LEGAL ASPECTS OF USING NUCLEAR REACTORS ON THE MOON

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Abstract

While much attention has been given to the question of using nuclear power sources in space, especially Earth orbit, relatively little debate has emerged about the emplacement and operation of nuclear reactors on the Moon or other celestial bodies. This paper addresses the legal aspects of using nuclear reactors on the Moon. Other than general statements such as that in the Outer Space Treaty about avoiding contamination of planetary environments, space law is virtually silent on the issue. The principles adopted in June 1992 by the U.N. Committee on Peaceful Uses of Outer Space do not specifically refer to use of nuclear reactors on the surface of the Moon (or planetary surfaces in general). When those principles are reopened in COPUOS (as provided for in Principle 11), it should be made clear whether they apply to use of nuclear reactors on the Moon and other planetary surfaces. If they do not, it would appear prudent to begin negotiations expeditiously on guidelines for using nuclear reactors on the lunar surface while designs for such devices are still in their preliminary stages.

Introduction

The United States has initiated a program for returning humans to the Moon and then going on to Mars in the 21st Century. Formally called the Space Exploration Initiative (SEI), the program has received little funding since it began in fiscal year 1991, but the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and other U.S. Government agencies, are conducting design studies and performing technology development activities related to achieving SEI's goals. There is an apparent assumption on the part of NASA that nuclear reactors will be used to provide electricity for lunar bases, raising the question of what treaty obligations or other guidelines exist for emplacing, operating and

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decommissioning reactors on the lunar surface. While this paper focusses on the U.S. SEI program, its conclusions would apply to any country or group of countries planning to use reactors on the Moon that is (are) signatory(ies) to the relevant documents.

Nuclear power has been used on the Moon, in fact, since the landing of Apollo 11 in 1969. In addition to Neil Armstrong and Edwin (Buzz) Aldrin, the Apollo 11 lunar module carried an experiment package powered by a plutonium-fueled radioisotope thermal generator (RTG). Each subsequent Apollo mission also carried RTGs and left them on the Moon--a total of six. The Soviets apparently used polonium-fueled RTGs for their two Lunokohod missions in 1970 and 1973. While RTGs pose their own hazards (and consideration probably should be given to recovering them for proper disposal or marking their locations as areas to be avoided) they do not pose the same magnitude of questions as the operation of nuclear reactors.

No objections were publicly raised to the use of RTGs on the Moon during the Apollo era, but attitudes towards environmental issues have changed significantly in the past 20 years. No assumption can be made today that use even of RTGs, not to mention reactors, would go forward without controversy. For example, environmental objections were registered against the launch of two planetary spacecraft by the United States in 1989 and 1990 (Galileo and Ulysses, respectively) because they carried RTGs. More recently, 24 activist groups have formed a new coalition called Global Network on Weapons and Nuclear Power in Space[1] to prevent the use of nuclear power in space. Attention is focussed today on nuclear power sources in Earth orbit and the launch of any spacecraft carrying nuclear material (which would include reactors destined for the Moon). The operation of reactors on the Moon could easily become the subject of their concern as plans proceed for building lunar bases.

Legal Setting

Five treaties governing activities in space have been negotiated through the United Nations. The United States and the other major spacefaring countries are parties to all except the last, the Moon Treaty. In addition, a pair of conventions developed through the International Atomic Energy Agency (IAEA) relate to the use of nuclear power in space; the United States and the other major spacefaring countries are also signatories to those. Finally, principles on the use of nuclear power in space were adopted by the U.N. Committee on Peaceful Uses of Outer Space (COPUOS) in June 1992. These principles are non-binding.

The Outer Space Treaty

Article IX of the 1967 Outer Space Treaty[2] states that

> States Parties to the Treaty shall pursue

studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose. If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultation before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, may request consultation concerning the activity or experiment. (Emphasis added.)

While the language about contamination appears primarily to address concerns about biological contamination of other bodies (and back contamination of Earth) it can also be taken to mean other types of contamination. In the context of use of nuclear reactors, for example, it could mean contaminating the Moon with nuclear waste, including decommissioning reactors by in situ abandonment.

The Moon Treaty

The focus of this paper is use of nuclear reactors on the Moon in the context of the U.S. Space Exploration Initiative. The United States is not a signatory to the Moon Treaty[3] (nor are the other major spacefaring countries), so its provisions would not directly affect U.S. activities. However, it does set forth an international viewpoint on how activities on the Moon should be conducted, and hence is included here.

Several articles could apply to the use of nuclear reactors on the Moon. Article 7 requires States Parties exploring and using the Moon to "take measures to prevent the disruption of the existing balance of its environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise." Furthermore, it requires States Parties to notify the Secretary-General

"in advance of all placements by them of radio-active materials on the moon and the purposes of such placements." States Parties also are to report on areas of the Moon "having specific scientific interest in order that . . . consideration may be given to the designation of such areas as international scientific preserves for which special protective arrangements are to be agreed upon . . . . "

Article 9 permits States Parties to establish "manned and unmanned stations on the moon" but requires that they be installed so that "they do not impede the free access to all areas of the moon. . . ." Article 10 states that States Parties "shall adopt all practicable measures to safeguard the life and health of persons on the moon" and regard any person on the Moon as an astronaut within the meaning of the Outer Space Treaty and the Astronaut Rescue and Return Agreement.

Article 12 asserts that "In the event of an emergency involving a threat to human life, States Parties may use the equipment, vehicles, installations, facilities or supplies of other States Parties on the moon." Article 14 addresses the question of liability for damage caused on the Moon by stating that arrangements in addition to those provided for in existing treaties may be required as activities on the Moon become more extensive. Article 15 requires all "space vehicles, equipment, facilities, stations and installations on the moon" to be open to other States Parties.

Other U.N. Space Treaties

Neither the Liability Convention[4] nor the Registration Convention[5] explicitly address the issue of use of nuclear reactors on the Moon. Since the reactors would be launched from Earth, however, the conventions clearly would apply to the launch of the spacecraft and its journey to the Moon. Hence, States Parties would be required to register the launch with the United Nations and the launching state would be liable for damages resulting from the spacecraft's launch. The launching State is "absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft in flight" (Article II). For damage that occurs "elsewhere than on the surface of the Earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State", the launching State is liable "only if the damage is due to its fault or the fault of persons for whom it is responsible" (Article III).

The Astronaut Rescue and Return Agreement[6] provides for rendering assistance to "personnel of a spacecraft" in distress. Since the Moon is not a spacecraft, this presumably would not apply to astronauts on the Moon. Similarly, the treaty addresses recovery and return of "a space object or its component parts," but it is not clear that an object on the Moon falls within this definition.

International Atomic Energy Agency Conventions

In the wake of the 1986 Chernobyl nuclear accident in the (then) Soviet Union, the International Atomic Energy Agency (IAEA) adopted a pair of conventions on notification and providing assistance in the case of nuclear accidents. While the motivation for the conventions clearly was concern about nuclear accidents on Earth, they also apply to space, though not necessarily the lunar surface.

The Convention on Early Notification of a Nuclear Accident[7] defines nuclear facilities covered by it as "any nuclear reactor wherever located" (Article 1). While it would be easy to initially conclude that the language was intended to refer only to activities on Earth, the fact that Article 1 also includes "the use of radioisotopes for power generation in space objects" suggests instead that space activities are not excluded and "wherever located" would apply to the Moon as well. However, the Convention requires States Parties to notify States which may be physically affected and the IAEA about a nuclear accident "from which a release of radioactive material occurs or is likely to occur and which has resulted or may result in an international transboundary release that would be of radiological safety significance for another State" (Article 1). (Emphasis added) Since the Moon is not subject to national appropriation (Outer Space Treaty, Article II), national boundaries cannot be drawn and thus a "transboundary release" is not possible. Since both conditions must be met (radioactive release and transboundary event), it does not appear that this Convention applies to the Moon (though it clearly does apply to RTGs on spacecraft).

The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency[8] requires in Article 1 that States Parties cooperate between themselves and with the IAEA "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." No mention is made in this convention of space, though the fact that its text was developed simultaneously with the Notification Convention implies that it applies to the same nuclear accidents as identified in that document. However, since the Notification Convention seems not apply to the Moon, neither would this one.

COPUOS Principles on Use of Nuclear Power Sources in Outer Space

At the June 1992 meeting of the U.N. Committee on Peaceful Uses of Outer Space (COPUOS), non-binding principles on the use of nuclear power sources in outer space were adopted (A/AC.105/L.198, 23 June 1992). The principles do not appear to apply specifically to emplacement and operation

of nuclear reactors on the Moon. Principle 3, Section 2.1 identifies places where nuclear reactors may be operated as

> (i) on interplanetary missions;
>
> (ii) in sufficiently high orbits as defined in paragraph 2.2;
>
> (iii) in low-Earth orbits if they are stored in sufficiently high orbits after the operational part of their mission.

Thus, while reactors clearly would be governed by the principles during their trip from Earth to the Moon, it is not clear that they apply to reactors on the lunar surface. The preamble to the principles refers to the use of nuclear power "in outer space" which logically includes the Moon and other celestial bodies. However, in the Outer Space Treaty, the phrase is written so as to leave no doubt: "outer space, including the moon and other celestial bodies." Principle 1 states that activities involving the use of nuclear power sources shall be carried out in accordance with, inter alia, the Outer Space Treaty. Thus the question remains whether the words "moon and other celestial bodies" were intentionally omitted from the principles, or if the assumption was made that the moon and other celestial bodies are automatically included by reference to the Outer Space Treaty.

Assuming the principles are meant to apply to use of nuclear power on the lunar surface, they recognize at the outset that "for some missions in outer space nuclear power sources are particularly suited or even essential due to their compactness, long life and other attributes." However, Principle 3 states that "In order to minimize the quantity of radioactive material in space and the risks involved, the 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." The question then becomes whether there are other ways to accomplish the goals envisioned for nuclear reactors on the Moon. If nuclear reactors are considered essential, they would be governed by dose limits (1 mSv in a year, or "a subsidiary dose limit of 5 mSv in a year for some years, provided that the average annual effective dose equivalent over a lifetime does not exceed the principal limit of 1 mSv in a year") and safety design requirements set forth in Principle 3.

Using Nuclear Reactors on the Moon

On July 20, 1989, the 20th anniversary of the first Apollo landing on the Moon, President George Bush announced new goals for the U.S. civilian space program, including returning humans to the Moon and then going on to Mars in the 21st century. The program, formally called the Space Exploration Initiative (SEI), but more commonly known as "the Moon/Mars program," has been endorsed

philosophically by the congressional committees that fund NASA,[9] though they have not provided NASA the requested funding for the program because of fiscal constraints.

Despite restrictive funding, NASA's Office of Exploration is studying ways of accomplishing President Bush's goals. NASA's briefings on the SEI program usually involve the assumption that nuclear reactors will be used for lunar bases. One advantage to reactors is that they can operate continually regardless of the 28 day lunar cycle (14 days of sunlight followed by 14 "days" of night). If solar arrays (photovoltaics) are used, storage systems would have to be provided for the lengthy nights (some suggest using fuel cells). The mass of the arrays plus the storage devices means that a solar energy system would weigh more than a nuclear system and hence might increase costs (a significant fraction of the cost of a lunar base is expected to be the transportation costs of getting material there). Hence NASA's attraction to nuclear reactors for this application.

In addition to NASA's efforts, the White House National Space Council created a special group to study "architectures" for fulfilling the Moon/Mars program. The so-called "Synthesis Group," headed by former astronaut Thomas Stafford, released its report in June 1991. The Stafford report also recommended nuclear energy for the lunar base, although its proposal envisioned a "habitat/lab" prior to construction of the base, and concluded that solar power would be sufficient for its initial operation. The report envisioned a transition from solar to nuclear energy between the "initial operational capability" and the "next operational capability" of the habitat.[10]

The mass of a solar energy system versus a nuclear system was a factor in their decision to recommend nuclear for long duration stays on the Moon. "For a 25 Kw [kilowatt] habitat load, nuclear systems as compared to solar photovoltaic systems will weigh one-fifth as much and save 8,000 kg [kilograms] on the lunar surface. Continuous base power that can increase to 1 MW [megawatt] will weigh about 12,500 kg using nuclear power, versus 330,000 kg using photovoltaics with energy storage."[11]

Not everyone agrees that nuclear systems are the best option for powering a lunar base. At hearings before the Committee on Science, Space and Technology of the U.S. House of Representatives on Mar. 15, 1992,[12] concerning a U.S. government program to develop a space nuclear reactor, called SP-100, the question of alternatives to nuclear reactors for providing electricity for lunar base operations was addressed. Witnesses from companies that build solar energy systems, fuel cell systems and energy storage devices testified that they could develop systems

capable of providing the requisite power for lunar bases.

Reflecting concern about the health and safety of astronauts in the area of lunar nuclear reactors, Representative Howard Wolpe, chairman of the subcommittee holding the hearings, asked whether the reactors would be enclosed in a containment structure (as they are on Earth). The response from NASA and DOE witnesses was that a final design of the reactor had not yet been determined, although one concept was to bury the reactor in the lunar soil or surround it by a berm, not by a containment structure. If that concept were used, Rep. Wolpe noted, citing information from DOE, "an astronaut could not come within 180 meters of an operating reactor without exceeding an allowable dose rate."[13] Further noting that documents from NASA on the evolution of a lunar base suggest the need for as many as 15 reactors of the SP-100 type, Rep. Wolpe remarked that "It appears to me that you would be creating a rather large uninhabitable area adjacent to your permanent manned base." The concept NASA and DOE is currently considering calls for each reactor to have a design life of 15 years, but operate for only 7 years, and no refueling of the reactors is planned. After their operational phase is completed, the reactors would be decommissioned by in situ abandonment, in other words, abandoning them in place. A DOE witness confirmed Rep. Wolpe's assertion that the area around the reactors would have to be "roped off for at least a few hundred years," leading the Congressman to observe:

> . . . establishing a permanent base on the moon while it's not high on my list of priorities, the manner in which this base is to be established under this proposal is even lower on my list of priorities. . . . But I am simply mystified that anyone who would place great importance in establishing a permanent manned colony on the moon, would be so willing to make such large parts of it uninhabitable for hundreds of years. . . . I would not want future generations to curse us for short-sighted decisions, to rely on dangerous technologies, and then to rely on disposal strategies, such as in situ abandonment.
>
> I personally don't think that we should take anything up there that we can't bring back if necessary. . . .
>
> The Department of Energy . . . is already knee deep in radioactive waste . . . .
>
> In light of that, I find rather remarkable what I take to be a somewhat cavalier attitude toward the adoption of policies that will spread this stuff throughout the heavens . . . .[14]

Throughout the hearing, NASA and DOE repeatedly stressed that it is very early in the development of reactors for use on the Moon, and no definitive plans have been made either for containment vessels or decommissioning.

Rep. Wolpe observed that "it just seems that the application of solar technology in this instance, that is, the moon mission, sounds to me like it would avoid an awful lot of grief, uncertainty, complexity and cost."[15]

Conclusion

No provision of existing law prevents the use of nuclear reactors on the Moon. Some language appears to regulate their use, however, and other provisions would affect their launch and journey to the Moon.

The Outer Space Treaty (OST), the Liability Convention, and the Registration Convention would affect U.S. plans for launch and operation of reactors on the Moon since the United States is party to all those treaties. The reactors would have to be designed and operated so as to avoid harmful contamination of the Moon (OST, Article IX). If their emplacement, operation or disposal would interfere with activities of other States Parties, the United States would have to undertake appropriate international consultations before proceeding (OST, Article IX). Thus, if plans called for in situ abandonment of the reactors, rendering the surrounding area unusable for "a few hundred years," or if astronauts could not approach the area of an operating reactor without exceeding permissible radiation dose limits because containment vessels are not provided, this certainly could affect the activities of other States Parties and thus international consultations would be required before proceeding. The Registration Convention would require the launch of a reactor destined for the lunar surface to be registered with the United Nations, and the Liability Convention would govern liability for damage during launch or in-flight.

However, the two main documents of relevance to this issue are not binding on the United States--the Moon Treaty, to which the United States is not a signatory, and the COPUOS principles, which are non-binding on any State. Through consensus, however, the United States has agreed with the COPUOS principles, suggesting that their provisions could not be easily ignored, especially in an era of environmental awareness.

Perhaps of most importance in the COPUOS principles is the language asserting that nuclear power be used only for those missions "which cannot be operated by non-nuclear energy sources in a reasonable way" (Principle 3). As the congressional hearings elucidated, there are other methods for generating electricity on the Moon. Trade-offs would have to be made between the expected

additional cost of a solar energy system compared with nuclear, versus the potential long term environmental effects of using nuclear reactors on the Moon. If nuclear reactors were determined to be essential to lunar base operations, then they could be governed by the dose limits and safety design requirements set forth in Principle 3.

Although it undoubtedly will be many years before any country or group of countries can afford an enterprise such as establishing bases on the Moon, it is not too early to begin negotiations of principles to guide the operation of nuclear reactors on the lunar surface. The first question is whether nuclear reactors are essential for technical or cost reasons. If they are, then designing them for maximum safety and minimal environmental contamination, and developing plans for their prudent disposal at the end of their lifetimes, should be high priorities. Negotiating internationally accepted guidelines now, while the reactors are still in the conceptual stage, should avoid costly redesigns in the future and mute concerns by environmental organizations that may oppose the use of nuclear reactors in space.

The principles adopted by COPUOS in June 1992 include a provision in principle 11 that they be reopened for revision "no later than two years after their adoption." This could serve as the opportunity for addressing whether they apply to nuclear reactors on the lunar surface (and other planetary bodies), and if not, to begin discussion of principles that would apply. If a decision were made not to raise the issue of lunar surface nuclear operations within the context of those principles, Article IX of the Outer Space Treaty requires international consultations before initiating any activity that could potentially cause harmful interference to activities of other States Parties. If operation of reactors will require cordoning off certain areas of the moon, a case could easily be made that they could create such harmful interference and trigger the need for international consultations in any case.

Notes

1. Kiernan, Vincent. Opponents of Military, Nuclear Space Form Coalition. Space News, July 27-Aug. 9, 1992, p. 26.

2. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies. Jan. 27, 1967, 18 U.S.T. 2410, T.I.A.S. 6347, 610 U.N.T.S. 205 (effective Oct. 10, 1967).

3. Agreement Governing the Activities of States on the Moon and Other Celestial Bodies. U.N. GAOR. 34th Sess. (1979) Supp. No. 20 (Doc. A/34/20) (Effective July 11, 1984).

4. Convention on International Liability for Damage Caused by Space Objects. March 29, 1972. 24

U.S.T. 2389. T.I.A.S. 7762. 961 U.N.T.S. 187 (effective Oct. 9, 1983).

5. Convention on Registration of Objects Launches into Outer Space. January 14, 1975. 28 U.S.T. 695. T.I.A.S. 8480. 1023 U.N.T.S. 15 (effective Sept. 15, 1976).

6. Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space. April 22, 1968. 19 U.S.T. 7570, T.I.A.S. 6599. 672 U.S.T.S. 119 (effective Dec. 3, 1968).

7. Printed in: Organisation for Economic Co-Operation and Development. Nuclear Energy Agency. Nuclear Law Bulletin. No. 38 (supplement). Dec. 1986.

8. Id.

9. While they zeroed funding for the program for fiscal year 1991, the House and Senate Appropriations Committees stated in the conference report accompanying the FY1991 VA-HUD-IA appropriations bill (which includes NASA) that their decision was based on budgetary constraints. They added that "It is implicit in the conduct of the Nation's civil space program that such human exploration of our solar system is inevitable." (Emphasis added)
Conference Report [To accompany H.R. 5158] from the Committee of Conference.
Making Appropriations for the Departments of Veterans Affairs and Housing and Urban Development, and for Sundry Independent Agencies, Commissions, Corporations, and Offices for the Fiscal Year Ending September 30, 1991, and for Other Purposes. 101st Cong., 2d Sess. (House Report 101-900. p. 44.)
The SEI program is also funded as part of DOE's activities and the congressional committees that oversee DOE have not been supportive of that activity.

10. The White House. National Space Council. Report of the Synthesis Group on America's Space Exploration Initiative. Washington, U.S. Govt. Print. Off., 1991. p. 69.

11. Id., p. 71.

12. Hearings before the Subcomm. on Investigations and Oversight of the House Comm. on Science, Space and Technology.
The SP-100 Space Reactor Power System Program. 102d Cong., 2d Sess. (Comm. Print, 1992).

13. Id., p. 219.

14. Id., pp. 221-222.

15. Id., p. 220.