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I. INTRODUCTION

On January 14, 2004, President Bush announced a multi-decade long "Vision for Space Exploration" that encompasses human and robotic travel to the moon, Mars, and beyond. Central to this vision, the National Aeronautics and Space Administration ("NASA") is pursuing "Project Prometheus," a program that will manifest NASA's intention to revolutionize exploration in the twenty-first century. Project Prometheus represents a tremendous development in technology. When complete, it will utilize new and highly advanced power systems, including nuclear fission reactor technology, to enable systemic and propulsive power generation in space. Eventually, future nuclear thermal propulsion applications realized under Project Prometheus would hope to cut the travel time for a human journey to Mars from three years round-trip to a mere ninety days each way. Prometheus plans to provide spacecraft and potential future outposts with thousands to hundreds-of-thousands of watts of electricity ("We"), as opposed to the mere tens or hundreds of watts currently realized (equivalent to a few household light bulbs). The amount of energy generated represents a true paradigm shift for mission planners, both due to the amounts of power that will be available for scientists to conduct their investigations and research, as well as the future ability to provide power to maneuver a spacecraft throughout its mission via nuclear electric propulsion.

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In light of such innovation and on the brink of such a fundamental transformation in space exploration, the United States has an important opportunity to engage the international community in analyses of issues related to the use of Nuclear Power Sources ("NPS") in space. NPS have been the subject of numerous recent international discussions. Most notably, at the United Nations, NPS has been on the agenda of the Scientific and Technical Subcommittee ("STSC") of the Committee on the Peaceful Uses of Outer Space ("COPUOS"). Additionally, the American Institute of Aeronautics and Astronautics ("AIAA") recently hosted a Working Group on Nuclear Power Sources for Space Exploration. With so much attention being directed to NPS issues, it is appropriate to examine international legal issues related to nuclear-powered space exploration, and further, to consider opportunities facing the United States and other spacefaring nations to ensure the prudent application of this technology.

In this article, we will first provide a brief explanation of what NPS is and how it works. The article will clarify how terms are used and explain some factual background so that the issues can be discussed with clarity. It will follow with a brief history of the use of NPS in space, illustrating that the United States and Russia (including the former Soviet Union) have employed various forms of NPS in space for more than forty years. Next, the focus will shift to a discussion of the international legal regimes governing NPS both in space and, to a limited extent, on Earth, before launch. After the international legal regime, the United States's domestic regulatory and procedural structure is examined, with a discussion of an illustrative case in which plaintiffs attempted to enjoin the US Government from launching the NPS-equipped *Cassini* spacecraft.[1] We conclude by examining several policy issues concerning nuclear power and propulsion systems in space, including the rationale and need therefor, while advocating extensive public participation and transparency in the safety reviews and decision making related to the use of this technology. Finally, the Article calls for spacefaring nations to establish and observe an international, technically-based safety framework to provide assurance to the world population that space NPS

1 *Hawaii County Green Party v Clinton*, 980 F Supp 1160 (D Hawaii 1997). The subject of that lawsuit, the *Cassini-Huygens* mission to Saturn and Titan, has recently been well publicized. The NASA *Cassini* craft, powered by three radioisotope thermoelectric generator units, maneuvered between Saturn's rings in June 2004. It later jettisoned the European Space Agency's *Huygens* probe, which successfully landed on Saturn's moon, Titan, on January 14, 2005, beaming back the first-ever pictures from the moon's surface. See NASA, Jet Propulsion Laboratory, *Titan-Bound Huygens Probe Detaches From Cassini*, News Release 2004-296, available online at <http://saturn.jpl.nasa.gov/news/press-release-details.cfm?newsID=519> (visited Feb 4, 2005). See also text accompanying notes 65–66.

will be used in a safe manner and to facilitate bilateral and multilateral cooperation on missions using nuclear reactors and technologies in space.

II. HISTORICAL BACKGROUND AND USE OF TERMS

An initial clarification of term usage is prudent. As background, it is important to note that there is a significant distinction between nuclear fission and natural radioactive decay. Both phenomena have been used to power spacecraft instruments, and (perhaps because both use certain heavy elements as fuel) space law and policymakers have long considered both processes together under the umbrella term "Nuclear Power Sources."[2] This article, therefore, does not depart from the popular definition of the terms *nuclear power* and *NPS* as they relate to spacecraft. In this section, though, it explains the history of NPS technologies, how they are distinguishable, and how they are on the brink of a new paradigm already under development known as "Project Prometheus."

A. RADIOISOTOPE THERMOELECTRIC GENERATORS

Thus far, use of NPS onboard US spacecraft has primarily been composed of radioisotope thermoelectric generators ("RTGs"). An RTG unit does not involve nuclear fission; it is not a reactor. Nevertheless, the device is considered to be a Nuclear Power Source, because it uses plutonium (primarily, radioactive isotope plutonium-238 ("Pu-238")) as fuel by converting heat, naturally generated from the plutonium isotope's decay, into electricity.[3]

Because RTGs have no moving parts and the half-life of their Pu-238 fuel is so predictable, they are a highly reliable power source.[4] The rate of decay is sufficiently fast to generate adequate heat, yet not so fast as to decay so quickly that the mission cannot be completed. RTGs are ideal for missions where

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2 The Oxford English Dictionary defines "nuclear power" as "electric or motive power generated by a nuclear reactor," and this is consistent with the term in its terrestrial applications. However, usage of the term "Nuclear Power Sources" in the context of outer space normally includes not only reactor-based power sources, but also any system that utilizes heavy elements such as uranium or plutonium to produce heat, if only from natural decay of radioactive isotopes. See, for example, United Nations, *Principles Relevant to the Use of Nuclear Power Sources in Outer Space*, Principle 3, Subsections 2–3, General Assembly Res No 47/68, UN Doc No A/RES/47/68 (1993) ("NPS Principles").

3 This technology takes advantage of a phenomenon known as the Seebeck effect, where an electric current is generated at the junction of two plates kept at different temperatures. As a result, RTGs have no moving parts. See US Department of Energy ("DOE"), Office of Nuclear Energy, Science, and Technology, *Nuclear Power in Space*, DOE/NE-0071 at 18–19, available online at <http://local.ans.org/mi/Teacher_CD/Beneficial%20Uses/ Space%20Exploration/DOE-NE-0071.pdf> (visited Jan 31, 2005). Other elements also used include strontium-90 and curium-244.

4 Plutonium-238 has a half-life of 87.7 years. After five years, approximately 96 percent of the original heat output of plutonium-238 is still available. Id at 20.

distance from the sun, extreme closeness to the sun, or sheer duration make other power sources, such as solar panels, untenable. Furthermore, the heat from natural radioactive decay can also be harnessed in its own right to protect instruments from the extreme cold of deep space, using a much smaller and simpler device called a radioisotope heater unit ("RHU").[5] The use of RHUs has become relatively common to keep instruments warm in outer space. In fact, they have been used by the US on four occasions in the last sixteen years, and numerous other space agencies have contemplated RHUs in their exploration activities.[6]

Although their resilience to the deep space environment is without fault, one disadvantage of RTGs is their relatively low power output. The first RTG unit (launched aboard a Navy satellite in 1964) produced only 2.7 We. Advances in technology have enabled new generations of RTG units, like those used on *Cassini*, to produce approximately 300 We at the beginning of the mission. While this is a marked improvement, it falls far short of the amount of power needed to enable spacecraft propulsion or provide significant power to advanced onboard systems (so-called "systemic" power), which would enable higher-powered instruments and advanced telecommunications abilities. As solar system exploration has advanced, NASA has utilized multiple RTGs for a single spacecraft. Since 1964, the United States has launched forty-four RTG units aboard twenty-five missions, including manned *Apollo* moon missions, the *Viking* robotic missions to Mars, and several robotic solar system exploration programs including *Pioneer*, *Voyager*, *Galileo*, and *Ulysses*.[7] NASA's *Cassini* spacecraft, currently orbiting Saturn, is equipped with three modern GPHS-RTG units, each capable of generating about 285 We for scientific instruments at the time of mission launch.[8] Meanwhile, the RTGs aboard *Pioneer* 10 and

5 RHUs are tiny cylindrical devices, about 1 cubic inch, weighing only 1.4 ounces. The *Cassini* mission to Saturn utilized 117 individual RHUs in various positions to heat the spacecraft, which encountered temperatures of negative 400 degrees Fahrenheit. More recently, both Mars rovers are using eight RHUs. See NASA, *National Environmental Policy Act; Mars Exploration Rover—2003 Project*, 66 Fed Reg 11184, 11184 (2001).

6 Consider, for example, the planned use of RHUs by the German Space Agency to melt through the 10–30 kilometer ice sheet on Europa (one of Jupiter's moons) to determine whether liquid water exists, making the existence of microbial life much more probable. Paul Rincon, *Plan to Melt through Europa's Ice*, BBC News (Mar 15, 2004), available online at <http://news.bbc.co.uk/2/hi/science/nature/3548139.stm> (visited Feb 4, 2005).

7 *Galileo* and *Ulysses* are robotic missions although they were both launched aboard manned, Space Shuttle missions.

8 *Cassini* and several other modern craft incorporated an advanced class of RTG known as the General Purpose Heat Source Radioisotope Thermoelectric Generator ("GPHS-RTG"). DOE, Office of Space and Defense Power Systems, *Radioisotope Power Systems*, available online at <http://www.ne.doe.gov/space/gphs.html> (visited Feb 4, 2005).

Voyagers 1 and 2, launched in 1972 and 1977, respectively, and now cruising well beyond Pluto, are still functioning predictably, generally allowing the farthest human-made objects from Earth to communicate with NASA.[9]

An advantage of the Pu-238 isotope used to fuel RTGs is its relatively low radiation level. Because Pu-238 radiates mainly "alpha" particles, RTGs require only thin, lightweight materials to shield other onboard instruments from their radiation. However, instrument shielding is not the only design consideration, as RTG-enabled missions must also contemplate the possibility of launch failure, and the subsequent fate of the onboard Pu-238 fuel. It is for this reason that the plutonium in the GPHS-RTG is encapsulated in multiple layers of protective materials, including, for example, iridium cladding, graphite, and carbon-carbon Fine Weave Pierced Fabric.

The former Soviet Union is known to have employed RTGs in multiple missions. Two Soviet lunar missions in 1969, which presumably incorporated RTGs, failed, and both created detectable amounts of radioactivity in the upper atmosphere.[10] The Soviet Union was not the sole source of accidents involving RTGs, however. The US space program has seen three accidents since it began using RTGs onboard spacecraft in 1964. The first involved an RTG referred to as "SNAP 9-a," which was launched aboard a weather satellite in 1964 and failed to achieve polar orbit. Before falling back to Earth, the RTG burned up and dispersed all of its radioactive material while still in the upper atmosphere, operating exactly as designed at the time.[11] After SNAP 9-a, the US moved to a

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9 John Cooper, *30th Anniversary Contact with Pioneer 10*, NASA, National Space Science Data Center, available online at <http://nssdc.gsfc.nasa.gov/nssdc_news/mar02/pioneer10.html> (visited Feb 4, 2005); Tony Phillips, *Voyager 1, Prepare For Action*, NASA, available online at <http://science.nasa.gov/headlines/y2004/13jul_solarblast.htm> (visited Feb 4, 2005). *Voyager* 1 is 14 billion kilometers from Earth and *Voyager* 2 is 11 billion kilometers away. Both are still communicating as of the date of this article. *Pioneer* 10 is 13 billion kilometers from Earth and sent its last signal home in January 2003.

10 NASA, Fact Sheet, *Past Accidental and Incidental Releases of Radioactive Material from Space Nuclear Power Sources* (1989), available online at <http://www.nuclearspace.com/past_accidents.htm> (visited Feb 27, 2005).

11 In the early 1960s, prior to the Limited Test Ban Treaty which prohibited nuclear testing in the atmosphere, under water, and in space, see Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Underwater, 14 UST 1313 (1963), the then-current level of knowledge about abating the effects of nuclear exposure could be summed up as: *Dilution is the solution to pollution.* In short, the safety design philosophy of the RTGs was to have them burn up and disperse any plutonium at a very high altitude over the widest area in order to minimize any detrimental effect. However, today, after forty years of knowledge and experience working with NPS, current thinking prefers containment over widespread dilution. In the event of a failed Shuttle launch, NASA has calculated the worst case "reflected pressure" in an accidental explosion during ascent to be 5,300 pounds per square inch ("psi"), and has tested modern RTGs to withstand a front reflected pressure of 19,600 psi. NASA, *Facts on RTGs and Contingency Plans*, available online at <http://spacelink.nasa.gov/NASA.Projects/Human.Exploration.and.

policy objective of "full fuel containment," and designed RTGs with the aim of completely containing all radioactive fuel regardless of the mission's outcome. The other two accidents involving American RTGs occurred subsequent to adoption of this policy, and in both cases, the RTGs performed as planned, with no evidence of radiological release.[12]

In the US, development of RTG technology continues, and NASA currently plans to incorporate RTG units into the New Horizons robotic mission to Pluto and the Kuiper Belt, scheduled for January 2006, and the Mars Science Laboratory robotic mission to the Martian surface, scheduled for 2009.[13]

B. FISSION REACTORS

More ambitious but far less prevalent in application up to now has been the development of space NPS systems based on nuclear fission reactors. The advantage of reactor-based power plants is plain: They are capable of producing more power and energy than RTGs through intense heat generated by controlled fission reactions. This heat energy can be converted to electricity and used to power spacecraft systems and onboard electric propulsion systems, or can be harnessed directly for propulsion.

The United States began experimenting with the concept of airborne fission reactors in the late 1940s both for avionics power and aircraft propulsion. By 1961, NASA had commissioned the Space Nuclear Propulsion Office to oversee aspects of its Nuclear Energy for Rocket Vehicle Application ("NERVA") program.[14] Testing under NERVA (including one NASA test of a

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Development.of.Space/Human.Space.Flight/Shuttle/Shuttle.Missions/Flight.031.STS-34/Galileos.Power.Supply/RTG.Fact.Sheet> (visited Mar 15, 2005).

12 NASA provided a more detailed account of the two subsequent RTG accidents:

> The first involved two SNAP 19 RTGs in a 1968 meteorological satellite while the other involved one SNAP 27 RTG in the Apollo Lunar Scientific Experiment Package (ALSEP) aboard Apollo XIII in 1970. Neither of these incidents caused release of radioactive materials. The two SNAP 19's were recovered from Santa Barbara Channel five months after the range destruct of the launch vehicle. The nuclear fuel was reprocessed and later re-launched in new RTGs. No release of the fuel was detected. The mission abort maneuver of Apollo XIII separated the Command Service Module from the Lunar Module. The Lunar Module containing the SNAP 27 RTG (as part of the ALSEP) re-entered the atmosphere and impacted in the South Pacific Ocean in the region of the Tonga Trench, where it remains today.

NASA, Fact Sheet (cited in note 10).

13 NASA, *New Horizons Pluto Kuiper Belt Flyby*, available online at <http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=NHORIZONS> (visited Feb 4, 2005); Christopher Scolese, NASA, Office of Space Science, *NASA's Nuclear Systems Initiative* 8 (Apr 16, 2002), available online at <http://nuclear.gov/nerac/scoleseApr02NERAC.pdf> (visited Feb 4, 2005).

14 NERVA and the Space Nuclear Propulsion Office were joint efforts of NASA and the now-defunct Atomic Energy Commission. See *NASA Historical Data Book (Volume III): Programs and*

nuclear rocket engine at Jackass Flats, Nevada) and several related efforts continued until 1973, when the nuclear rocket program was cancelled.

The US never applied its nuclear rocket technology to space operations, and to date has launched only one fission reactor power plant into space, aboard an experimental satellite in 1965 that generated approximately 500 We for onboard systems. The reactor on that test flight (SNAP 10-a) was operational for forty-three days, and now flies dormant in a three-thousand year orbit.[15] In 1983, the US refocused on development of fission reactor technology for spacecraft that would be capable of producing between 10,000 and 100,000 We (or 10 to 100 kWe). This joint effort between NASA, the Department of Energy, and the Department of Defense, known as the SP-100 Program, produced ten years of research until its termination in 1993.[16]

The Soviet Union did not demonstrate a similar aversion to space fission reactor technology. Between 1970 and 1988, the USSR lofted thirty-two radar ocean reconnaissance satellites ("RORSATs", also known as "Kosmos" or "Cosmos" spacecraft) equipped with onboard fission reactors to satisfy the energy demands of the spacecraft's instruments. The Soviet reactors were capable of generating between 5 and 6 kWe.[17] In Europe, NPS systems based on fission reactors have been researched but never applied.

While RTG units begin generating electricity even before launch, NPS systems that utilize fission reactors do not begin producing heat until the reactor core is made "critical." Because fission reactors can be designed to remain in a sub-critical (non-fissioning) state during launch and ascent, the risks of "meltdown" associated with terrestrial reactor plants can be avoided while the

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Projects 1969–1978, 376 (GPO 1988). The Space Nuclear Propulsion Office was similar in some respects to the current US Department of Energy Office of Naval Reactors, while the NERVA endeavor was, in many respects, similar to the current NASA-DOE relationship for reactor development, further described in note 23.

15 NASA, Fact Sheet (cited in note 10).

16 See generally John Barnett, *Nuclear Electric Propulsion: A Summary of Concepts Submitted to the NASA/DoE/DoD Nuclear Electric Propulsion Workshop, Pasadena, California, June 19–22, 1990*, Paper Presented to the Nuclear Propulsion Feedback Meeting, Houston, Texas (Nov 15, 1990), available online at <http://www-rsicc.ornl.gov/ANST_site/nuclear.pdf> (visited Mar 30, 2005).

17 The Soviet fission reactors incorporated into RORSAT spacecraft were code-named the TOPAZ I and TOPAZ II devices. After the Cold War, the US government purchased TOPAZ II technology from Russia for testing. See Alexander G. Parlos and Kenneth L. Peddicord, *Investigation and Feasibility Assessment of TOPAZ-II Derivatives for Space Power Applications* (May 1998), available online at <http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?1998/CR-195423.html> (visited Feb 4, 2005) (abstract only). See also American Institute of Aeronautics and Astronautics ("AIAA"), *Space Nuclear Power: Key to Outer Solar System Exploration* 10 (Mar 1995), available online at <http://pdf.aiaa.org/downloads/publicpolicypositionpapers/ SpacePower-1995.pdf> (visited Feb 4, 2005).

device is in, or capable of re-entering, the Earth's atmosphere.[18] Before becoming critical, the uranium-235 fuel used in reactors is significantly less radioactive in its natural state than even the Pu-238 used in RTGs. However, even before becoming critical, uranium-235 is still naturally (if only mildly) radioactive, and at risk of being dispersed in the event of a failed launch or unplanned re-entry, just like the fuel in an RTG. The Soviet RORSAT program suffered three accidents, including a 1978 incident involving the *RORSAT/Cosmos 954* spacecraft, which broke up over Canada and released radioactive debris over an unpopulated area.[19]

After the final Soviet RORSAT launch in 1988 and the subsequent dissolution of the Soviet Union, the application of fission reactor technology to spacecraft power systems came to an end.[20]

C. PROJECT PROMETHEUS

In 2003, NASA began an effort to "develop and demonstrate the safe and reliable operation of a nuclear-reactor-powered spacecraft on a long-duration space science mission."[21] NASA's nuclear systems initiative soon came to be known as Project Prometheus, after the Greek mythological figure who stole fire from the gods and delivered it to man.

In January of 2004, President Bush called on NASA to develop "new power generation, propulsion, life support and other systems that can support more distant travels."[22] Starting in August of the same year, NASA signed a

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18 See generally DOE, Fact Sheet, *Space Fission Reactor Power Systems: Their Use and Safety* (Feb 2003), available online at <http://www.aboutnuclear.org/docs/space/readmore/fissiontechsafety.pdf> (visited Mar 30, 2005). The NPS Principles also address the point at which a nuclear reactor may be made critical. UN, *Principles Relevant to the Use of Nuclear Power Sources in Outer Space* at Principle 3, ¶ 2.d (cited in note 2). See also text accompanying note 76.

19 See *Canada: Claim against the Union of Soviet Socialist Republics for Damage Caused by Soviet Cosmos 954*, 18 ILM 899 (1979). Canada based its claim, jointly and separately, on Article II of the Liability Convention and Article VII of the Outer Space Treaty (see discussion of the treaties in Section III) and the general principle of absolute liability applicable to "fields of activities having in common a high degree of risk." Id at 905, 907. However, the claim was settled by an ex gratia payment from the USSR without acknowledgment of legal liability. See *Canada–Union of Soviet Socialist Republics: Protocol on Settlement of Canada's Claim for Damages Caused by "Cosmos 954"*, 20 ILM 689 (1981). For further discussion, see Carl Q. Christol, *International Liability for Damage Caused by Space Objects*, 74 Am J Intl L 346 (1980).

20 Note, however, that research based on Russian technology continued in the US into the 1990s. See note 17.

21 NASA, Jet Propulsion Laboratory, *Project Prometheus: Frequently Asked Questions* (Dec 2003), available online at <http://www.jpl.nasa.gov/jimo/prometheus_faq.pdf> (visited Feb 4, 2005).

22 NASA, Fact Sheet, *President Bush Delivers Remarks on U.S. Space Policy* (Jan 14, 2004), available online at <http://www.nasa.gov/pdf/54868main_bush_trans.pdf> (visited Feb 4, 2005).

series of memoranda of understanding ("MOUs") with the Department of Energy ("DOE"), agreeing to a framework for development of a propulsion reactor program.[23] In February of 2005, NASA proposed allocating approximately $320 million of the Fiscal Year 2006 Budget to Project Prometheus.[24]

The most salient aspect of Project Prometheus is its potential application to propulsion. Aside from drawing-board efforts and limited test site experiments, previous NPS efforts involving fission reactors, both foreign and domestic, have been limited to instrumental power systems intended for Earth orbit. A mission such as the proposed Jupiter Icy Moons Orbiter, once contemplated as a primary candidate for incorporation of a Prometheus power system, would require about 100 kWe for its advanced, long-duration instruments, including an electric ion-drive propulsion system with ability to change course in deep space in response to real-time discoveries.

While the specific design information for nuclear propulsion spacecraft continues to be classified for reasons of national security, the new technological applications and capabilities of this advanced NPS technology would be unprecedented in terms of size and scope.[25]

The use of advanced NPS in outer space will revolutionize exploration. In 2003, then-NASA Administrator Sean O'Keefe said: "It's going to finally, once and for all, break the technology limitations we've been living with for so many years, of speed and capacity, to get anywhere in a timely manner to perform discovery and science missions."[26] Indeed, this was envisioned nearly a century ago by Robert Goddard, the father of modern rocketry, who in 1907 noted, "the navigation of interplanetary space depends for its solution on the problem of

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23 See NASA and the National Nuclear Security Administration (DOE), *Memorandum of Understanding regarding Civilian Space Nuclear Reactors* (Aug 5, 2004); *Memorandum of Agreement regarding the Project Prometheus Jupiter Icy Moons Orbiter Mission* (Oct 21, 2004). Responsibilities concerning design, development, fabrication and delivery of RTGs and RHUs from DOE to NASA are generally covered in the *Memorandum of Understanding concerning Radioisotope Power Systems for Space Missions* (July 26, 1991) (on file with authors). The Deputy Administrator for Naval Reactors does not report exclusively to the Secretary of Energy, but also to the Chief of Naval Operations. See Pres Exec Ord No 12344, 1 Pub Papers 97 (1982).

24 Brian Berger, *NASA Budget Request Falls Short of Expectations,* Space News Intl 4 (Feb 7, 2005).

25 The UN Committee on the Peaceful Uses of Outer Space ("COPUOS") has apparently contemplated this inevitable paradigm shift in the future use of NPS. The NPS Principles expressly apply only to nuclear power sources "which have characteristics generally comparable to those of systems used and missions performed at the time of the adoption of the Principles." UN, *Principles Relevant to the Use of Nuclear Power Sources in Outer Space* at Preamble (cited in note 2).

26 Shelby B. Spires, *O'Keefe Says Local Center's Place in Space is Crucial to Agency's Key Programs,* Huntsville Times A1 (Aug 16, 2002).

atomic disintegration . . . ."[27] As technology tends to precede law, the focus of this article now turns to the international and domestic regulatory structures that authorize the use of NPS in outer space.

III. LEGAL AND REGULATORY FRAMEWORK

In this section, we address both the international and domestic laws and regulatory processes applicable to NPS. First, we will address international law and attempt to organize the bodies of law into general categories, such as space law, nuclear energy law, and more generally, international environmental law. We then provide an analysis of both hard law (explicit, legally binding treaty provisions) and soft law (voluntary principles and declarations) as applicable, before turning to a discussion of US domestic law and process applicable to NPS.

A. INTERNATIONAL LEGAL FRAMEWORK

1. Space Law

a) The Outer Space Treaty. Manfred Lachs, former President of the International Court of Justice, once referred to the Outer Space Treaty[28] as the "rock on which all further principles and rules are built."[29] The Treaty is the cornerstone of international space law, and it has several provisions relevant to a discussion of NPS.

Article VI of the Outer Space Treaty provides that Parties bear "international responsibility" for "national activities" in outer space (including the moon and other celestial bodies), and for assuring that such activities are carried out in accordance with the Treaty.[30] Article VI also requires that such activities be subject to "authorization and continuing supervision" of the

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27 US Presentation on Nuclear Power Sources to the Scientific and Technical Subcommittee of COPUOS (Feb 2005) (presented by Ray Taylor, NASA Exploration Systems) (on file with authors).

28 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 18 UST 2410 (1967) (hereinafter Outer Space Treaty).

29 Manfred Lachs, *The Treaty on Principles of the Law of Outer Space, 1961–1992*, 39 Netherlands Intl L Rev 291, 300 (1992).

30 The Outer Space Treaty also requires that activities be conducted in accordance with international law and the UN Charter. Outer Space Treaty, art III (cited in note 28).

appropriate State Party to the Treaty.[31] Article VIII of the Treaty states generally that a Party launching an object shall:

> retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth.[32]

For purposes of NPS, then, Article VIII is relevant to the extent that: (1) a State does not lose jurisdiction over an object by launching it into outer space; and (2) objects in outer space remain subject to the supervision of the launching State.

Additionally relevant for considerations of liability for NPS is Article VII of the Treaty, which provides that:

> Each State Party to the Treaty that launches or procures the launching of an object into outer space . . . and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space . . . .[33]

Thus, under the Outer Space Treaty, a State launching a space object containing NPS would be liable for any damage caused to the surface of the Earth by its space object.

Article IX of the Outer Space Treaty requires States pursuing studies of outer space, including the moon and other celestial bodies, to "conduct exploration of them so as to avoid their harmful contamination," to avoid any "adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter," and, where necessary, to adopt "appropriate measures" for this purpose.[34] Although Article IX is primarily intended to address contamination of other planets (for example, by introducing microbial contamination), some might assert that it can be extended to address NPS contamination risks on Earth. On the other hand, a more literal interpretation of this provision would reasonably conclude that it was not intended to apply to scenarios involving contamination of Earth by matter originally *from* Earth.

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31 Id, art VI. In general, the authorization and continuing supervision provision has been interpreted to mean that States need to create domestic legislation, such as licensing regulations, or have other forms of national regulation of their nationals' activities in outer space.

32 Id, art VIII.

33 Id, art VII.

34 Id, art IX.

b) The Liability Convention. The Liability Convention[35] is the primary source of international law addressing liability for damage caused by space objects. In relation to NPS in outer space, several of its Articles deserve attention. Article I of the Liability Convention provides a description of the term "space object" that would encompass NPS: "The term 'space object' includes component parts of a space object as well as its launch vehicle and parts thereof."[36] The provision never explicitly mentions Nuclear Power Sources, and there has not yet been any clear determination or interpretation that the term "space object" encompasses RTGs, RHUs, or any reactors. Implicitly, since a "space object" *includes* its component parts, the space object would also include its heat source or power source.

The Liability Convention is further relevant because of its imposition of absolute liability on a "launching State" for damage caused by its space object. The term "launching State" is defined as: (1) a State that "launches or procures the launching of a space object"; or (2) a State "from whose territory or facility a space object is launched."[37] The term "launching State" was deliberately defined broadly to encompass as many states as possible, in order to assist potential claimant states in finding a responsible party able to compensate damages caused by a space object. The Convention sets up a regime in which a launching State is absolutely liable for damage caused on the Earth or to aircraft in flight.[38] Further, the launching state is liable for damage to a space object of another state, if its fault—or the fault of persons for whom the launching state is responsible—can be established.[39] Read together, the Outer Space Treaty and the Liability Convention make clear that the legal liability for damage caused by a space object will rest with the state launching the object or the state responsible for the private parties launching that object.

If a spaceborne NPS device were to damage another space object in outer space, a preliminary fault determination would have to be made.[40] In this regard, discussion of the legal issues related to an internationally agreed safety framework is most relevant. As explained in Section IV, a party's degree of compliance with an agreed safety framework could be relevant to assertions of fault or negligence. In the end, however, determining whether one space object

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35 Convention on International Liability for Damage Caused by Space Objects, 24 UST 2389 (1972) (hereinafter Liability Convention).

36 Id, art I(d).

37 Id, art I(c).

38 Id, art II.

39 Id, art III.

40 Id.

caused damage to another spacecraft in outer space would be a technical question, rather than a legal one.

c) Rescue and Return Agreement. With specific regard to NPS in outer space, the Rescue and Return Agreement[41] has limited direct application. However, one provision may have particular relevance. If a Contracting Party has reason to believe a space object or its component parts discovered in its territory, or recovered by it elsewhere, is of a hazardous or deleterious nature, it may notify the launching authority. The launching authority would then be required to "immediately take effective steps . . . to eliminate possible danger of harm."[42]

d) The NPS Principles. The United Nations General Assembly adopted the Principles Relevant to the Use of Nuclear Power Sources in Outer Space in 1992 ("NPS Principles"). The General Assembly recognized that for some space missions the use of NPS is essential, given the then-existing devices' compactness, long life, and other attributes, while it also recognized that the use of NPS should be based on a thorough safety assessment and risk analysis.[43] While the NPS Principles are applicable to RTGs and RHUs, they do not apply to nuclear propulsion.[44] Apart from the inadequacies noted by the United States (see discussion in note 76), the Principles do not add anything from a strictly legal point of view. First, as a UN General Assembly resolution, they are by definition not binding, in spite of their use of "treaty language" (for example, "shall."). Second, they merely restate the applicability of existing international law, including the UN Charter, the Outer Space Treaty, the Liability Convention, and other general duties, such as notification in the event of re-entry of objects utilizing NPS in outer space.

2. Nuclear Treaties

Currently, the Legal Subcommittee ("LSC") of COPUOS lists NPS on its agenda, although it has suspended work on this item pending STSC consideration of technical issues. While it does not appear that the LSC would have a role in working on any type of NPS safety framework, it might be useful

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41 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 19 UST 7570 (1968).

42 Id, art 5.4.

43 See generally UN, *Principles Relevant to the Use of Nuclear Power Sources in Outer Space* at Preamble and Principle 3 (cited in note 2): "[T]he use of nuclear power sources in outer space shall be restricted to those space missions which cannot be operated by non-nuclear energy sources in a reasonable way."

44 Id at Preamble ("Affirming that this set of Principles applies to nuclear power sources in outer space devoted to the generation of electric power on board space objects for *non-propulsive* purposes.") (emphasis added). Moreover, as discussed in note 25, the Preamble of the NPS Principles states that they only apply to technology in use as of 1992.

for the LSC to consider, at some future time, the potential applicability of existing international agreements to NPS safety, even though the four Conventions discussed below by the Working Group on the Use of NPS in Space were originally drafted for terrestrial nuclear power applications.[45]

a) The Convention on Early Notification of a Nuclear Accident. All the countries that utilize NPS in outer space are parties to this Convention.[46] Any accident involving such a source that could lead to radioactive material re-entering the Earth's atmosphere could potentially be within the scope of this Convention.

b) The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. This Convention requires Parties to "cooperate between themselves and with the International Atomic Energy Agency . . . to facilitate prompt assistance in the event of a nuclear accident or radiological emergency to minimize its consequences and to protect life, property and the environment from the effects of radioactive releases."[47] It is likely that this Convention could apply in the case of an accident involving Nuclear Power Sources re-entering the Earth's atmosphere.

c) The Convention on Nuclear Safety. On one hand, this Convention does not apply to NPS in outer space, and contains no provision for reporting on or reviewing safety measures taken in relation to such sources. Nevertheless, the safety objectives and, where relevant, the specific safety obligations set out in the Convention may, to some extent, still be instructive or serve as a basis for guidance.[48]

d) The Convention on the Physical Protection of Nuclear Material. The potential relevance of this Convention[49] relates to protecting or safeguarding nuclear material in international transport either prior to launch or subsequent to re-entry, as opposed to being directly related to launch nuclear safety.

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45 Findings of the Working Group are provided in UN, General Assembly, Committee on the Peaceful Uses of Outer Space, *A Review of International Documents and National Processes Potentially Relevant to the Peaceful Uses of Nuclear Power Sources in Outer Space: Report of the Working Group on the Use of Nuclear Power Sources*, UN Doc A/AC.105/781 (2002), available online at <http://www.oosa.unvienna.org/Reports/AC105_781E.pdf> (visited Feb 27, 2005).

46 See Convention on Early Notification of a Nuclear Accident, S Treaty Doc No 100-4, Hein's No KAV 2219 (1986), available online at <http://www.iaea.org/Publications/Documents/Infcircs/Others/inf335.shtml> (visited Feb 6, 2005).

47 Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, art I, S Treaty Doc No 100-4, Hein's No KAV 2218 (1986).

48 Convention on Nuclear Safety, arts 1–3, 33 ILM 1514 (1994).

49 Convention on the Physical Protection of Nuclear Material, TIAS No 11080 (1980), available online at <http://www.iaea.org/Publications/Documents/Infcircs/Others/inf274r1.shtml> (visited Feb 6, 2005).

3. International Environmental Law

There is no consensus on whether general principles of international environmental law apply to the use of NPS in outer space. While there is no doubt about their potential applicability to the terrestrial segments of working with nuclear and radioactive materials (such as handling, storage, and shipment), so far, we are unaware of any tribunal's application of international environmental law—customary or otherwise—to activities solely occurring in outer space. However, some commentators have posited that there may be a supervening notion of international law that imposes duties with respect to the Commons, including outer space: "[g]eneral customary international law requires that all States behave in a manner so as not to cause harm to the environment of areas beyond the jurisdiction of any state including, *a fortiori*, the high seas, outer space, and the Antarctic."[50] Nevertheless, as these environmental notions clearly apply to the terrestrial activities involving NPS (like the nuclear treaties discussed above), a discussion of fundamental notions of potentially applicable international environmental law is warranted.

A principle tenet of international environmental law is the duty of a state to protect areas outside of its own jurisdiction from environmental damage. Although some commentators have suggested that this notion can be traced back to *Trail Smelter*,[51] it is most clearly seen in Principle 21 of the Stockholm Declaration.[52] Although Principle 21 is merely a declaration of a conference, and thus not itself legally binding, it was echoed subsequently in the 1992 Rio Declaration,[53] and some suggest that it either has become declaratory of, or is in the process of crystallizing as, customary international law.[54]

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50 Jonathan I. Charney, *Third State Remedies for Environmental Damage to the World's Common Spaces*, in Francesco Franconi and Tullio Scovazzi, eds, *International Responsibility for Environmental Harm* 149, 175 (Graham & Trotman 1991).

51 *United States v Canada (Trail Smelter Arbitration)*, 3 Reps of Intl Arb Awards 1911 (1938) (preliminary decision), 3 Reps of Intl Arb Awards 1938 (1941) (final decision) (Canada ordered by an international arbitration panel to pay for damage to US crops and forests caused by a lead and zinc smelting complex).

52 UN, General Assembly, *Report of the United Nations on the Human Environment*, Principle 21, UN Doc A/CONF.48/14/Rev.1 (1973), available online at <http://www.unon.org/css/doc/unep_gcss/gcss_viii/bg/Stockholm_Declaration/Stockholm_Declaration.pdf> (visited Feb 27, 2005). Principle 21 states that:

> [s]tates have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

Id, Principle 21.

53 UN, General Assembly, *Report on the United Nations Conference on Environment and Development*, UN Doc A/CONF.151/26 (1992) ("Rio Declaration"). Principle 2 of the Rio Declaration states, in

Closely related to this notion of a duty to protect areas outside of a state's national jurisdiction is the "precautionary principle" or "precautionary approach."[55] While there is no consensus as to the norm's precise content, there is general agreement that when there is a lack of scientific certainty relating to an activity that may have harmful, damaging, or irreversible or transgenerational effects, one of the following three results should follow: (1) the activities should not be permitted; (2) the benefits from such activities should be weighed against the potential environmental damage, considering the likelihood and magnitude of the damage; or (3) appropriate steps should be taken to mitigate the anticipated environmental harm.[56] In many respects, US environmental law has implemented the precautionary principle.[57]

One last element in this discussion of international environmental law can be found in § 601 of the Restatement (Third) of the Foreign Relations Law of the United States, which provides:

> (1) A State is obligated to take such measures as may be necessary to the extent practicable under the circumstances, to ensure the activities within its jurisdiction or control
>
> > (a) conform to generally accepted international rules and standards for the prevention, reduction, and control of injury to the environment of another state or of areas beyond the limits of national jurisdiction; and

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relevant part: "States have . . . the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction." Id, Principle 2.

54 See the UN Convention on the Law of the Sea (1982), art 194(2), 21 ILM 1261 (1982):

> States shall take all measures necessary to ensure that activities under their jurisdiction or control are so conducted as not to cause damage by pollution to other States and their environment, and that pollution arising from incidents or activities under their jurisdiction or control does not spread beyond the areas where they exercise sovereign rights . . . .

See also US Dept of State, Office of the Legal Advisor, *Draft Principles Prepared by the World Meteorological Organization's and United Nations Environmental Program's Informal Meeting on Legal Aspects of Weather Modification, April 1978*, 1978 Digest of US Prac in Intl L 1204–05 ("States shall take all reasonable steps to ensure that weather modification activities under their jurisdiction or control do not cause adverse environmental effects in areas outside their national jurisdiction.").

55 While the Rio Declaration refers to it as the "precautionary approach," it does so under the caption of Principle 15. UN, *Report on the United Nations Conference on Environment and Development* at Principle 15 (cited in note 53).

56 Edith B. Weiss, *International Environmental Law and Policy* 159 (Aspen 1998) (quoting M.P.A. Kindall, *UNCED and the Evolution of Principles of International Environmental Law*, 25 J Marshall L Rev 19, 23–25 (1991)).

57 This is further discussed below in Section II.B, during consideration of National Environmental Policy Act ("NEPA") application to NPS used in outer space.

(b) are conducted so as not to cause significant injury to the environment of another state or of areas beyond the limits of national jurisdiction.[58]

The two obligations described in this provision could, in the future, be extended to cover NPS. As further explained in Section IV, a state's noncompliance with a minimum safety framework for use of NPS in space could be relevant under § 601(1)(a) of the Restatement, since it provides that a state must comply with such generally accepted rules and standards.[59] Secondly, § 601(1)(b) imposes a duty upon states (as noted earlier) to avoid causing significant injury beyond the limits of their national jurisdiction.

Whether or not all of these principles of environmental law or "soft" space law apply to NPS now, or arguably may be extended to apply to advanced NPS in the future, is uncertain. However, in addition to compliance with international law, any NPS powered mission is clearly also subject to stringent legal and regulatory US domestic requirements, as outlined in the next section.

B. US LEGAL AND REGULATORY FRAMEWORK

Discussion of the US legal and regulatory framework must be clearly delineated. In terms of US laws per se, NASA's NPS activities are subject to a concurrent, two-prong procedure. First, NASA must comply with the National Environmental Policy Act ("NEPA"). Second, however, and completely separate from the NEPA legal analysis, NASA's NPS missions must undergo a set of thorough safety reviews involving multiple layers of examination by multiple US agencies and external experts. This is known as the Nuclear Launch Safety Approval ("NLSA") process. Both NEPA and NLSA are detailed below.

1. The NEPA Process

As part of NASA's consideration of the environmental impacts of any mission using NPS, NASA complies with the National Environmental Policy Act.[60] Congress enacted NEPA because it determined that the federal

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58 Restatement (Third) of the Foreign Relations Law of the United States § 601(1) (1987).

59 Standard practices in an industry can eventually mature, leading to the further development of custom in international law. See Myres S. McDougal, Harold D. Lasswell, and Ivan A. Vlasic, *Law and Public Order in Space* 115–19 (Yale 1963) (laying down the traditional requirements for the establishment of customary international law). See also Statute of the International Court of Justice, art 38(1)(b), 39 Am J Intl L 223 (Supp 1945), available online at <http://www.icj-cij.org/icjwww/ibasicdocuments/ibasictext/ibasicstatute.htm> (visited Feb 4, 2005), which includes international custom among the sources of international law. See also, Anthony Aust, *Modern Treaty Law and Practice* 12 (Cambridge 2000) (providing examples in which new customary rules can result in modification of explicit treaty rules).

60 42 USC § 4331 et seq (2000).

government has a "continuing responsibility . . . to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources" to protect the environment and the renewable resources.[61] Among other things, NEPA requires that when a federal agency anticipates taking major federal actions significantly affecting the quality of the human environment, a detailed statement, called the Environmental Impact Statement ("EIS"), must be prepared by the responsible official. The EIS must include: (1) the environmental impact of the proposed action; (2) any adverse environmental effects which cannot be avoided should the proposal be implemented; (3) alternatives to the proposed action (including no action); (4) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and (5) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.[62]

If an agency does not comply with NEPA requirements, a plaintiff may seek judicial review under the Administrative Procedure Act ("APA"). In the US, courts are allowed limited review of an agency decision. As a general rule, pursuant to the APA, US courts will hold an agency decision in the NEPA process unlawful and set it aside only upon finding the agency's conclusions are "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law."[63] In certain instances, courts are deferential to the expertise of the agency.[64] For example, in litigation concerning the *Cassini* spacecraft, the court found that, in both the final EIS and the supplemental EIS, NASA noted that because of the vicinity of Saturn, where the Sun's intensity is only 1 percent of that available to the Earth, the use of "RTGs was identified as the only feasible power system."[65] The court concluded that NASA had demonstrated that solar power was not a feasible alternative to operate the *Cassini* spacecraft, and that

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61 42 USC § 4331.

62 42 USC § 4332(2)(C). NEPA also requires that copies of the environmental impact statements and any comments by other agencies shall be made available to the public. Id. NASA routinely provides copies to the State Department of its mission's EIS, and, for certain specific missions, such as launches with NPS onboard, NASA also requests that the State Department provide the EIS to concerned organs of the United Nations.

63 5 USC § 706(2)(A) (2000); see also *Marsh v Oregon Natural Res Council*, 490 US 360, 375–76 (1989) (finding that an agency's EIS can be reversed only if it is arbitrary, capricious, or an abuse of discretion).

64 *Natural Res Def Council, Inc v Hodel*, 819 F2d 927, 929 (9th Cir 1987).

65 *Hawaii County Green Party*, 980 F Supp at 1168 (cited in note 1).

NASA had adequately considered potential accident scenarios and potential health risks.[66]

2. The NLSA Process

Use of NPS and other advanced technologies involves certain risks and responsibilities. In all of NASA's missions, safety and mission success are the primary operating principles, and this has always been the case with nuclear activities in particular. The US Department of Energy is the federal agency responsible for development and production of nuclear technologies for use by the government. Multiple agencies are involved in launching an NPS mission. Typically, NASA builds the spacecraft and designs the mission, DOE provides the power source and the nuclear Safety Analysis Report ("SAR"), and the Department of Defense ("DOD") provides the launch facilities. As a result, each agency has a substantive nuclear safety responsibility for the mission. In addition, US policy requires approval from the White House for the launch into space of systems involving NPS. This policy requires that an ad hoc Interagency Nuclear Safety Review Panel ("INSRP") conduct, prior to launch, an independent evaluation of the SAR of a proposed mission with nuclear material on board.[67]

As part of the Space Nuclear Safety Review process for a mission using NPS, the detailed SAR prepared by DOE is reviewed by the INSRP established for the mission. This INSRP is comprised of four experts from NASA, DOE, DOD, and the Environmental Protection Agency, and is supported by subject-matter consultants from government, industry, and academia. With technical assistance from the Nuclear Regulatory Commission, the mission's INSRP evaluates the SAR and prepares a Safety Evaluation Report ("SER"). Based on a review of both the SAR and SER, and after seeking "an expression of views" from DOE, DOD, and the Environmental Protection Agency, NASA decides whether to request launch nuclear safety approval from the White House. NASA submits the request along with the SAR and SER to the White House—precisely, to the Director of the Office of Science and Technology Policy ("OSTP"). The Director of OSTP may either grant approval or refer the request to the President for a decision.

It has been the authors' experience that the United States places the highest priority on assuring the safe use of radioactive materials on space exploration

66 Id at 1167–68.

67 The White House, Executive Office of the President, National Security Council, Memorandum 25, Scientific or Technological Experiments With Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems Into Space (Dec 14, 1977). The mission's empanelled INSRP does not make a recommendation of nuclear safety launch approval or disapproval.

missions. Accordingly, for the launch of a spacecraft containing naturally radioactive materials (for example, *Cassini*), NASA, in cooperation with the Department of Energy, coordinates development of a multi-agency radiological contingency plan to address any potential mishap that could release radioactive materials into the environment.[68]

Both the NEPA and NLSA processes find their theoretical impetus in a duty shared by the various US executive agencies to take actions consistent with the public interest. Through the existence of these finely tailored processes, with deference in their development to duly appointed technological experts, citizens have a standard by which to measure their government's actions. By following these practices, the US government is able to avoid unnecessary risks. In addition to the US safety framework already in place, however, the next section of this article examines the needs for, and potential benefits from, an international, technically-based safety framework for NPS.

IV. THE NEED FOR AN INTERNATIONAL, TECHNICALLY-BASED SAFETY FRAMEWORK

A. TRANSPARENCY AND PUBLIC PARTICIPATION

Public participation and engagement in discussions of the value of using Nuclear Power Sources in space will be key to its future application. NASA may face opposition to future NPS development if public opinion is based on fears raised from past accidents involving terrestrial nuclear power plants. Public understanding will thus be necessary not only as an end in itself, but also as a means of building support. Larry Kos, an aerospace engineer focusing on future flight technologies at NASA's Marshall Space Flight Center in Alabama, has stated that the downside of nuclear propulsion stems not primarily from technical concerns, but rather from public perception, which is generally anti-nuclear. "Nuclear thermal propulsion," Dr. Kos explained, uses "enriched uranium, not plutonium, so it is less radioactive by a factor of 100,000."[69]

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68 This plan, developed in cooperation with US Federal agencies with relevant responsibilities (for example, the Federal Emergency Management Agency, Department of Agriculture, and the Department of State), and other participants (including some state and local authorities) serves as NASA's implementation of the US Federal Radiological Emergency Response Plan, 61 Fed Reg 20944–970 (1996). It also serves as implementation of the guidance provided by the International Atomic Energy Agency ("IAEA"). See IAEA, *Safety Series No 119: Emergency Planning and Preparedness for Re-entry of a Nuclear Powered Satellite* (1996), available online at <http://www.iop.org/EJ/abstract/0952-4746/17/1/011> (visited Feb 4, 2005) (abstract only).

69 NASA, *Destination: Mars* (Sept 20, 2001), available online at <http://media.nasaexplores.com/lessons/01-060/9-12_article.pdf> (visited Feb 7, 2005).

Discussions of safety should separate spacecraft vulnerability from human health. For example, as Pu-238 decays, it "emits radiation mainly in the form of alpha particles, which have a very low penetrating power. Only lightweight shielding is necessary because alpha particles cannot penetrate a sheet of paper."[70] This makes it relatively easy to protect spacecraft elements from exposure to this source of radiation.

In regards to human health, another benefit of transparency and wide public participation will be the minimization of fear and misperception. The public should be widely informed of the results of the various safety review processes. Space agencies should reach out to environmental groups and regulatory agencies specialized in space nuclear power systems and seek their input into discussions of environmental impact. Communications with the public should adequately address the use of NPS, any environmental impact of the mission, safety concerns, and potential for any health risks.[71]

B. Proposal for an International Safety Framework

In the recent colloquium of the AIAA on space NPS, the Working Group on Nuclear Power Sources for Space Exploration recommended that spacefaring

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70 DOE, *Nuclear Power in Space* at 20 (cited in note 3). This illustrates that the primary safety issue, therefore, is containment, and DOE is fully capable of proper handling of the material. Rigorous testing is conducted to ensure that the nuclear fuel will survive intact in the event of a launch accident or mishap, including under conditions of fire, blast, re-entry, Earth impact, immersion in water, shrapnel, or large fragments. See id at 23–24 for discussion of safety tests demonstrating that RTGs meet the design objective of preventing or minimizing any fuel release.

71 NASA's awareness of the importance of public involvement was recently reflected in the Risk Communication Plan of its New Horizons Mission. This plan provides some fundamental principles for communicating information to the public:

Principle 1: Be transparent

- Be honest, candid, and open;
- Make information available and easily accessible, as early as possible;
- Use plain language;
- Ensure the transparency to the public of the process by which missions are chosen, designed and operated;
- Ensure that communications channels to the public easily provide information about safety, mission objectives and benefits, programmatic changes, successes and failures.

Principle 2: Be inclusive

- Seek as many perspectives as possible;
- Be sensitive to cultural differences.

Principle 3: Be interactive

- Listen respectfully and respond constructively to colleagues, critics, and supporters;
- Be clear in establishing where NASA can and is willing to accept input;
- Based on input, be open to modifications or new options.

NASA, New Horizons Mission, Risk Communication Plan (Dec 9, 2004) (on file with author).

nations should be encouraged to "set and follow international standards for development and test of space reactor systems."[72] It justified its recommendation asserting that international cooperation in the actual safety review of missions utilizing space reactors might increase public confidence and could substantially enhance overall confidence in space reactor systems. While international standards for testing and development of space reactors do not yet exist, there is support in the STSC of COPUOS for developing an international technically-based framework of goals and recommendations for the safe use of NPS applications in outer space.[73]

The objectives of such a safety framework would include goals and recommendations to provide guidance relating to the safety aspects of launch and operation of Nuclear Power Sources for use in outer space. Such a framework could recommend activities over the course of the life cycle of NPS, through design, launch, operation, and other relevant phases. As a result of such an international framework, national standards and programs could adapt the high-level guidance to their own domestic regimes, promoting harmonized implementation of the international practices. For the most part, activities concerning the ground-based segment of NPS, such as development, manufacturing, handling, and transportation, are likely adequately addressed in existing national and international standards applicable to terrestrial activities. This framework could serve as the basis for cooperation between countries or groups of countries on missions utilizing NPS and would help to assure the global population that NPS are being used in a safe manner. This safety framework should be technically accurate and reflect broad international agreement. Although there is no such framework yet in existence for outer space application, there are analogous safety fundamentals found in the International Atomic Energy Agency ("IACA"), which could serve as a starting point for further discussion.[74]

Creation of such a safety framework would lead to some generalized consensus and common understanding regarding safety. It could be expected

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72 AIAA, International Activities Committee, Working Group on Nuclear Power Sources for Space Exploration, *International Space Cooperation: From Challenges to Solutions* 39 (May 2004).

73 See UN, General Assembly, COPUOS, Report of the Scientific and Technical Subcommittee, UN Doc A/AC.105/823 (2004), available online at <http://documents-dds-ny.un.org/doc/UNDOC/GEN/V04/514/64/pdf/V0451464.pdf?OpenElement> (visited Feb 27, 2005). The Scientific and Technical Subcommittee ("STSC") reported: "Some delegations were of the view that a workshop to be organized by the Office for Outer Space Affairs jointly with the IAEA . . . should be held to discuss the scope and general attributes of a potential technical safety standard for NPS in outer space." Id at ¶ 113.

74 See, for example, IAEA, Safety Series No 110, *The Safety of Nuclear Installations*, IAEA Doc STI/PUB/938 (1993), available online at <http://www.iop.org/EJ/abstract/0952-4746/17/1/011> (visited Feb 4, 2005).

that such a framework would be voluntary and would function as general guidance to users of space NPS. As such, and almost by definition, it would not be legally binding. On the other hand, establishment of this safety framework could, over time, entail legal implications, particularly if a party complies, or fails to comply, with the provisions found in this framework. In a paper presented on the topic of legal issues related to orbital debris, a representative of the Legal Adviser's Office of the Department of State observed the possibility that compliance with voluntary standards could have some legal implications:

> Beyond treaty provisions, a claimant might well seek to invoke technical standards or guidelines that have been adopted by a group of nations. For example, a claimant might argue that non-compliance with such guidelines is evidence of fault; others might argue that compliance with such guidelines is evidence of lack of fault.[75]

Another way to look at the issue is that the framework could lead to a general notion of what constitutes a minimum standard of care; an injured party may later assert that failure to comply with this standard breached a duty of care. This may be a relevant factor not only as applied to the "fault" provisions found in the Liability Convention, but also may be more generally relevant in regard to § 601 of the Restatement (Third) of the Foreign Relations Law, as discussed above in Section III.A.3.

Still another benefit from broad participation of NPS experts in drafting the proposed safety framework is that it will result in a technically precise document. Without a technically sound basis, what may appear on the surface to be effective standards are unlikely to be implemented.[76]

C. ADEQUACY OF EXISTING FORA

While ongoing discussions regarding the application of future NPS systems continue within the STSC of COPUOS, some have questioned whether this is an appropriate or sufficient international forum for the same. The report of the Working Group of the recent AIAA colloquium recommended the creation of

75 See Heather A. Schildge, US Dept of State, Office of Legal Advisor for UN Affairs, *Legal Implications of Collisions in Space*, Second Annual Satellite Operations and Safety Workshop, Massachusetts Institute of Technology (Oct 22, 2003).

76 For example, although the US did not block consensus at the General Assembly on the NPS Principles, it issued an interpretive statement upon joining consensus. In a press release from the United States Mission to the United Nations, the US repeated its concern that: "[T]he principles related to safe use of nuclear power sources in outer space do not yet contain the clarity and technical validity appropriate to guide safe use of nuclear power sources in outer space." The US also stated that it "has an approach on these points which it considers to be technically clearer and more valid and has a history of demonstrated safe and successful application of nuclear power sources. We will continue to apply that approach." United States Mission to the United Nations, Press Release No 116-(92) (Oct 28, 1992).

an international forum for discussing technology and policy directions related to the use of nuclear reactors in space, and questioned whether such a forum should resemble the Interagency Space Debris Coordinating Committee ("IADC") for nuclear power considerations.[77] The IADC experts come from national space agencies with large, multifaceted programs, and they have recently recommended guidelines for spacecraft design and operation that would vastly diminish the potential for debris generation. If a multilateral space NPS expert group were to formulate a technically accurate model safety standard for NPS, it could then present its findings to the STSC and/or the International Atomic Energy Agency ("IAEA") for independent review.

The concerns about selecting or creating the appropriate forum for discussions on the use of NPS are many. As discussed earlier, the 1992 NPS Principles were created by the UN General Assembly, based on input from the COPUOS and the STSC. Unfortunately, the Principles contain technical flaws, and the US continues to apply its own, more technically sound approach. Further, even though the Principles themselves call for review and revision by COPUOS no later than two years after their adoption[78] (which was in 1992), the COPUOS has never reopened the Principles, and there is no consensus on doing so in the future. The NPS Principles have thus become an example of why establishing a sound technical foundation must be a condition precedent to any potential future deliberations regarding the use of NPS in outer space.

Various fora may be utilized for the development of NPS safety standards. One option might involve the IAEA leading development of a voluntary space nuclear safety technical standard. The IAEA does have expertise in terrestrial nuclear power applications, but does not have significant expertise with space NPS. A second option is an STSC-led initiative. The limitation of this approach is that, while some advisers to the STSC delegation have access to technical expertise in NPS issues, the STSC itself does not function as the kind of technical standards-setting body needed to ensure development of suitable standards. A third option, a joint IAEA/STSC-led initiative, may suffer the combined limitations of the first two initiatives. Additionally, it is doubtful that such an approach could achieve consensus within a reasonable timeframe, given the demands of the coordination processes within and between the two organizations. A fourth option could involve creation of a new forum: that is, a multilateral group of space NPS experts. This group would have substantial technical expertise in space NPS—a completely different environment than terrestrial use of nuclear power. We are unaware of any other existing fora

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77 AIAA, *International Space Cooperation* at 39 (cited in note 72).

78 UN, *Principles Relevant to the Use of Nuclear Power Sources in Outer Space* at Principle 11 (cited in note 2).

concerning either the environment, nuclear power, or outer space, that has the technical expertise essential to maintain scientific accuracy and ensure broad buy-in by both participating and nonparticipating entities.

This approach of a multilateral group of space NPS experts may hold the greatest promise of achieving consensus in the relatively near future. Such a group could include experts from the US, Russia, the European Space Agency, and the national agencies of European states, as well as the space agencies of China, India, Japan, Argentina, and others. Such a group would have the ability to peer-review technical safety standards while ensuring their real world application, free from political or other influences unrelated to the actual technical safety standard. Space agencies could fund their own participation.

Indeed, the Statute of the IAEA specifically authorizes it to collaborate with other competent UN bodies to establish or adopt safety standards.[79] If the STSC and/or the IAEA reviews the model safety standard recommended by the NPS Expert Group and judges it to be appropriate and technically sound, then either the COPUOS itself or the IAEA could endorse the standard and recommend that States voluntarily and expeditiously implement the standard in their national programs. Alternatively, the NPS Expert Group's standard could be presented to the General Assembly for its endorsement of the group's results, perhaps leading to a General Assembly resolution, encouraging states to voluntarily comply with this standard.[80] Fostering technical consensus on an appropriate NPS safety framework before attempting to forge political consensus seems, in our opinion, to be the correct approach. At the same time, however, we do acknowledge that, in place of a voluntary safety framework, some Member States of COPUOS might prefer that the issue be studied in the Legal Subcommittee before action is taken in the STSC, in order to understand fully any legal implications resulting from such a framework. In our view, however, this approach would delay appropriate technical action during the time that the initiative is undergoing legal review, a process which could last several years.

Another important advantage of centering NPS discussions in a technical experts group, at least at this stage, is that it avoids burdening COPUOS with issues it may not be properly equipped to handle. COPUOS's charter makes clear that the Committee's primary focus is to "study practical and feasible means for giving effect to programmes in the peaceful uses of outer space"

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79 Statute of the International Atomic Energy Agency, art III(A)(6), available online at <http://www.iaea.org/About/statute_text.html> (visited Feb 4, 2005).

80 The genesis for this idea comes from the UK, which, in the context of the IADC orbital debris mitigation guidelines, suggested that the General Assembly endorse the IADC's recommendations. See COPUOS, Report of the STSC at para 99 (cited in note 73).

which could appropriately be undertaken under UN auspices,[81] a responsibility it has discharged with considerable success and distinction. Reliance upon an outside group of NPS space experts could provide COPUOS the technical support it needs to fulfill its responsibilities to the General Assembly. On the other hand, it could also be noted that one disadvantage of this approach is that states with no expertise in space NPS would not participate in the "expert group" and may feel excluded from discussions which may later have an impact on them. Thus, achieving widespread buy-in to the safety framework may, in fact, prove more difficult under this approach.

V. CONCLUSION

While law should not precede the advance of technology, NASA's decision to embark on Project Prometheus gives the United States a unique opportunity to engage the international community on issues related to NPS generally and nuclear propulsion specifically. Prometheus will usher in an era of space exploration that utilizes nuclear fission to enable power systems with characteristics incomparable to anything used in space to date, harnessing nuclear energy for propulsion and unprecedented systemic power. While the NPS Principles do not appear to apply to Project Prometheus, or other forms of "advanced NPS" which contemplate propulsive systems, they are demonstrative of some of the political concerns the US will face in the UN and other fora.

While various agreements in international nuclear energy law have established clear duties and responsibilities in the event of a terrestrial accident involving radioactive material, current space law has also appropriately provided a liability regime for an accident that may occur in outer space. At the dawn of Project Prometheus, questions have arisen concerning whether states that utilize space NPS have a legal duty to take certain *preventative* steps to minimize risks to areas beyond their national jurisdiction, and also, whether an appropriate international forum exists to formulate generally agreed concepts of safety, perhaps leading, over time, to the crystallization of a standard of care in a rapidly advancing technical environment.

Whether or not it has become customary international law, the "precautionary principle" in international environmental law appears to reflect that states have a duty to take substantive, preventative measures concerning actions that pose certain potential transboundary risks. In the US, before any launch of NPS, and consistent with the public interest, executive agencies already participate in an exhaustive and carefully detailed environmental and

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81 General Assembly Res No 14/1472 at para 1, UN Doc No A/RES/14/1472 (1959) (establishing COPUOS).

safety review process. As evidenced in *Hawaii County Green Party v Clinton*, this process is performed by professionals with expertise in space NPS, while still applied by courts as an objective standard of preventative practice. The success of the NEPA and NLSA processes in the US suggests that, given the transboundary nature of space exploration, the time may be ripe for creation of an international framework of goals and recommendations for the safe use of NPS applications. Such an endeavor would help assure the world community that NPS in space are being used in a safe manner, while serving as some evidence of fulfilling whatever customary duty spacefaring states have to take preventative measures when using this technology.

Because space NPS technology is at once both sensitive and constantly advancing, international will to create a forum bound by traditional convention does not exist. However, the success of other technically based fora (such as the success IADC has had in issuing guidelines to mitigate orbital debris) demonstrates that the development of a voluntary, multilateral safety framework is achievable in the NPS context.

As NASA counts down to the launch of its first Prometheus-enabled mission, perhaps less than a decade away, it becomes clear that advanced NPS technology will continue to develop, with or without an international safety framework in place. Today, then, as the US develops this advanced technology, it should also seize this opportunity to engage the international community. Initiating multilateral technical discussions now will enable NASA to receive the benefit of international concerns, and, in the future, help all space agencies to persuade potential critics that this technology is indeed being used in as safe a manner as possible, with due regard for the environment both on Earth and on other celestial bodies as well.

CJIL