock somebody in the U.S. that what they're buying calm and the reality is that calm that relay communication is an infrastructure on the other side of the moon and SpaceX would, if they used it would use the China standard for that communication and they're free to buy it the bandwidth. So, what's the U.S. going to do? Do we have a communication infrastructure on the far side of the moon to enable that commercial activity? And the answer is no. So, I just you could go on these. You can go through these examples, and I still don't think it's driving the point home that it's an economic war, not a prestige war.

**Expert 5:** [00:24:34] Yes. So, it's not just a one mission satellite, it’s also for the Chang'e 6, the Chang'e 7, and it’s infrastructure!

**Researcher:** [00:24:50] Infrastructure. Telecommunication infrastructure.

**Expert 5:** [00:24:53] Yes. And so anyway, I'm glad that your research is pointing this out, because I've tried to and, in a way, when I testified, there was complete shock that China was investing in relay communication and space based solar power for their infrastructure building in space. They saw solar power satellites as part of that infrastructure. And so and so I think, yeah, the U.S. doesn't seem to be able to understand that space is no more about national prestige, it's an economic competition. I hope it will go once we keep, you know.

**Researcher:** [00:25:24] Yeah, exactly. Well, so I like this conversation, but let me ask and go back to the core themes. Did you so setting the infrastructure competition aside, did you have any comments or thoughts on the other three themes? The next one was space competition. And again, this was really just culling through the policy documentation and extracting some themes in these areas.

**Expert 5:** [00:25:57] Okay. So, the second theme is space competition, right?

**Researcher:** [00:26:00] Yeah. And again, most of this obviously came from the national space policy. It really didn't come from national security policy, which was supposed to be broader. So, in my mind a more seamless integration between the relevance of space with national security is better.

**Expert 5:** [00:26:28] Yes. Yes, go ahead.

**Researcher:** [00:26:30] And I didn't mean to stovepipe the discussion in each one of these, because, again, it's better to stand back and look at it as a whole instead of in in each one of these kinds of stovepipe theme areas.

**Expert 5:** [00:26:47] I see your theme and your thoughts here is current and analysis. So I think if you look at the space competition side, I think if you look at for example, even if you look at documents the space forces put out, for example, their doctrinal statement as to why they exist,

it's all very clear that it's more a lot about ensuring free access to space, especially to the U.S. and its allied nations. It's a lot about making sure that an adversary does not have an advantage over you, if I may say that word. But I think I mean, just generally in terms of competition, again. Right. You also have to identify what you are competing on. So, you're competing with China, you're competing for military advantage, you're competing to ensure that your assets remain free and open and not destroyed, but are you actually competing? So, what is your area of focus? Is it just low-Earth orbit or is it beyond that? Most of the conversation today, including those coming from the Space Force, is a lot about terrestrial support. But if you actually look at it, they talk about cislunar space, but there is no clear identification of what it means by that.

**Expert 5:** [00:28:10] And so it's not just a word. There is detailed capacity building that is required. For example, as China is building the permanent station and then solar power satellites and a research base on the on the moon. And then, for example, President Xi Jinping has directed the People's Liberation Army Strategic Support Force to also develop operational capability on the Earth-Moon Zone as they call it. So, there is clear direction, and once you have that direction, you build the capacity, right. So, when you are competing, I mean, it's great that you want to maintain leadership or that you want to strengthen and expand U.S. space leadership. But what is the timeline? Do you have a time zone? Do you have a specific mission set that you want to accomplish right for by a particular time zone? Because, you know, that's critical because once a country takes leadership, it's very difficult to take that leadership. Look at 5G, look at quantum. And so and so that would be my response to this particular team space competition.

**Researcher:** [00:29:16] Obviously, you haven't seen some of the other piece parts of the writings that I've done with this. But one thought that I've tried to instill in this report is China challenging the U.S. leadership in a terrestrial infrastructure is harder than space, because the

U.S. is already there and it's harder to displace than it is to get there first. But this Earth-Moon Zone or cislunar, there isn't anybody there with infrastructure leadership. So now it's not displacing, it's about getting there first. So, when I read policies like you just hit there, which was maintain space leadership, well, that's interesting. But there's nothing there to maintain. You know, it's the first-to-market. In the Earth-Moon zone. And we're all on a clean slate, as it were. The playing field is level, so it really just becomes the first person there. So, if you want to be the first there for this particular area, you almost have to take more of an expansionist, stronger policy stance than just maintain because maintain just maintain by definition means keep the status quo. And the status quo is nobody has leadership there.

**Expert 5:** [00:30:50] Right. I think those words are used because I think their vision is thinking in low-Earth orbit. So, I think they when the U.S. articulates maintain leadership, I think they are thinking about the leadership, as you said they have today with regard to low-Earth orbit or terrestrial mission support. Right. But this is not really what the competition should be about. The competition is not about whether you have assets that support your military or civilian communication systems. For example, this is about a presence, as you were mentioning, which goes beyond just low-Earth orbit. It just goes beyond just looking at how low-Earth orbit competition is going to play out because this is deep space articulation. And so, yeah, I think the U.S. might be shocked, like it was shocked with the Soviet Union when they launched Sputnik. And so, once China and Russia establish a permanent presence, how will you ever ask them to leave? Because they'll be there first.

**Researcher:** [00:32:04] And I think me personally what I think will drive that point home is when commercial U.S. companies start to engage in this zone, and they start to use Chinese services. I talked about the relay satellite and my analogy here is back many a couple of decades

ago, at least when U.S. satellite manufacturers started going to Ariane IV for launch. But China too, right. Because the U.S. just was not competitive in the space launch market. That sent a huge shockwave to policymakers here to address that through policy and. That is the near earth thinking that continues. And I don't think it's going to take some shock like a U.S. company using some Chinese infrastructure in this Earth-moon zone before somebody in the U.S. says, hey, well they can't do that, can they? Yeah, they can, actually. And they did.

**Expert 5:** [00:33:19] So again taken by shock.

**Researcher:** [00:33:20] Yeah, yeah, yeah. And so, it'll sneak up on them trying to put an infrastructure there. Some commercial entity will just start using it and U.S. policymakers will not like that. And then the problem is China is established a first market, a presence there before the U.S., and that's going to be harder to change that. So yeah.

**Expert 5:** [00:33:42] Very first, first mover advantage as they say.

**Researcher:** [00:33:45] Yeah, well I'll get off the space competition here for a second, but I drive home your point again. That was interesting in the Trump policy, he talked about extending space situational awareness to deep space a little bit, obviously for military, but it was really for planetary protection purposes and some other reasons. But I saw great. I saw that as an infrastructure that could support future users out there by providing space situational awareness of both natural and manmade and natural objects. Space weather would be a great utility of that, but the Biden policy brought that back and deleted that and said, just use it for space debris. And as soon as they said space debris, you know, they're really thinking near Earth.

**Expert 5:** [00:34:30] Yes, absolutely.

**Researcher:** [00:34:31] And that so. Yeah. And that you bring up another point, and that is people just keep saying space, but they're not separating it from the near-Earth space and the

lunar space. They just talk space. And in this competition, I think they're different environments. They're different markets.

**Expert 5:** [00:34:54] Absolutely. And I agree with you. And the mindset is still to look at it, to think of space as just low Earth orbit. Because that's where most of the activity or geosynchronous orbit. But this is actually much beyond that. And so, yeah, there is a complete lack of analytical framework as well. And so, analysis drives policy. So, in our book, as you know, we looked at the epistemic community discourses and then we saw how actually made to policy. And I mean, our book was published in 2020. So, we didn't have time to analyze the Biden administration. Right. It came out before that. But the but it made it to policy and then it stayed there and did not get funded. That was another tragedy of some of the policy statements.

**Researcher:** [00:35:48] I don't think I'll dwell exclusively on the last two, which was establishing the human presence and the commercial, because they're kind of interrelated. Let me instead ask an odd question to you. You know, the hope for the U.S. to solve this competitive issue with China and granted this as an economic war and not a prestige war. The hope is Nasser. I use analogy to somebody. I said, if you were building a city, Boston or Chicago, and you had to lay out the power grid and the sewer system and the communications and the highway system, would you hire an explorer to do that or would you hire a city planner to do that? So, my question is, in space in this future Earth-Moon economic zone, do you want an explorer architecting that future economic infrastructure or would you hire a. Planner that knows how to set up infrastructure to make money and be competitive. And when I said it like that, people were like, oh, no, no, we wouldn't hire NASA to do that. We need them because they have very relevant expertise. But that's not who we would have lay it out. And in the case in point in the get your comments on this is you build a system like SLS and then you want to try to commercialize

that later and it's not commercialized. All right. It's just too expensive to operate as a commercial back and forth freight way. So as is I don't know. What do you think? What's the role of NASA in this? How successful are they going to be? Do they need help? And this goes all the way from planning this future infrastructure architecture to implementing and seeding it with seed money to the eventual commercialization. They obviously had a challenge as commercializing the shuttle and the space station in the past.

**Expert 5:** [00:38:05] Well, I think at least if you ask me what is the way forward, right? For example, if there is this competition in Earth-Moon infrastructure building and also which includes human presence and as you said, the commercialization, how do you promote commercialization of that? I think NASA's plays a role, but it does not play a leading role. So, I would say that we would need not just planners, but developers, those who actually are able to implement those plans. And in that, I think the private space sector is going to play a critical role in the U.S. They are already testing concepts like lunar habitat that are already concepts testing about life sustaining system, you know, space based solar power. All of these investments are at least in the ideas you will need government investment. There has to be a public-private partnership. But I think the ideas and the development of concept is getting out into the private sector more and more in the U.S., not the contracts are also with the private sector right now.

**Researcher:** [00:39:11] That begs a question because there's kind of two models here. One model is NASA must provide government investment do cost prohibitive and too much risk for private industry. Got that. So, the one model is NASA who builds and then they own and operate. The other model is what I would call a DARPA model, which is they build with industry, but they don't operate that. They seed it to get the innovation going and maybe buy down some risk. But quickly, they let the industry run with that and create an industrial

capability that can be purchased back from the DoD. I don't know if this emphasizes your point about NASA.

**Expert 5:** [00:40:00] The second model, so I don't think NASA should take the lead. In fact, when you talk about space stations, we have several private space stations that are going to go up. Axiom Lab is building a space station, including contracts of the ISS being some portions of it being contracted out to private sector. Now, at the time when it was conceived in 1998, it was about Russia. The world has shifted dramatically for the U.S. I was making a point just the other day that so there was a question asked as to what is the future for any kind of space development? Why should we give it to the billionaires? There is also this question, right? So, my point was that. Yes, but I mean, we do get carried away by Musk and Bezos, but there are so many other space companies that are there who are investing in capability capacity. Think of your launch infrastructure. So, in 2008, when Russia invaded Georgia and the two provinces of Ossetia and Aspasia and the U.S. sanctioned Russia, Russia threatened that they would not launch astronauts to the ISS. At that time the U.S. did not have a launch capacity. Remember in 2008 and there was huge consternation today Russia cannot make that particular threat anymore because thanks to the private sector, you do have a reusable capability to send American astronauts to the ISS.

**Expert 5:** [00:41:27] So in the future, I'm talking about a very similar model can be used. Supported by I mean NASA obviously give contracts to Space X and help. But SpaceX had to do a lot of the fighting to actually get the contract and to build that infrastructure and mindset. So, I think for Earth-Moon infrastructure as well, I think first of all, there has to be a market for it which has to be identified, which the Chinese are identifying. The U.S. also needs to identify such a market. Second, when it comes to looking at the Earth-Moon infrastructure, China is

already starting to include Cislunar space as part of their Belt and Road Initiative. They are talking about a spatial information corridor, including building partnership 132 member nations of the BRI. Is the U.S. doing something similar or is it trying to build that kind of infrastructure? I think the U.S. needs to articulate a much more visionary leadership beyond just data sharing, and I think that that should include a clear articulation of why the U.S. is investing in EarthMoon infrastructure, why it's important for U.S. allies and partners, and how they will benefit from this particular enterprise. The Artemis Accords tries to do this a bit, but it is interesting to me that even when it comes to the accord where it talks about space, lunar resource utilization, safety zones, countries can keep the resources they have based on the outer space treaty stipulation and the U.S. Commercial Space Launch Competitive Act.

**Expert 5:** [00:43:06] Even then, a country like Luxembourg, which is a lead actor in lunar resource and space mining legislation, decides to join BRI as well. Right. It joins Artemis, but it's also joined and signed an MOU with China. Exactly your point. So private companies and U.S. allied nations will look for the economic clarity. BRI is offering them the economic clarity in terms of space infrastructure. They will put a hand there as well. And private I mean, these are these are states doing it tomorrow, as you said, you'll have private entity that will look at, ok, this is a possibility. I mean, that's happening on Earth, right? You have so many Apple and Tesla manufacturing in China and so a very similar environment can repeat itself in space. Once China has the infrastructure, you will obviously go to the country that gives you the best service for the least cost.

**Researcher:** [00:44:05] Right. And they've borne that investment in that infrastructure. So now if you are a commercial person wanting to do something in this zone, you don't have to invest in that infrastructure exists now. You just pay a service fee for whether it's comm or navigation or

freight back and forth, just pay by the pound to shuttle it. This is a race to see who's the first to establish this. I'd love to see, in the future say, we will build infrastructure X, infrastructure Y, and infrastructure Z, because those are the most important and we will have them done by this date, this date and this date, and then we will have them commercialized by this date, this date and this date, very, very clear of what are you going to build, when is it going to be done and when is it going to be commercialized and then let somebody seed that. I just don't know if we're on a path to do that. I don't see it.

**Expert 5:** [00:45:12] Yeah, I. I'm still waiting for the Biden administration to come up with another policy document on Space. I know they have released two, I think, but they're not very, very ambitious.

**Researcher:** [00:45:25] Yeah, so, you know, there's hope. Again, you've got this infrastructure piece and then the SpaceX piece. He's got this build back Better World Initiative going on, which is exactly the coalition to go head-to-head with China and offer alternative infrastructure financing deals and that sort of thing. If he would only put Space into that and expand that out to be build back better domains rather than this continuation of spaces over here in this infrastructure, things over here, it just needs to be blended together in both policy and implementation.

**Expert 5:** [00:46:13] I think one way where Biden -- actually so you know there is the quadrilateral security dialogue where you have India, U.S., Australia and Japan coming together. And so, the last time they met, of course space was not included. And an Australian colleague of mine, wrote this very critical piece as to how can four space faring nations, Australia being a recent entrant with a space agency, not talk about space and space cooperation. And I mean, fortunately, maybe they read this piece or maybe they realized that space has not been included

in terms of high-level cooperation but it's an interesting thing as you have countries like Japan that are investing in the space economy very heavily, India is starting to do it as well, but then the conversation in the Quadrilateral Security Dialogue was about climate change and data sharing. It wasn't about this with Japan. I mean, if you look at Japan space ambition, they want to establish also a presence on the moon by 2040. Right. They are a great country to push. India has a moon program. Australia wants to take advantage of the commercial space sector and look beyond. And yet the ambition was missing even from the Quadrilateral Security Dialogue Joint statement because the Biden administration did not want to push that. I hope they do, because this is really critical in terms of even building coalition structures that are outside of your comfortable allied partners. And so, it's critical. I think the time is now, though, at least from my perspective.

**Researcher:** [00:47:52] And I'm conscientious of the time. If you were to give me some thoughts as to the biggest challenge facing the U.S. and what might be a policy way ahead to enable the U.S. to be a leader in this area. What suggestions or recommendations do you have?

**Expert 5:** [00:48:26] I think one.  Have you seen my written testimony to the Congress, the one that got published?

**Researcher:** [00:48:37] In the last. Was that in the last year?

**Expert 5:** [00:48:41] No, it was 2020.

**Researcher:** [00:48:44] Because I did read one and I don't remember the date. Did you just do one? Okay.

**Expert 5:** [00:48:48] I'll send it to you. So, I did have some recommendations then. So, I think one.

**Researcher:** [00:48:54] Was the Chinese, the China U.S.-China Economic Commission.

**Expert 5:** [00:49:00] Oh, you read that one of those recommendations still holds value today, and that is that the U.S. really needs to create a vision or plan of space industrialization.

**Researcher:** [00:49:09] Yeah, I like that word.

**Expert 5:** [00:49:11] Yeah. They completely lack it and are very don't want to say it, but I think it's really critical. And as you said, the second important thing is to set some really specific timelines. China wants to go back to the moon to collect samples from the South Pole by 2025. They are not sending humans. They are actually. And then by 2028, they want to go and, you know, basically survey the South Pole for establishing their base by 2034. They want to do 3D printing and manufacturing and by 2036, 2040. So, the U.S. also needs to identify, first of all, goals that are clear in terms of space industrialization, earth, moon industrial policy and what are the goals that they want to do in the next 10, 15 years. And it really is important to identify timelines. I think the other important thing is for the U.S. to establish this as a leadership point of view. They also need to have a bilateral relationship with countries outside of their allied partners. So very important to build partnership with Africa, for example. You know what China is doing, which is so strategically clever, and I think I am really respectful of whoever the grand strategist is behind this is that they have actually started to think about signing an MOU with the African Union who is going to establish an African space agency, right. The African Union has 55 member states. They are also member states of the United Nations, which means they are going to vote as a bloc when it comes to space policy and China's efforts in space. If they sign an MOU with China, they get legitimacy, right. The U.S., I don't think is even thinking about how Africa is going to become so critical in the next 30 years.

**Expert 5:** [00:51:07] Nigeria is going to become the 14th economy in the world, according to Price Waterhouse Cooper, and Nigeria is investing heavily in its space program in collaboration with China. So, building those partnership structures for looking at cislunar space with countries outside of, say, the Artemis Accord signatories is very critical. And I'll finally end by saying that a way to showcase seriousness is to direct the U.S. Space Force to develop operational concepts for cislunar space. So, if you look at the doctrine of the U.S. Space Force, it's a lot about things that the U.S. Space Force knows very well how to do today, and also in terms of ensuring U.S. space assets in LEO or GEO. But I think they should be forced to think as a sense of Congress to develop capacity for cislunar operations, which President Xi Jinping has directed the Peoples Liberation Army (PLA). And once your military service that is for space starts building concepts for cislunar operations, that tells your society that this is critical and important. Because I think there is a misunderstanding that policy is made at the mass level, it's not. It comes from an epistemic community that pushes forward. Right. The Cold War, who built that grand strategic? It was George Kennan, who built their entire idea of containment. It didn't come from the mass, it came from one person and then built into it where several others who actually thought about it. I mean, the whole founding of America was based on some people getting together, the founding fathers, and deciding that this is what is important.

**Researcher:** [00:53:03] Thank you. Two comments. One is and this was in conversations with a staffer, a Senate staffer, one of my friends, they said the best one to do this to build an infrastructure in a new area. Going back to your previous comment, when the U.S. was expanding West, the westward expansion and this eminent domain kind of thought and the grand strategy was keep going to the California, to the Pacific. The one that led most of that infrastructure was the military. Yeah, they built forts, they set up telegraph lines, they set the

railroads in place. They had Pony Express for mail service. That infrastructure, initial infrastructure was really done by the U.S. military. And quite frankly, in all wars the U.S. military is really good about going in and setting up little towns that are infrastructure. Probably not the first choice of doing it in the space environment because that might be provocative. But as far as competencies go, they are really good at planning out an infrastructure and a logistics supply chain for that. And I agree completely. They should be partners with NASA who has core knowledge in this area. But really, the DoD is the expert in setting up infrastructures and supply chains and that sort of thing.

**Expert 5:** [00:54:27] NASA and the Space Force signed an MOU in regard to the operational domain for the U.S. Space Force. I haven't done that study, but in your report, it will be very useful to see what exactly has come out of that MOU, where are they? So, they signed that MOU where they looked at space and beyond, it was a policy document they signed. And so, what have they actually done to achieve that? That was signed in 2019? I think so. Since then, what is actually happening in terms of achieving those and that's something that will be very useful.

**Researcher:** [00:56:54] I resonated with your other comment. The users of any infrastructure, whether it's terrestrial or in this future Earth-Moon zone has to be beyond just the U.S. or just allies of the U.S. to make our infrastructure useful. Whether it's on the sea or in air, it has to be a common domain that anybody can use, even maybe people you're not so friendly with, because all it is a set of standards that people comply with. Whether you use GPS in your airplane to navigate or whether, you know, you might not like it, but it's just a set of standards. And I think that the U.S. will be dead if they pursue a strategy of infrastructure development and they try to do it just to support DOD or NASA or the U.S. industrial base, and they don't consider users of

that to be well beyond their allies, to make it a common use public infrastructure that any paying person can use unless they do something wrong. And we all know.

**Expert 5:** [00:58:07] Exactly, but there are. Yeah, yeah.

**Researcher:** [00:58:10] This gets into the whole purpose of this thing, right. Is to shape norms and behaviors and if you're a bad person, then you don't get to use the infrastructure anymore. And if you behave and conform to norms and behaviors, then you can use the infrastructure.

**Expert 5:** [00:58:23] I have to get to another topic.

**Researcher:** [00:58:29] Sorry for keeping you.

**Expert 5:** [00:58:30] Oh, that's all right. I really enjoyed this conversation. I think one country that I'm actually impressed with today is the United Kingdom. So, if you look at the United Kingdom (U.K.) space agency, they're actually coming up with concepts like developing operational capability for cislunar space, space based solar power. I think they've recently supported the Space Energy Initiative. They put out some videos on it. What is interesting is that they are one of the closest U.S. allies and they are prodding the U.S. to take leadership. Right, and putting out these pressure points of what should be done. So that's actually a great way of anarchistic and leadership for responsible behavior in space as well in the United Nations. So, it's interesting to see how the U.K. is actually starting to take a role that actually incentivizes the U.S. to do more. It's a very interesting development.

**Researcher:** [00:59:23] Yeah, I think the European Space Agency did a study about this whole topic a year or two ago, how to set up infrastructures. They had a niche thing. I think they were looking at calm and nav. Right. Ma'am, thank you very much. I greatly appreciate your time. It's been extremely helpful and very interesting, and I'd love to chat with you in the future about this or any other subject because it's just been very nice.

**Expert 5:** [00:59:48] Best of luck with your thesis. Great achievement.

**Researcher:** [00:59:54] I'll make sure you get a copy of it when we're done and maybe it's helpful for you in the future.

**Expert 5:** [01:00:00] Absolutely, absolutely. Thank you so much and have a good evening.

**Researcher:** [01:00:03] Thank you. Bye.

## Appendix G

Expert 6 Transcript

Interview 24 March 2022

**Researcher:** [00:00:02] Okay. So, as I'm recording. So. Okay. Well, the first of the four themes that I came up with looked at national security policy, national space policy. I also looked at the NASA budget just because I didn't want to get into the DoD budget too much. First of all, there's not a lot of system stuff going on in that area. So, I just kind of wrote myself out of the DoD budget and the first theme that I was looking for, since it's really about cislunar. I keep using that term but I'm going to use the China or the Indian term Earth-Moon Zone infrastructures to include the cislunar void, but also lunar orbit and the lunar surface. So, I didn't focus on asteroids and going to Mars and things like that, it was really how to industrialize this Earth-Moon Economic Zone area, which is kind of where China thinks they want to go in life. And the reason…

**Expert 6:** [00:01:08] So can we talk about that for a second?

**Researcher:** [00:01:10] Yeah. Infrastructure competition comes to light because there's China's goal of this BRI Silk Road thing to develop those infrastructures.

**Expert 6:** [00:01:19] So I'll just go record saying I am skeptical of that. I see that being touted by people here in the U.S., but there are all the same people that a have been trying to get America to do that stuff for decades and are people who are extremely hawkish on China. So, I think there's a selection bias there about who's talking about this and who's promoting this. I am skeptical that that there's a lot of buy in within China on this. This is a huge national initiative. I think it's more a reflection of the same sort of space advocates within the Chinese government selling this to the non-space political leadership, or at least trying to sell it to them. We saw

similar things happening in the U.S. during the Apollo Program. Keep in mind that Kennedy didn't give a rat's ass about space, he was looking for a competition we can win. And he was evaluating a whole range of them and the one that came out of that was a human space, human mission to the Moon. Same thing on the Soviet side. They didn't actually start a Moon program until 1963 or 64. It wasn't until they realized, oh, the Americans actually are serious about this Apollo stuff. I'll just put that out there, that kind of frame our remarks that I am skeptical that China is all bought in and sold on this mainly because I'm not sold there's a huge amount of value to the Earth in doing all this. I think there's potential. Right. Absolutely. Some interesting potential. But it's by no means guaranteed that there's going to be huge societal, economic, political, technological benefits from all this stuff. So, let's put that out there and I'm sure happy to expand on that if you want. But I'm assuming that going in, you're sort of assuming that this is the thing that China is doing. And as I understand, you're looking to see how the U.S. is reacting to it. Is that sort of the main premise?

**Researcher:** [00:03:34] That's it. Exactly. They certainly are doing it in the terrestrial world, for sure. They are certainly spending money to do something in space, whether it's for prestige, absolutely or there’s different motivations there. One that pops up that's related to this obviously is economy, some economic power and economic gain from this.

**Expert 6:** [00:04:03] Absolutely.

**Researcher:** [00:04:04] But yeah, you hit a good point connecting the two terrestrial infrastructure investments and space. And again, in this context space beyond LEO. infrastructure investments, certainly even in the U.S., that's a harder connection to make. And without just looking on the surface of China's discussions, you can see that discourse going on. So, you never know exactly what's going on in the China bureaucracy.

**Expert 6:** [00:04:39] In my sense is, look, it's certainly a big part of that. For example, Beidou, right. They want to get all the same benefits we've gotten from GPS. They look at, depending on how you measure it, $40 billion a year in direct economic value, $1T a year of, you know, three or four layers down value that we get from GPS. They would definitely like to have that. I think there's a much stronger connection in China to regional and local economic development. You see all this competition between cities and provinces that have their own kind of mini space programs. And they're pushing things like they're heavily involved in the GW net, their version of the broadband Internet constellation. Right. So again, they're looking for jobs, infrastructure, economic development. But a lot of that is the jobs to build this stuff and sell this stuff, not necessarily from the space stuff itself. So absolutely, they're looking at that. Question is, is it going to materialize? Right. Is this sort of the broader question?

**Researcher:** [00:05:56] You don't see all the homework behind the study here. But I tried not to make this a competition too much with China. It was really a… let's for the for the sake of assuming something… assume that China thinks they're going to do this by 2049 because that's what they say they're going to do. But rather than get in a net assessment, to use a word, between China's capabilities and the U.S. capabilities and who's landing things first and yadda, yadda, yadda, I just took the premise that it is what it is and what's needed to get the U.S. policies related to these Earth-Moon Zone infrastructures in place by 2049, whether competition was there or not? Certainly China, if you believe it creates competition if you don't believe it, that's different. Make sense?

**Expert 6:** [00:06:59] I think it kind of does. Right. And certainly, in the discussions I've been involved here around the D.C. area for the last several years, you can't get three words into a space conference without China coming up. Right. So there certainly is an element politically.

There absolutely is an element of competition there. I think some of that is because there is a crowd of people trying to create that right there. They're space enthusiasts who are pissed that we haven't done anything since the end of Apollo, that we just keep going round and round in LEO, and you've seen that happening for the last ten years. They're, trying to put up China as sort of look they're doing we've got to go do it things. They're trying to drive that messaging. But absent that, there is a much broader China competition outside of the space world that's already there and well established and very bipartisan. So even if the Space thing I think might be a little manufactured, it certainly is getting traction, I think, because of the broader competition concern outside of China, outside of space between us and China.

**Researcher:** [00:08:16] And I would also even ask it like this if you don't believe this space competition, and I'm not saying you do, I'm just saying if you don't buy into that that deadline for this strategic competition that's been set up for space, then let's just look at the U.S. policy and let's look at the U.S. activities and let's say if not 2049, then when is the policy sufficient to get the U.S. to create some infrastructures in this zone, whether 2049 is a date and driven by a competitor or whether it's not a date driven by a competitor. But at some point, you can't keep spending money without dates.

**Expert 6:** [00:09:03] How long you've been around the U.S. government for?

**Researcher:** [00:09:07] Well, you probably saw my notes in some of the other sections.

**Expert 6:** [00:09:10] I did.

**Researcher:** [00:09:11] The dates out of the budgets, but we're still spending money, so no, that one. Yeah.

**Expert 6:** [00:09:15] So that's the question. Is your time horizon for this, right. So, like I said, my work focused on some specific decisions in the interagency process. So, my time horizon

was on the immediate before the interagency process. And then a couple of months after the process concluded and the decision was put out. So that was my time frame. So, you are starting in 2017 with that year's five-year plan, I think it was right?

**Researcher:** [00:09:49] I recognize that there was chatter in China in 2013, but I took it as when they put it in their constitution in 2017, that was the starting point. Because, well, I had to pick a starting point.

**Expert 6:** [00:10:06] Of course. No, what? I mean. Absolutely.

**Researcher:** [00:10:08] And so like any good intel person, yeah you would listen to the chatter that's important in 2013, but when they put it in, you know, government documentation and their constitution is somewhat official, then you've got to kind of take them seriously. So, I zeroed in on the 2017 date. And why that's important, obviously, is which administration does that clock start? And you start looking at things and it just conveniently, conveniently lined up with the Trump administration recognizing that Obama obviously had some stuff going on in his as well. That, to your point because I saw your earlier email, was probably related to more I would just call near-Earth counterspace.

**Expert 6:** [00:10:57] Yeah. Well, that and also there's also the really pressing, really difficult question of how much of what the Trump administration did they would have done anyway. Right. Because for example, Scott Pace. Right. We know his history. I know him very well. You know, you knew the moment he came into the Administration that SPD-1 was going to be that directive because he'd been talking for several years after that point about how the only thing he didn't like about 2000 national space policy, was how it shortchanged the human spaceflight program. It didn't talk about the Moon, so you knew that was coming, regardless of who he was working for, whether it was Jeb or anyone else. Because if you knew Scott, you knew that was

coming, right? You know, he's a Moon guy. He's an L5 society, National Space Society guy. You just knew that was coming. So, I think that is for you, one of the tricky things to figure out here is the causality, right? How much of this is if you're trying to do that, how much of this is caused by what China is planning to do versus people that kind of want to do this anyway? And they and I would say what China is doing is sort of enabling it, right, if that makes sense. Right. Because in the public policy, we'll talk about the policy streams theory is a pretty big one… You've got sort of a problems stream, solutions stream, and a political stream. And I would say in that framing, certainly China saying they're going to go do this helps with that political stream. In terms of raising and getting this on the policymaker's agenda and getting them to back it, even if they don't care about space, they might care about China. And that might be a useful, useful hook there. So sorry, I just put that out there.

**Researcher:** [00:12:54] I'm going to key in on your thoughts here. So, let's take China out of the equation. So, I certainly see Scott's fingerprints in a lot of policy and activities. Let's say China again, take it out of the equation, what I'm really trying to poke around at is can the U.S. lead this? And I say infrastructure's plural because there's not one. There are several infrastructures.

**Expert 6:** [00:13:28] I think of infrastructure a plural word. But I get your point. Yeah.

**Researcher:** [00:13:31] So then that's important because that implies there's a prioritization. Right. You can't do them all at the same time. And which one's first which one's most important? So can the U.S. lead these infrastructures by…at some point in the future, and I pick 2049 just because that was the date with the China thing. So, it was interesting in the policy, obviously it was fixated on the 2024 landing, but that really doesn't do a lot for infrastructures. No, the more significant date that was in the policy was the 2028 first sustained human presence. And even

that doesn't do a lot for infrastructures because as someone asked me, what does sustained human presence mean? Does that mean you go back every three months?

**Expert 6:** [00:14:19] Exactly.

**Researcher:** [00:14:20] Turn it on to see if it works. And in the meantime, you turn everything off and you put it in mothball and what is sustained and what do you need for an infrastructure, for a sustained human presence? And oh, by the way, do you need human presence for an infrastructure? So even that to me begged some policy questions and thoughts here. So aside from the human piece, aside from China, do you have any thoughts on what infrastructures, plural, are needed that could be done, should be done, or could-should…

**Expert 6:** [00:14:58] Done.

**Researcher:** [00:15:00] Before the mid-2000s, right? 2050, 2049. And do you think the policy is sufficient to enable the U.S. to put an instantiation of this infrastructure there and then operate it. Yeah. When I say infrastructure, there's probably two kinds. One is an infrastructure for infrastructure's sake, right?

**Expert 6:** [00:15:29] Like launchpads and ranges and that kind of stuff. Right?

**Researcher:** [00:15:33] There's infrastructures like you would have in a city, there's an infrastructure and you pay like T-Mobile and Verizon, and you pay for those infrastructure. So, it's more of a public infrastructure, common use for private commercialized entity.

**Expert 6:** [00:15:48] So, just before for that, I just want to say back the causality thing, the timing as I'm talking this through, I think there's a strong chance that whatever the next republican administration was, it was going to make a big Moon push even if China wasn't doing this. Think back to the second Bush administration, right. With the vision for space exploration that came about and even the first Bush administration, there was sort of discussions that didn't

really about originally, until they revived the Space Council for the first time. Mark Albrecht in that crowd, of course, obviously there's big human spaceflight, Moon, U.S. leadership kind of stuff. So, infrastructure kind of thing, right? I mean, it depends on what you're going to do, but I would say most broadly, one is space situational awareness, right? Because as people have talked about quite a bit, a lot of that right now is focused around Earth orbit. There was Cheyenne Mountain looking for the first space control squadron, which was the predecessor to the current 18th Space Control Squadron, which is tasked to track all the stuff in Earth orbit and produce the catalog.

**Expert 6:** [00:17:11] So but all of that stuff that they do, the U.S. military did at the time and still mostly today is basically a little bit above GEO and in. That's what they're tracking, not just their awareness. NASA of course, had some capabilities to do tracking beyond that, but they're a different sort. It's mostly around Tracking, Telemetry and Communications (TT&C) kind of tracking of live vehicles. They don't really do the sort of broad environmental tracking of all the stuff that the DoD does for an operational mission. And so, as there's more stuff going to lunar orbit and in cislunar space, there's going to be a need for better SSA to support everything going on there. So, I say that's more of an infrastructure for infrastructure, kind of category. The other is just comms stuff, right? Being able to provide TT&C and comm relay for lunar and cislunar missions is still kind of a challenge. There are some things out there, there's some commercial services today in addition to the government stuff. But that itself is just basic infrastructure to enable those activities. Right. Can you have spacecraft operating in that space and have them getting stuff back to the Earth, given the fact that the Moon moves? Right.

**Expert 6:** [00:18:44] And so, you know, it's always kind of challenging. The third is some sort of a GPS equivalent or PNT for the Moon itself. Just because you're going to do an activity, it's

nice to kind of be able to know where you are. And while GPS is great, it's actually a global satellite. Navigation services in general are great. They're the ones we have in operation are all Earth-centered. And so, something like that for the Moon would probably be necessary. So, off the top my head, those are the three big ones that I would say would apply to all space activity on the Moon. Not necessarily human. It's like human habitation and remote sensing and robotic science and rovers and all that kind of stuff. I guess there's an open question as to whether or not the United States needs to develop all of that by itself. And I guess I'll ask get clarification for you. Is that what you're hitting at or are you talking about sort of the U.S. playing a role in doing that? Just kind of explain that a little bit, what you're looking for there or what the premise is, at least I think.

**Researcher:** [00:20:09] I think for the U.S. to develop it for U.S.-only purposes is not going to create any kind of national power. Certainly not economic power. The U.S. to create it for and with their allies. Maybe more commercial allowing it to be used by anyone like a public infrastructure? Any government and any commercial user. Yeah. Now you're talking, right? Let's say, you know, you're transiting the…

**Expert 6:** [00:20:41] Ocean.

**Researcher:** [00:20:43] And the U.S. put GPS up there, but you could go buy a commercial service that translates the GPS and puts it on your navigation screen or whatever. Yeah, but China does that. Russians use it. You know, there's it's free use, right? So, the economic return on the person that made the box or the company that built the box or whatever, it is really, really large. So, I guess what I'm I guess hopefully I've clarified that that it really isn't just for U.S. ownership and U.S. use to really maximize value to the U.S.  It would be available for others to use.

**Expert 6:** [00:21:32] Yeah. Okay. So. So. So. Yeah.

**Researcher:** [00:21:36] To buy that, it's got to be commercial, right?

**Expert 6:** [00:21:39] Yeah. So, so to that one, I want to talk about whether or not the U.S. needs to create it. I think that's a questionable assumption and certainly the U.S. needs it to exist. I think the question is what the U.S. role should be and whether or not possible. But just picking up your GPS thing, I'll just say that that there is a whole sordid policy history behind GPS in there. It started as a DoD program. It still is a DoD program. There's lots of policy debates along the way about whether or not it's opened up, whether or not because originally they had a random up to 100-meter error on the civil signal and there was a huge. So that was actually the policy debate in the Clinton era. Do we turn do we turn that off or not? And it was knockdown, drag out between the DoD and FAA over that. The DoD did not want to take that off. And it ended up that the White House stepped in and basically kind of forced that to happen. But there was there was no real appreciation of the potential socioeconomic value of doing that.

**Expert 6:** [00:22:52] It was basically you're going to create military threats for us. Don't do this kind of a thing. And then the second fascinating piece, because relevance here is the Bush era. The big GPS decision is what do we do with Galileo? Do we try and kill it dead? Or do we collaborate with the Europeans? We tried to kill it dead. It didn't die. So, we ended up kind of cooperating with them in that today there is an international entity, the International Global Navigation Satellite System (GNSS) Committee (IGC) that all the major countries are working through to create a common civil signal for all the genes. Galileo, Glonass, Beidou, GPS, Indian Regional Navigational Satellite System (IRNSS), etc. So that they're all going to be broadcasting a common civil signal, but they all have separate and competitive military signals. That was sort of how we worked out that thing. I can totally see that happening for different kinds of lunar

infrastructure, particularly like a lunar sort of navigational system. Back to whether or not the U.S. needs to build this and own this. I think the I mentioned earlier the W. Administration's vision for space exploration is a kind of interesting example here when they pitch the Constellation program, it was very U.S.-centric in that we explicitly said that only America is going to be on the critical path for all the fundamental technologies and capabilities.

**Expert 6:** [00:24:47] And we sort of invited other countries to come along for the ride. But we would be building all the critical stuff ourselves. And it didn't go anywhere. It didn't get any buy in from Congress. We still have pieces of it lingering around today, Orion and that kind of a thing. But the program as a whole didn't go anywhere. Contrast that to the Artemis program, where the U.S. has been much, much more open to other countries participating and contributing capabilities. I have not been directly involved in those discussions, but I've talked to people who have and from the very beginning they were, hey, what can you bring? What can you contribute? Let's do this in a more collaborative fashion than the plans under Constellation. I think that signals the political economic challenges of the U.S. going it alone and being the entity that builds the infrastructure going back to the Moon, while also kind of giving a nod to the soft power benefits of letting other countries participate in this more fully.

**Researcher:** [00:26:17] In the document analysis. I didn't see anything that would preclude coalitions and allies.

**Expert 6:** [00:26:32] Yeah, yeah, yeah.

**Researcher:** [00:26:34] And as for Biden, it's even got more. Right? Yeah. So, yeah. So, to your point, I don't see any, I didn't see anything in the policy that specifically precluded other nations from participating.

**Expert 6:** [00:26:51] Absolutely. But I'm saying it's different than precluding the messaging that we are giving to other countries is fundamentally different for the Gateway and Artemis (because they're kind of separate programs at the moment) and what it was like for a constellation. Right. So, for example, for the Artemis the Europeans are building the service module, I believe. Right. You know, it's not going anywhere without that. That's sort of a piece of critical infrastructure for those missions, and the Gateway is international right. The Canadians just announced that their contribution is going to be a Canadarm 3 for the Gateway. And I'm guessing that like with the Canadarm 2 on the ISS, we're probably not going to be able to fully assemble and do the stuff we want to do at Gateway without that arm. That's kind of a critical piece of infrastructure for that arm, not, of course, for the whole Earth-Moon system that you're talking about. So, you know, and of course, the details and Artemis are not out there publicly. We've talked about our piece of it, which is the Orion and the human lander system that is being procured commercially and stuff.

**Expert 6:** [00:28:20] I think that you're not seeing a lot of public documentation out there on what other countries are doing because they're still trying to figure that out. I know that all those countries that have the (18 or 19 nowadays), that have signed on to the Artemis Accords and there's kind of two parts there. There is the public endorsement of the principle, the endorsement of the public principles in the accord which is sort of common for everybody. But there's also a bilateral piece of that which outlines what each country is contributing to the Artemis program and what they get in return. So, if they're contributing, I don't know, a rover, they get X amount of science time on something, something along those lines. None of that stuff is public. That's all sort of a bilateral MOU. I'm sure it'll be public at some point, but for the moment it's not. Which probably makes it difficult for you to do what you're trying to do. But I know those discussions

have been happening because I've talked to people both in the U.S. and the other countries that have been involved in this stuff.

**Researcher:** [00:29:35] Going back to your…well I won't go back to SSA because that would be a lengthy conversation.

**Expert 6:** [00:29:41] It would be. I'm just saying that I think pretty much everyone agrees that that's kind of an important piece of infrastructure. Right. Right. Knowing where stuff is.

**Researcher:** [00:29:48] Oh, yeah. That was fundamental.

**Expert 6:** [00:29:50] Foundational, right?

**Researcher:** [00:29:51] Yeah. Do you think NASA is, it's certainly the only choice other than DoD, but do you think NASA is the right agency to build these to enable these infrastructures? I won't say build.

**Expert 6:** [00:30:17] Yes because I think they're the best choice among what's available. And that's because I don't think this is appropriate for the DoD in general, this sort of Earth-Moon lunar infrastructure. I am, I mentioned earlier, sort of not yet convinced it's going to be all that big of a priority in general. I'm even less convinced it is a military priority and something that DoD should be focusing on. They have far more pressing issues to deal with just in GEO and inside. The one area that I could see them having a bit of a role is in the SSA mission. And that's because there are some hypothetical, but actually possible cases where you can put something in a cislunar orbit and have it sort of come back around and potentially collide with something in the GEO belt. I don't think anybody's going to do that because it doesn't really make sense for a whole host of military utility reasons, but it's potentially possible. So, yeah, I could see I could see the military playing potential role in the SSA mission, what they call XGEO, to help detect potential threats.

**Expert 6:** [00:31:52] But I'll submit they shouldn't be leading there for the exact same reasons why I've said for a decade now they shouldn't be leading in the Earth orbit SSA mission. And if you want a reference on that. I will give you a link to. Something I wrote? Not quite. In September. It'll be a decade ago. On the problems with the military leading the SSA mission for Earth orbit. Basically, culturally, they can't keep up with the pace of innovation. They can't modernize their systems fast enough. And their risk averse, security focused culture prevents the kind of data sharing and collaboration that you need among all the actors in that space. And that's all that stuff is still true today, even though I said it set at ten years old. So, for that reason, I think the DoD, even though they probably should have a role in the SSA mission, going to again what they say XGEO. I do not think they should be leading it because they're going to bring back all those same problems now.

**Researcher:** [00:33:16] They should have a role in architecting it, certainly putting the whole infrastructure in, not leading it, but just a role.

**Expert 6:** [00:33:28] I don't know. Again, I am I am not sold that there's military value in the move. I know, I know that's in their space community. That's sort of an outlier position. But I just I look at all that stuff, then I compare it to, you know. The other priorities they have here on Earth and the problems they have to focus on. And I'm not sure it’s there. And then of course there's the added challenge of it's illegal for the U.S. military to do a lot of stuff on the Moon and under the outer space treaty and a couple of other treaties that were parties to so. I'm going to have to say no, I don't really think they should have a role in that unless there is more of a well-defined. Military mission or role there. And I'll say that I met someone at U.S. Space Command who said that they don't actually have an operational requirement for this mission. So, CHIPs are this AFRL mission to do this cislunar SSA. There's a whole lot of bad optics around it, but

basically it will do highway patrol for cislunar space. Now it's being done by AFRL, and the Space Force is sort of supporting it. But they're not the warfighters, right? It's not their area of responsibility (AOR), they're not conducting mission, the operational mission.

**Expert 6:** [00:35:14] That's U.S. Space Command's Area of Responsibility (AOR), they're the warfighters and operators for space. And they don't have an operational requirement for that. They're not really looking at doing that. Now. I don't know if that's maybe because they're still figuring that out, but they don't have one. So, to me, that CHIPs is a clear example of how much of space people in the Space Force are like, let's go do cool space stuff even though the warfighter who's supposed to be driving our investments doesn't actually think it's a requirement yet or an important thing to do. I think that's certainly not the first time that's ever happened in the history of the Army, the Navy and the Air Force. There're tons of examples of the Services developing capabilities and platforms that they want to build that are not necessarily what the warfighters are asking for. That's sort of a thing. And I would say this struck me as a pretty good example of this. But I would just say note the lack of U.S. Space Command talking about Cislunar Highway Patrol System (CHIPS) and the lunar patrol mission.

**Researcher:** [00:36:46] How about other agencies participating with NASA or even in the upfront architecting of this?

**Expert 6:** [00:36:54] So I mean, the one obvious one that stands out is the Department of Commerce. Right. Because. Since 2017, 2018, they've been slated to play a much bigger role in sort of U.S. space activities in general. And if you I think we all sort of envision industry and private sector playing a much bigger role in all space activities, including Earth, Moon and lunar stuff, then yeah, I think they would have to play a role there. They may even be a candidate for the lead because they can bridge sort of the government side and the private sector side. The

challenge is exactly the same challenge we're having with them taking the lead or anything else is at the moment they've got like one and a half people, right? And they have no leader and they're shoved down five layers down inside of NOAA you know, it's so this gets to my personal frustration over the whole space traffic management thing, which is sort of one of my pet projects. We had the Obama Administration sort of working on that in 2010. They didn't actually publish a decision, but they laid the groundwork for SPD-3 that came out in June of 18 under the Trump administration that sort of formally gave Commerce a lot of this.

**Expert 6:** [00:38:22] And they started getting a much higher priority. But Congress didn't actually appropriate the funds for that until December 2020. And then you had transition, which was made even worse. And all of that stuff in the Department of Commerce was largely enabled by the political entities, Secretary Ross, Vice President Pence, Kevin O'Connell. And once they changed and left office, there was not nearly as much buy in at the at the civil servant level. And so now we're coming up on four years since SPD-3 came out and hardly any of it has been implemented because of all these factors. So, for example, Congress, even though they appropriated a little bit of money for this civil SSA pilot program. They didn't give the Office of Commerce, any new authorities to do the oversight piece, the mission authorization piece that we've been talking about for four years. So, yeah, I think commerce is on the list of potential entities to be involved in this, potentially even the leading entity. But I'm skeptical that that's going to happen because they just don't have the resources. They don't have pretty much anything going on at the moment.

**Researcher:** [00:40:03] And you start talking about resources, is it a threat?

**Expert 6:** [00:40:09] Potentially, yeah.  Although for the Commerce, it's a little bit different. Right. Because there's is I mean, of course, you could sell it as it's a China threat, but you could

also sell it as, hey, this is a socioeconomic value to the U.S. Right. And they can they there's plenty of stuff they do on that line of reasoning where there isn't some sort of big global national threat motivating. They have a whole other line of argument that they can bring in, which is the economic value.

**Researcher:** [00:40:41] Right. And by the way, when I say threat, I don't necessarily mean military. In this case, it's completely economic.

**Expert 6:** [00:40:50] Threat. Okay. So, you made economic the threat.

**Researcher:** [00:40:52] Oh, absolutely. The whole premise of this study is it's not a military threat per se in the cislunar area. I mean, there's piece parts of it and it’s all national security, but the competition is for economic supremacy and power.

**Expert 6:** [00:41:05] Yeah, no, I get that. I get that.

**Researcher:** [00:41:08] I'm just saying, NASA's the right entity to lead the charge on the infrastructure to win the economy. Or to your point, DOC?

**Expert 6:** [00:41:20] Yeah. Sorry. Your staff can probably get that.

**Researcher:** [00:41:23] Entity to at least architect it with industry. Because it's a matter of global traded.

**Expert 6:** [00:41:31] I'm pretty much I don't know. That's like saying the I don't know the economic threat that is Antarctica. I don't know. Again, I know we have lots of different opinions on this in the space community.

**Researcher:** [00:41:48] Well, coming up on the hour here, I don't want to take all your time.

**Expert 6:** [00:41:52] Yeah, and I'm sorry. I'd be happy to talk longer, but I've got a 1:00. But is anything else?

**Researcher:** [00:41:57] No. Do you have any other thoughts on this matter or what might be the recommended way ahead to establish policy, regardless of whether it's a China competition or not, but to establish these infrastructures for some sort of economic benefit to the United States?

**Expert 6:** [00:42:14] Yeah.

**Researcher:** [00:42:15] How do we get it moving forward?

**Expert 6:** [00:42:18] So I would say that's a really challenging question. I'm going to talk about it through analogy, and the analogy is to orbital debris removal. Which is something that I and others have been talking about for quite a while and isn't happening at all. As far as I can tell, the reason it's not happening because it's nobody's job to do that. There isn't a government agency that's tasked to manage the space environment, including cleaning up orbital debris. NASA is operating there, and they care about this a little bit in the case of protecting the space station and their assets don't really care about it. Beyond that, saying the DoD. Right. They care about it for detecting threats and operating the stuff, but they don't really care about cleaning it up. Now, both have said different degrees. And actually here, the more that cleaning up is important, but not important enough for either one of them to put in a budget request to go do it in a serious manner. And as far as I can tell, that's because I'm a big organizational behavior, organizational culture or process kind of a guy, that's the big thing that came out of my doctoral work is that when they do their internal rack and stack right. And it goes up against all the other things that they want to do, it drops off the table because it's not in their mission statement and it's not an existing constituency. And so, when it gets compared to the rack and stack, nobody's going to fight for it.

**Expert 6:** [00:44:01] They would have to take it out of hide because Congress isn't giving them money to go do it and it doesn't get done. And so, to change that, the latest argument I've been on

is you change that by getting Congress to change the mission for an agency to include managing the space environment. And once you do that, I think that is what sets the wheels in motion, because now the agency has to go do something and so they can submit budget requests even better. If Congress gives them the mission, it gives them some money. Right. Because that's the key that unlocks at all. But even if it doesn't come with money, they now build an office. That office now in the next president's budget request puts in it and says, we are mandated to do this, and they start fighting for stuff and it's not going to happen immediately. But that's how I understand it to get that change. The other way to do it is creating a new entity. This is the Space Force argument, the thought being that the Air Force in general doesn't give that much of a crap about space. They're not going to care about all this. So, we need to get out from underneath them in order to have our own say and go out and do our own thing. That is possible. But man, it takes a lot of political will and political capital to do that.

**Expert 6:** [00:45:37] And you saw it pretty much it took Donald Trump to do that, not because he really cared that much, but because he saw it as a legacy thing, and he was able to arm twist and force all the Republicans in Congress to go along with this. And so now we have it. But man, absent someone with that kind of political clout who's willing to do that, that level of organizational change is huge. And I'll close by saying a lot of us are making the same case for the Office of Space Commerce that tucked down underneath this office, underneath NOAA. It's being stifled by the broader bureaucracy. And NOAA that doesn't care about any of the stuff that commerce does. He's got to pull it out and make it a separate Bureau of Space Commerce. That argument has fallen on deaf ears for four years now because there's no political champion there. There is no one who's willing to force it through and has the clout to be able to force it through. So, anyway, so that's long sort of anecdotal way of answering your question about how do you

make this happen? I think it happens through the organizational behaviors, which means changing the mission and existing organization and building a constituency to start, then arguing for it through the traditional budget process or by creating a new organization. A la the Space Force model who could then go off and do that?

**Researcher:** [00:47:15] I agree. I think a lot of that came out of my analysis, too, was put somebody in charge and there's choices.

**Expert 6:** [00:47:24] Absolutely right. Just like this whole civil SSA thing. Right. Should it be a NASA thing? Should it be a Commerce thing? Is it a governmental thing? So, yeah, it's very similar.

**Researcher:** [00:47:35] Architecting infrastructures around the globe. The U.S. does know how to do that on Earth, in space, maybe not so much.

**Researcher:** [00:47:48] Okay. Well, I'll let you go to your meeting. Thank you very much for your time. I appreciate it. And I'll let you know how this turns out.

**Expert 6:** [00:47:56] Appreciate it.

**Researcher:** [00:47:56] Good luck. Thank you very much. Bye bye.

## Appendix H

Summary of Reconciled Results

| No Changes Needed | Changes Needed to Existing Policy | New Policies Needed |
|---|---|---|
| **1.** The U.S. should continue commitment to safe, secure, stable environment to attract U.S. private capital and investment to the Earth-Moon Economic Zone.<br><br>**2.** The U.S. should continue the Trump policy and extend SSA to deep space and consider SSA as a U.S. infrastructure for the Earth-Moon Economic Zone.<br><br>**3.** The U.S. should continue the Trump policy to strengthen U.S. space leadership but focus it on developing U.S. infrastructures in the Earth-Moon Zone before others.<br><br>**4.** The U.S. should continue policy to ensure freedom of movement in the future Earth-Moon Economic Zone to ensure the free movement of goods and services on Earth and in space.<br><br>**5.** The U.S. should continue policy to lead technology standards to ensure future Earth-Moon infrastructure standards are U.S. based.<br><br>**6.** The U.S. should continue to promote growth of commercial space but focus more on development of the Earth-Moon Economic Zone. | **1.** The U.S. should develop a unified and seamless infrastructure competition strategy and awareness policy across all infrastructure domains that China seeks to lead.<br><br>**2.** The U.S. should continue the Trump policy to continually ensure responsive regulatory review and establish a date to complete the Biden regulatory reviews so as not to impact the development of Earth-Moon Zone infrastructures.<br><br>**3.** The U.S. should include the Moon in planetary contamination policy and consider it a future Earth-Moon Economic Zone environmental infrastructure to support all sustained human presence on the lunar surface or in lunar orbit.<br><br>**4.** The U.S. should include initial and sustained operational dates for government and commercially aligned programs in **policy** for specific Earth-Moon infrastructures to be operational before 2049 including:<br>• A definition of sustained as human, robotic, and provide operational availability.<br>• Priority infrastructures for the U.S. to develop.<br>• Public-private partnership infrastructure opportunities.<br><br>**5.** The U.S. should include initial and sustained presence dates for government and commercially aligned programs in **budgets** for specific Earth-Moon infrastructures to be operational before 2049. Budget requests should support policy dates and enacted budgets should update and reflect the new dates. | **1.** The U.S. should direct NASA or an independent body to perform an assessment on the appropriate acquisition and ownership model to ensure U.S. Earth-Moon Economic Zone infrastructures are commercially viable and economically competitive by 2049.<br><br>**2.** The U.S. should create an industrialization plan to develop Earth-Moon Economic Zone infrastructures by 2049. The plan should include:<br>• An interagency approach, identifying lead and supporting agencies to include industry for a whole-of-nation approach.<br>• Identification and prioritization of Earth-Moon Zone infrastructures to complete by 2049.<br>• An architecture for commercially viable infrastructures.<br><br>**3.** The U.S. should create an economic strategy to articulate the vision, priorities, return on investment, and resourcing needed to ensure the U.S. can develop Earth-Moon Economic Zone infrastructures by 2049. Consideration should be given to the National Economic Council to lead its development. The strategy should include:<br>• An interagency approach.<br>• An end-state economic vision for the U.S.<br>• Economic purpose and priorities for the U.S.<br>• A national resourcing strategy. |