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NASA'S PROJECT PROMETHEUS AND NUCLEAR PROPULSION SYSTEMS[1]

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I. Introduction

The Mission Statement of the National Aeronautics and Space Administration (NASA), to understand and protect our home planet, to explore the universe and search for life, and to inspire the next generation of explorers, requires that NASA invest in technologies that will transform the Agency's capability to explore the universe. NASA's Space Science Enterprise is developing the tools, insights, and abilities necessary to answer some of humanity's most profound questions: How did the universe begin and evolve? How did we get here? Where are we going? Are we alone?

NASA began to answer such questions back in 1962, when it launched the Mariner 1 and 2 missions to Venus. These were the first missions to escape Earth's gravity and explore another planet in our solar system. At that time, NASA depended on chemical rockets to send spacecraft on their journeys. In order to escape Earth's gravity, a chemical rocket expends all of its thrust within the first few minutes after launch. Once the fuel is expended, the rocket is jettisoned, and the spacecraft begins its expedition by coasting along a fixed path to its final destination in space.

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[2] The views expressed herein are those of the authors and may not reflect the views of the National Aeronautics and Space Administration or of the United States of America. E. Jason Steptoe, NASA Associate General Counsel for International and Commercial Law, and Reed E. Wilcox, Cross Program Launch Approval Engineering Manager at the NASA Jet Propulsion Laboratory, assisted in the preparation of this paper.

Occasionally, there is an opportunity for the spacecraft to swing around another planet to change the spacecraft's direction and velocity.[3]

While these launch scenarios have worked well and have allowed the Agency to explore many destinations in our solar system, the constraints they presented over 40 years ago are still present today. To overcome these limitations, NASA is pursuing alternatives to enhance its capability for launching missions to objects throughout the solar system and beyond. In the field of space exploration, this translates to finding more effective ways to safely power, propel, and maneuver spacecraft, while developing innovative scientific instruments to explore areas of the universe beyond our current reach.

Project Prometheus

In Greek mythology, Prometheus is attributed to be the wisest of the Titans, and he gave the gift of fire to humanity. The name Prometheus means "forethought." For NASA, the name "Prometheus" is indicative of NASA's hope to establish a new tool for understanding nature and for expanding exploration capabilities. Project Prometheus anticipates a tremendous advance in technology. Most noteworthy is its ability to provide orders of magnitude more power – thousands to hundreds of thousands of watts – to spacecraft. The amount of energy generated represents a true paradigm shift for mission planners, not only because of the amounts of power that could be made available to the scientific community, but also in the ability to provide continuous power to maneuver a spacecraft throughout its mission via nuclear electric propulsion.

After NASA Administrator Sean O'Keefe took over the reins of NASA in December 2001, he instilled within NASA a comprehensive approach to space exploration that he called "building blocks" or "stepping stones." In his testimony to Congress, Mr. O'Keefe explained that human space flight capabilities should be enhanced to enable research and discovery. NASA ought to continue to expand human presence in space – "not as an end in itself, but as a means to further the goals of exploration, research, and discovery." [4] The same is true for technological developments. They should be crosscutting and emphasize technologies with broad applications, such as propulsion, power, computation, communications, and information technologies. This building-block approach ensures that NASA has a solid foundation from which to build its programs.

> But, our ability to fully achieve our Mission is constrained by the need for new technologies that can overcome our current limitations. We must provide ample power for our spacecraft as well as reliable and affordable transportation into space and throughout the solar system. We must deploy innovative sensors to probe Earth, other planets, and other solar systems. We must be able to communicate large volumes of data across vast distances, so that we can get the most from our robotic explorers.[5]

Achievement of this ambitious vision requires a bold approach to the next generation of spacecraft, including revolutionary improvements in energy production, conversion, and utilization. As Nobel Prize winning physicist and chemist Marie Curie stated: "... Never see what has been done . . . only see what remains to be done." NASA's

[3] This maneuver – called a gravity assist – is highly dependent upon launching during a specific, and often very short, launch window. Once that window closes, the time and energy it takes to reach the target destination can change dramatically.

[4] Statement of Sean O'Keefe, NASA Administrator, Before the Subcommittee on VA-HUD Independent Agencies, House Committee on Appropriations, April 8, 2003.

[5] *Id.*

Project Prometheus proposes to develop the near- and long-term use of nuclear energy to power certain scientific missions that could not otherwise be accomplished.

In general, radioisotope power systems are limited to providing spacecraft with electrical power that would approximate the power needed for a few household light bulbs. However, the ingenuity of the science and engineering communities has adapted mission plans to this present reality and developed spacecraft and instruments capable of utilizing these small amounts of power. Since NASA's earliest days, this has been a constraint to the ability to gather and transmit data and, ultimately, to generate knowledge.

Today (chemical propulsion & radioisotope power)	**Future (nuclear electric propulsion)**
Launch, then coast	Much greater ability to change speed
Constricted ability to operate science instruments (power limits)	Much greater (practically unlimited) power for instruments
Constricted ability to transmit science data to Earth	Vastly greater ability to transmit science data to Earth
Constricted launch opportunities	Substantially fewer launch period constraints
Cannot orbit multiple moons of outer planets	Can orbit multiple objects or moons
Cannot change target mid-mission	Can change target mid-mission (to support change in priorities)

II. NASA's Experience with Nuclear Power Sources in Space

A. Brief History

On January 16, 1959, U.S. President Eisenhower unveiled what he called the world's first atomic battery -- the radioisotope thermoelectric generator (RTG). While not actually batteries, these amazing devices have become NASA's energy source for missions to the outer planets; they have proven to be rugged, compact, and capable of working in severe, sunless environments. Subject to environmental safety requirements, NASA is considering using radioisotope power systems to support the safe and peaceful exploration of outer space and the surfaces of planets and moons on potential missions.

The importance of the radioisotope power system's contribution to humankind's exploration beyond Earth orbit is often overlooked. To date, RTGs have flown on 17 NASA missions. They provided electricity, during lunar day and night, to five Apollo Lunar Surface Experimental Packages. They powered the two Viking Landers while they conducted research on the surface of Mars. They also powered the recently completed Galileo mission to Jupiter and the Pioneer and Voyager interplanetary missions as they explored the outer solar system. Amazingly, Voyagers 1 and 2 continue to operate today, after more than 25 years in space, exploring the outer frontiers of our solar system. An RTG currently powers the Ulysses spacecraft as it voyages around the Sun's poles, and the Cassini spacecraft relies on three RTGs for electrical power as it approaches the beginning of its multi-year orbital exploration mission of Saturn.

RTGs are lightweight, compact, extraordinarily reliable spacecraft power systems.[6] They are not nuclear reactors and have no moving parts. They use neither fission nor fusion processes to produce energy. Simply stated, they provide power through the natural radioactive decay of plutonium dioxide (mostly PU-238, a non-weapons-grade isotope). The heat generated by this natural process is changed into electricity by solid-state thermoelectric converters.

B. Europa and Jupiter's Icy Moons

Project Prometheus plans to utilize the extensive work done to date on space nuclear systems to embark on an ambitious science mission, the Jupiter Icy Moons Orbiter (JIMO), which would use nuclear fission for electric power and propulsion.[7] Nuclear fission would provide the high levels of sustained energy necessary to power larger payloads of more complex, "active" scientific instruments, power electric propulsion systems that would allow visits to multiple destinations per mission for close-range, long-term observations, and enable significantly larger amounts of data to be transmitted back to Earth.

In his testimony to Congress last June, Dr. Edward J. Weiler, Associate Administrator of NASA's Space Science Enterprise, explained that the initial activity for the fission power and propulsion program would focus on defining the near-term technology research goals, and on identifying planetary science missions uniquely enabled by nuclear fission electric power and propulsion. The JIMO would be an ambitious mission to orbit three planet-sized moons of Jupiter -- Callisto, Ganymede and Europa -- which may harbor vast oceans beneath their icy surfaces. The mission would orbit each of these moons for extensive investigations of their makeup, their history and their potential for sustaining life.[8]

JIMO's science instruments used to study these worlds would have far more power than those on Galileo and Voyager. More powerful cameras and spectrometers could document the entire globe looking for evidence of life, and lasers could measure the topography and characteristics of the surface. The huge amounts of data gathered by JIMO would be transmitted to Earth in torrents, using high-powered transmitters and optical communication links.[9]

Beyond JIMO, future missions making use of nuclear fission systems might visit destinations such as:

- Comets: to explore their surfaces and interiors and return samples to better

[6] Statement of Dr. Edward J. Weiler, NASA Associate Administrator for Space Science, Before The Senate Subcommittee on Science, Technology and Space, June 3, 2003 (Weiler Statement).

[7] At the same time, JIMO will respond to the National Academy of Sciences' ranking of a Europa orbiter mission as the number-one priority for a flagship solar system exploration mission: "The Europa mission has high scientific potential and would investigate the possibility that liquid water exists on that satellite of Jupiter." *New Frontiers in the solar system: An Integrated Exploration Strategy*, National Academy of Sciences, National Research Council (NRC), July 2002, at 3.

[8] Weiler Statement.

[9] *Id.*

understand the building blocks of the universe.

- Mars: to dramatically expand our capabilities for surface investigations, on-orbit exploration, and sample return.
- Various other destinations: interplanetary or interstellar probes to study Saturn, Uranus and Neptune, or investigate the interstellar matter beyond the Kuiper Belt region.

C. The Safety Review Process for NPS Missions

Use of nuclear and other advanced technologies involves certain risks and responsibilities. In all of NASA's missions, safety is the primary operating principle, and this has always been the case with nuclear activities in particular. Working with the U.S. Department of Energy (DOE), the Federal agency responsible for development and production of nuclear technologies for use by the government, NASA plans to extend that safety experience to the design, manufacture, and space flight of a fission reactor. NASA will continue to comply fully with environmental and nuclear safety launch approval processes applicable to the use of nuclear power systems in outer space. Safety must continue to be the predominant factor as humans explore the universe and attempt to unlock the many secrets it holds. NASA has an outstanding record of safety using nuclear power sources (NPS) in outer space.

Multiple agencies are involved in launching a U.S. nuclear-powered mission. Typically NASA builds the spacecraft and designs the mission, the DOE provides the power source and the nuclear safety analysis report (SAR), and the U.S. Department of Defense (DOD) provides the launch facilities. As a result, each Agency has a substantive nuclear safety responsibility for the mission. In addition, U.S. policy requires approval from the White House for the launch into space of systems involving nuclear power. This policy requires that an *ad hoc* Interagency Nuclear Safety Review Panel (INSRP) conduct, prior to launch, an independent review of the flight safety of a proposed mission with nuclear material on board.[10]

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 (EPA), supported by subject-matter consultants from government, industry, and academia. With technical assistance from the U.S. 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 concurrence from DOE, DOD and EPA, 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.

III. The Legal Framework and Environmental Impact Assessments

Completely separate from the interagency process discussed above, as part of NASA's

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[10] Presidential Directive/National Security Council Memorandum-25, Scientific or Technological Experiments With Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems Into Space, December 14, 1977. The mission's empanelled INSRP does not make a recommendation of nuclear safety launch approval or disapproval.

consideration of the environmental impacts of any mission using NPS, NASA complies with the National Environmental Policy Act (NEPA).[11] Congress enacted the NEPA, because it determined that the Federal 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. (42 U.S.C. § 4331) 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 by the responsible official must be prepared, called the Environmental Impact Statement (EIS), concerning:

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;
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.[12]

If an agency does not comply with NEPA requirements, judicial review under the Administrative Procedures Act (APA) can be sought. In the U.S., courts are allowed limited review of an agency decision. Pursuant to the APA, the court can hold an agency decision unlawful and set the agency decision aside only if the court finds the agency's conclusions are "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law."[13] In certain instances, courts are deferential to the expertise of the agency.[14] For example, in the 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% of that experienced by the Earth, the use of "RTGs was identified as the only feasible power system."[15] The Court concluded therefore that NASA had demonstrated that solar power was not a feasible alternative to operate the Cassini spacecraft. The Court also concluded that NASA had adequately considered potential accident scenarios and potential health risks.[16]

The United States places the highest priority on assuring the safe use of nuclear materials on space exploration missions.

[11] 42 U.S.C. § 4332(2)(C) *et seq.*

[12] *Id.* NEPA also requires that copies of the environmental impact statements and any comments by other agencies shall be made available to the public, and NASA routinely provides copies to the State Department of its mission's EIS, and, for certain specific missions, such as launches with NPS on-board, NASA also requests that the State Department provide the EIS to concerned organs of the United Nations.

[13] 5 U.S.C. 706; *see also Marsh v. Oregon Natural Resources Council*, 490 U.S. 360, 376-77 (1989) (finding that an agency's EIS can be reversed only if it is arbitrary, capricious, or an abuse of discretion).

[14] *Natural Resources Defense Council, Inc. v. Hodel*, 819 F.2d 927, 929 (9th Cir. 1987).

[15] Final Environmental Impact Statement for the Cassini Mission dated June 1995 at 2-12.

[16] For a copy of the opinion, *see Hawaii County Green Party, and the Florida Coalition for Peace and Justice v. President Clinton, John Gibbons, Director, Office of Science and Technology Policy, and Daniel Goldin, Administrator, National Aeronautics and Space Administration*, CV. Nos. 97-01422DAE, 97-01423DAE, United States District Court, Hawaii, Oct. 11, 1997, and the *Order Denying Reconsideration*, Oct. 17, 1997, 980 F. Supp. 1160 (1997)

Accordingly, for the launch of a spacecraft containing nuclear materials (*e.g.*, Cassini), NASA, in cooperation with DOE, coordinates development of a multi-agency radiological contingency plan to address any potential mishap that could release radioactive materials into the environment.[17]

IV. Nuclear Power Sources and COPUOS

The international community remains interested in the use of NPS in outer space. The United Nations General Assembly (UNGA) adopted the Principles Relevant to the Use of Nuclear Power Sources In Outer Space, in 1992 ("NPS Principles"). The UNGA recognized that for some missions in outer space, the use of NPS in space is essential due to their 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.[18]

The U.S. has long been interested in establishing a solid technical foundation for potential future deliberations within the Committee on the Peaceful Uses of Outer Space (COPUOS) on the use of NPS in outer space. The U.S. actively supported the multi-year work plan adopted by the Scientific and Technical Subcommittee (STSC) in 1998 that "focused on establishing a process and framework for developing information or data that would facilitate future discussions of safety processes and standards for nuclear power sources."[19]

Consistent with its commitment to further the work started in 1998, the United States supported intersessional Working Group discussions between the 39th and 40th meetings of the STSC. As a result of these discussions, the U.S. joined with Argentina, France, the Russian Federation, and the United Kingdom in proposing to the Subcommittee a new draft multi-year work plan for the Working Group on the Use of Nuclear Power in Outer Space (Working Group). This proposed work plan was adopted by the STSC in February 2003; it seeks to "establish the objectives, scope and attributes of an international technically-based framework of goals and recommendations for the safety of planned and currently foreseeable space nuclear power source applications."

NASA's experience demonstrates that development of safe and efficient spacecraft relying on NPS is a highly technical subject – and can be a controversial one. For this reason, it is essential to ensure that national and international discussions regarding the issue have a very solid technical foundation. COPUOS member states are highly aware of the necessity to forge common technical understandings among space faring and non-space faring nations concerning appropriate uses for NPS on spacecraft. Otherwise, without a technically sound basis what may appear to be effective but, in fact, are unrealistic standards, from a technical point

[17] This plan, developed in cooperation with U.S. Federal agencies with relevant responsibilities (e.g., 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 U.S. Federal Radiological Emergency Response Plan (FRERP), and the International Atomic Energy Agency's guidance described in Safety Practice Number 119 Emergency Planning and Preparedness for Re-entry of a Nuclear Powered Satellite (1996 Edition).

[18] *See* NPS Principles, U.N.G.A. Resolution 47/68 of 14 December 1992, Preamble.

[19] *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 in Outer Space*, A/AC.105/781, 12 March 2002, p.3.

of view, are unlikely to be implemented.[20] Accordingly, the STSC has been exploring ways and means of potentially developing common standards multilaterally, through direct discussions among national experts.

Several options regarding the development of effective NPS safety standards are under consideration. The first option would involve the International Atomic Energy Agency (IAEA) leading development of a non-binding space nuclear safety technical standard. The IAEA does have expertise in terrestrial nuclear power applications, but does not have significant expertise with space NPS. Also, such an initiative would likely require extra-budgetary funding resources. The 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. This approach could also entail significant expense for the U.N., for example, for translator services to support extended meetings. The 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. The fourth option, and, in our opinion, the most advantageous approach, involves the generation of a model technical safety standard for NPS in space by 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.

This approach of a multilateral group of space NPS experts holds the greatest promise of achieving consensus in the relatively near future. Such a group could include experts from the U.S., Russia, the European Space Agency (ESA), 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 would fund their own participation.

A. Proposal for a Multilateral Space NPS Expert Group

Such a multilateral group of space NPS Experts could operate similarly to the Interagency Space Debris Coordination Committee (IADC), which is composed of experts charged with developing technical guidelines for orbital debris mitigation. The IADC experts come from national space agencies with large, multifaceted programs, and they have recently developed recommended guidelines for spacecraft design and operation that would vastly diminish the potential for debris generation. COPUOS member states anticipate that the STSC will be in a position to endorse the IADC guidelines in the relatively near

[20] For example, although the U.S. did not block consensus at the UNGA on the NPS Principles, the U.S. issued an interpretive statement upon joining consensus. In a press release from the United States Mission to the United Nations, the U.S. repeated its concern that: "The 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 U.S. 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." USUN Press Release #116-(92), October 28, 1992.

future, perhaps as early as February 2004. This approach of the STSC reviewing and endorsing the work of an independent body of technical experts like the IADC holds promise for yielding technically sound – and widely accepted—guidelines. The same approach could very well be effective for NPS. 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 IAEA for independent review.

Indeed, the IAEA Statute specifically authorizes the Agency to collaborate with other competent UN bodies to establish or adopt safety standards.[21] 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 UNGA for its endorsement of the group's results, perhaps leading to a UNGA resolution, encouraging states to voluntarily comply with this standard.[22] We hope that when the STSC discusses NPS next February, it will recognize the advantages of relying on such a multilateral group of space NPS experts for the initial work needed in this area. In our view, the actual procedural steps identified as the elements of a follow-on COPUOS work plan for NPS issues seem secondary to the central goal of fostering technical consensus on appropriate NPS standards or guidelines before attempting to forge political consensus.

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' charter makes clear that the Committee's primary focus is to "study practical and feasible means for giving effect to programs in the peaceful uses of outer space" which could appropriately be undertaken under U.N. auspices,[23] 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 UNGA.

B. Future Work of the STSC and LSC

The STSC will select one of the four options concerning development of effective NPS safety standards in 2006. If it agrees that formulation of a space NPS Expert Group is desirable, the STSC still has significant work to do. Future work might involve studying launch approval processes or

[21] *See* Article III, section A, paragraph 6, of the IAEA Statute. The IAEA is authorized to: "establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property (including such standards for labor conditions), and to provide for the application of these standards to its own operation as well as to the operations making use of materials, services, equipment, facilities, and information made available by the Agency or at its request or under its control or supervision; and to provide for the application of these standards, at the request of the parties, to operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of atomic energy."

[22] The genesis for this idea comes from the U.K., which, in the context of the IADC orbital debris mitigation guidelines, suggested that the UNGA endorse the IADC's recommendations.

[23] UNGA Resolution 1472 (XIV), *International cooperation in the peaceful uses of outer space*, December 12, 1959 (establishing COPUOS).

exploring mechanisms for assuring that advances in space nuclear safety (including nuclear safety standards) become integrated into the infrastructure for potential future applications of the technology.

After the STSC completes its work, there is a possibility that the Legal Subcommittee (LSC) might become more involved in considering legal issues related to NPS. NPS has long been on the LSC's agenda, though the Subcommittee 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 establishing NPS technical standards, it might be useful for the LSC to consider, at some future time, the potential applicability of existing international agreements to NPS safety in outer space. By way of example, the Working Group on the Use of NPS in Outer Space preliminarily examined the following international instruments for their potential applicability to NPS in outer space:

- The *Convention on Early Notification of a Nuclear Accident* (which entered into force in October 1986). All the countries that utilize NPS in outer space are Parties to this Convention. Any accident involving such a source that could lead to radioactive material re-entering the Earth's atmosphere could be potentially within the scope of this Convention;
- The *Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency* (which entered into force in February 1987). 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." It is likely that this Convention could apply in the case of an accident involving nuclear power sources reentering the Earth's atmosphere;
- The *Convention on Nuclear Safety* (which entered into force in October 1996). On one hand, the 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; and finally
- The *Convention on the Physical Protection of Nuclear Material* (which entered into force February 8, 1987). The potential relevance of this Convention 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.[24]

Although the Working Group preliminarily examined these instruments, it focused on those more specific to NPS.[25] Thus, after the STSC completes its work, it may be useful for COPUOS to ask the LSC to consider, from a strictly legal point of view, the potential applicability of these Conventions, or other instruments of international law, to NPS in outer space.[26]

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[24] Findings of the Working Group are provided in the *Review of International Documents and National Processes Potentially Relevant to the Peaceful Uses of Nuclear Power Sources in Outer Space* (A/AC.105/781, 12 March 2002).

[25] *Id.* at 7.

[26] The Working Group concluded that the Conventions' "direct application to the launch and

V. SUMMARY

Project Prometheus will enable the means for fundamentally improving humankind's capability for solar system exploration through increases in the power available to spacecraft. The program is managed by NASA and supported by teams from DOE, industry, and academia. The safety of using NPS in outer space is of the utmost importance to NASA, which will rely on rigorous, independent safety reviews throughout design, development, testing and use.

Once electricity has been generated by the NPS, it can be used to power the spacecraft's electric propulsion and communication systems and its scientific instruments. Moreover, with access to greater power, scientists could power most, if not all, of the science instruments simultaneously, if desirable, and could make use of the power to transmit all of the science data back to Earth in greater quantities and at faster rates than currently possible. Such an endeavor will realize the prediction of Werner von Braun, who stated back in 1947, "I wouldn't be a bit surprised if we flew to Mars electrically." New technologies often raise new issues that can require considerable creativity and resourcefulness to handle. However, technology should precede law – not the other way around. For this reason, it is our firm contention that support for the development of technically accurate safety standards for utilizing nuclear power in actual space operations must precede any initiative to consider drafting legal standards. While the COPUOS itself may not be the appropriate body for developing suitable NPS technical specifications effecting spacecraft design and operation, work by an independent, multilateral space NPS Expert Group may well provide a workable option for consideration by COPUOS. After the technical studies are completed, perhaps the UNGA, in due course, may consider endorsing the work of the NPS Expert Group and encouraging states to comply with the newly created technically accurate safety standards for NPS.

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operational nuclear safety of space nuclear power sources is limited." *Id.* at 16. The four Conventions named above were originally drafted for terrestrial nuclear power applications.