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THE SP-100 NUCLEAR REACTOR PROGRAM

Should It Be Continued?

Statement of Mark E. Gebicke, Director, NASA Issues
National Security and International Affairs Division

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the SP-100 Space Nuclear Reactor Program. This program was established to develop technology for space reactor power systems to provide electrical power ranging from tens to hundreds of kilowatts for potential future space missions for the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA). The program has been struggling, and the government is at a point where it needs to decide whether this program should be continued. To contribute to the congressional deliberations on this issue, I would like to briefly highlight the results of our work and then discuss the following issues in a little more detail: (1) the program's past and projected costs, (2) missions identified by potential users of the technology, (3) recent events that raise questions about the program's continued viability, and (4) possible options for the program's future.

RESULTS IN BRIEF

The Department of Energy (DOE), NASA, and DOD have jointly invested over $420 million[1] in the SP-100 program since its inception in fiscal year 1983. While agency officials believe that technical progress has been achieved, challenges remain.

The projected costs of the program have more than tripled, and the program is projected to be over 13 years behind schedule. Funding shortfalls contributed to the cost increase and completion delay. Moreover, further cost increases and delays are likely.

DOD and NASA have identified potential missions where they believe the application of nuclear power, in the range expected to be generated by SP-100 technology, would offer advantages over other existing space power alternatives. However, no specific missions using SP-100 technology have been approved, and mission planners are unlikely to approve missions until they are satisfied that the technical and economic risks associated with applying the technology have been minimized.

DOD recently withdrew its funding support for the SP-100 program, raising concerns about the program's viability. The reasons DOD gave for withdrawing were (1) its concern over the continuing program cost increases and schedule delays, (2) changes to its planned missions, and (3) its belief that another nuclear reactor technology would meet its needs in a more cost-effective and timely manner. The Office of Management and Budget subsequently asked all

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[1]Dollars noted in this statement are expressed in current year dollars.

the agencies involved in the program to identify the most likely potential applications for space nuclear power systems and options for developing such systems.

Several options are available for consideration regarding the SP-100 program's future. These options include continuing the current program as planned, terminating the program, or accelerating the program to complete an SP-100 demonstration mission in the late-1990s. The preferred option or options may, however, depend upon the outcome of the Office of Management and Budget's review.

With that overview, I will provide some background on the operation of a space nuclear reactor power system and explain why the government started the SP-100 program and what has happened since the program's inception.

OPERATION OF A SPACE NUCLEAR REACTOR POWER SYSTEM

Space nuclear reactor power systems are made up of several subsystems in addition to the reactor. The design of these power systems can vary and depends on factors such as mission type and duration, operating environment, electrical load demands, and other performance requirements.

A nuclear reactor power system consists of several subsystems: (1) a compact nuclear reactor, (2) shielding, (3) a heat transport system, (4) a power conversion system, (5) a radiator, and (6) a power conditioning and control system.

The reactor power system operates as follows. When a reactor is in operation, a chain reaction fissioning process of the uranium material in the reactor core is sustained. The process generates tremendous quantities of heat, but also produces high levels of radioactivity. The shielding provides protection for other flight components from the radioactivity. In the SP-100, in order to convert heat to electricity, coolant passes through the reactor core, absorbs the heat and is pumped to an energy converter that converts the heat to electricity. A power conditioning and control system regulates and delivers power to other flight system components. Residual waste heat from the converter is transported to and through radiator panels and dissipated into space.

EVOLUTION OF THE SP-100 PROGRAM

In recent years, proposed DOD and NASA space missions have shown the need for electric power levels well beyond those needed during the first 25 years of the Space Age. These needs had been satisfied by well-understood and developed technologies. For example, the electric power used in space missions to the outer planets was generated by low-power nuclear sources. This source offers a unique advantage when the spacecraft is at great distances from the sun, but there are practical limits to the amount of electrical power it can supply.

From the 1950s through the early 1970s, the United States engaged in an extensive space reactor development program and even orbited, in 1965, a reactor power system that produced 500 watts in space. Though it was expected to operate for one year, the reactor operated for only 43 days due to an electrical, rather than a technological, problem. While reactor efforts continued through the early 1970s, work on space nuclear reactor programs was terminated because no firm missions that would use the technology materialized. Subsequently, DOD and NASA renewed their interest in developing space nuclear reactors because of their desire for higher power levels and other requirements associated with projected civil and defense missions.

As a result, DOE, DOD, and NASA embarked on an effort to identify what new power technologies could be developed or how existing technologies could be modified to satisfy power requirements ranging from tens to hundreds of kilowatts. Agency experts from the technological disciplines that could potentially produce the required power level reached a consensus that space nuclear power could best meet some of DOD's and NASA's future needs.

The decision to use space nuclear power led to the formation of, and subsequent funding from, the tri-agency--DOD, NASA, and DOE--SP-100 program in 1983. In the mid-1980s, the primary near-term mission considered for using SP-100 technology was the Strategic Defense Initiative program. At that time, the Strategic Defense Initiative Organization had expected that SP-100 technology would be sufficiently proven by fiscal year 1991 to satisfy mid-1990s missions. Since then, however, that organization's missions and deployment schedules have changed, and power requirements have been reduced from 300 kilowatts to the 5- to 40-kilowatt range. As of fiscal year 1992, DOD has stopped funding the SP-100 program.

PHASES OF THE SP-100 PROGRAM

The SP-100 program was originally divided into three phases: phase I--power system concept selection; phase II--technology development; and phase III--ground qualification[2] and flight demonstration. Phase I, which cost approximately $51 million and took place from 1983 to 1985, included technology assessment and the selection of a nuclear power system concept for further development in succeeding phases. The power system concept approved for development was a compact, high-temperature fast

[2]Ground qualification includes integrating all the reactor components and simulating environmental tests as if the system were launched.

reactor cooled by liquid metal, with a thermoelectric[3] power conversion process with no moving parts. An alternative power system concept, thermionics,[4] was a close runner-up in the selection process, but was not selected because of concerns about the performance and lifetime of the thermionic fuel elements.

Phase II objectives and scope have changed over the years. Initially, phase II efforts focused on engineering development and ground testing of major subsystems, with the objective of demonstrating that the nuclear reactor power system technology was ready for flight systems development. In December 1990, the tri-agency steering committee merged parts of phases II and III. Phase II currently emphasizes component and subsystem development and now includes ground qualification. Phase III is expected to encompass flight unit production, acceptance testing, flight demonstration, and use of the reactor power system in a space mission.

TECHNICAL PROGRESS AND REMAINING CHALLENGES OF THE SP-100 PROGRAM

According to program officials, the program made technological advancements in the reactor subsystem and in component development during phase II; however, several challenges remain. Advances have been made in the reactor to improve its safety, reduce its mass, and increase its useful life. Some of the key technical advancements in the reactor subsystem include the development of a fabrication process to make the uranium nitride fuel pellets and the demonstration of fuel pin technology. In the power converter subsystem, improvements have been made in the thermoelectric alloy material and in thermoelectric cell development. Some of the key remaining challenges of the SP-100 program include verifying and testing the lifetime of components in all subsystems, verifying the performance of the thermoelectric cells, and further reducing the overall mass of the system.

COST ESTIMATE INCREASES AND SCHEDULE DELAYS PLAGUE THE PROGRAM

Over the life of the program, estimated costs have repeatedly increased and scheduled completion has been delayed. Actual contributions of funds fell short of the amounts committed in the

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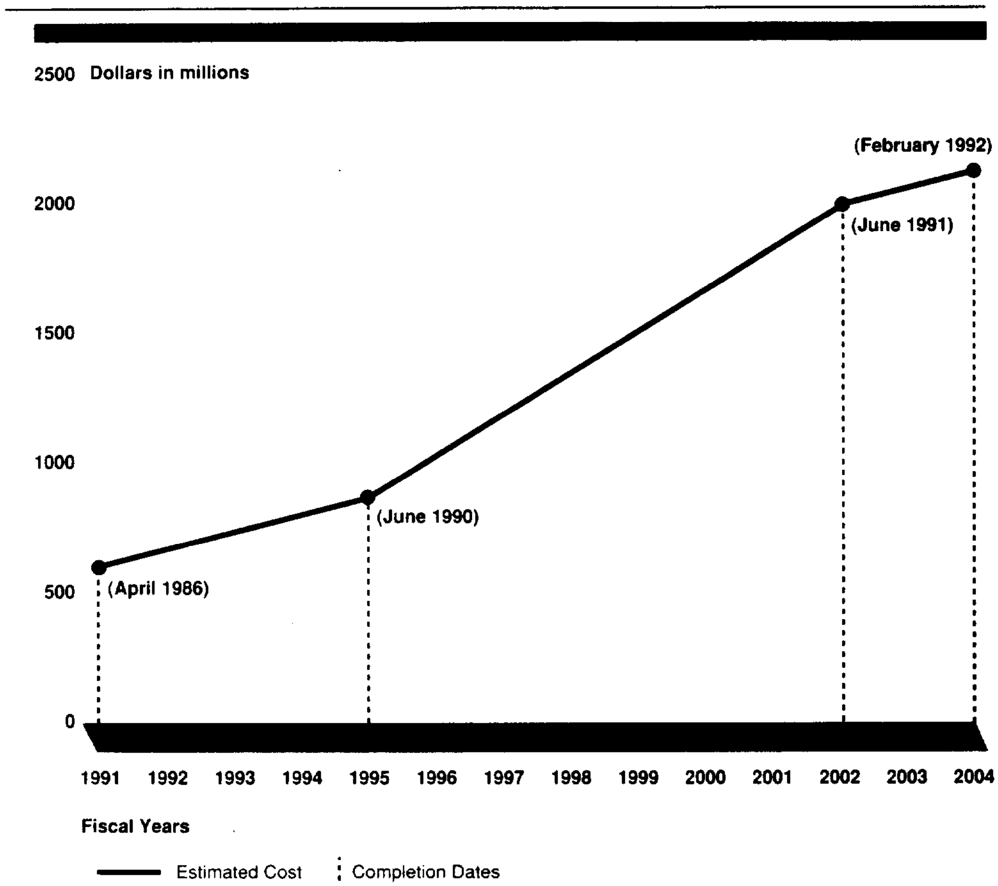
[3]A thermoelectric generator is a device that converts heat into electric energy by direct interaction of a heat flow and the charge carriers in an electric circuit that requires a temperature difference in the electric circuit.

[4]This concept relies on converting heat into electric energy by the emission of electrons from a heated cathode.

Memorandum of Agreement.[5] These shortfalls contributed to the increasing cost estimates and completion delays. Figure 1 shows the significant changes in the cost estimates and scheduled completion dates since phase II began in fiscal year 1986.

Figure 1: Estimated Cost and Completion Dates for Phase II



Note: The dates in parentheses show when the estimate was developed.

From 1986 to the present, the cost estimate for completion of phase II has more than tripled; also, the scheduled completion has been extended by 13 years. In April 1986, the cost to complete phase II was estimated at $586 million, with completion in fiscal year 1991,

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[5]A Memorandum of Agreement for phase II was signed in October 1985 by DOE, NASA, and DOD. Amendments to the memorandum were agreed to in May 1986 and October 1989. In addition to establishing respective agency roles and a management structure, the memorandum identifies agency funding level commitments.

to meet DOD's projected needs. By June 1990, before phase II was expanded in December 1990, the cost estimate rose to $865 million, with expected completion by fiscal year 1995. Under the new approach to completing phase II, ground qualification, once a phase III function, became part of phase II. By June 1991, the cost estimate for phase II was $2 billion, with expected completion by fiscal year 2002. As of February 1992, program officials predicted that the cost to complete phase II would be $2.1 billion, with completion by fiscal year 2004.

DOE officials estimate that phase III may cost between $250 million and $500 million. This estimate, however, is unofficial, and no documentation was available for our review. Also, this estimate does not include associated launch costs.

Annual funding has not reached the levels committed to in the Memorandum of Agreement. The annual funding shortfall has ranged from a low of $10 million, or 27 percent, in fiscal year 1986 to a high of $84 million, or 53 percent, in fiscal year 1989. Attachment I shows the proposed and actual funding levels by agency from fiscal years 1986 through 1992.

Funding shortfalls resulted for two reasons: (1) the agencies did not contribute the amounts identified in the Memorandum of Agreement and (2) Congress made adjustments to DOE's budget request.[6] First, in no year since phase II began has every agency contributed the amounts they agreed to in the Memorandum of Agreement. For example, in fiscal year 1988, DOD was expected to contribute $82 million but contributed only $25 million. Similarly, DOD did not contribute its expected share in fiscal years 1989 or 1990. Second, congressional budget adjustments also contributed to the estimated cost increases and schedule completion delays. For example, in fiscal year 1991, DOE requested $51 million but was appropriated $31.3 million. Similarly, Congress reduced DOE's fiscal year 1992 request.

POTENTIAL USERS OF THE SP-100 ARE RELUCTANT TO COMMIT TO AN UNPROVEN TECHNOLOGY

While it may be advantageous to use space nuclear power for certain missions, potential users want assurance that the technology is "proven" before they commit to using it for a mission. DOD and NASA officials, outside experts, and various studies have concluded that space power in the power range level expected to be produced by SP-100 technology could be used to satisfy both potential military and civilian applications. For example, power in this

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[6]DOE funding for the SP-100 program is a specific congressional budget line item. In contrast, DOD's and NASA's funding of this program is contained in a broader program budget line item.

range could be used to provide propulsion for a mission that orbits Pluto or Uranus rather than flying by them. However, mission planners are reluctant to link a specific mission to an unproven technology.

Potential NASA Missions
for SP-100 Technology

NASA officials indicated that there may be other potential NASA missions that could use SP-100 technology. Such missions include providing propulsion for the Space Exploration Initiative's lunar cargo mission or a piloted mission to the planet Mars and providing surface power in establishing permanent bases on the Moon or Mars. But, at this point, none of these potential missions have been approved. Rather, these are missions that NASA planners would like to see come to fruition.

According to NASA officials, no potential mission is ever wholly dependent on any one technology. But they stated it is impractical to use anything but nuclear electric propulsion for some missions, such as a mission to Pluto. They noted that the most attractive attribute of nuclear electric propulsion is its ability to maneuver with great fuel efficiency. For example, a spacecraft would be able to orbit a planet and its moons for extended periods of time, change orbits to obtain additional scientific data, or move from moon to moon, as required. Furthermore, the quality of scientific data would be enhanced because a nuclear-powered spacecraft can provide power for more scientific instruments and a greater data transmission rate than a conventionally powered spacecraft.

Potential DOD Missions
Requiring Space Nuclear Power

According to DOD officials, although SP-100 technology is planned to provide scalable power ranging from tens to hundreds of kilowatts, their analyses show that their power requirements for missions projected to start in the next decade now fall into the range of 5 to 40 kilowatts. DOD's potential missions generally fall into three categories: (1) power for surveillance systems, probably using active sensors; (2) housekeeping and weapon power for directed energy weapons; and (3) electric propulsion for orbital transfer vehicles. None of DOD's currently planned missions include the use of SP-100 technology.

RECENT EVENTS

Since DOD eliminated its funding for fiscal year 1992, program officials are now reviewing future funding needs. These needs, and subsequent changes to the program's cost and completion estimates, are unclear at this time. However, given the funding history of the program, we believe that the cost estimates will continue to increase and the completion schedule will be further delayed.

As an alternate to the current program, program officials are considering a demonstration mission in the late-1990s that would reduce program costs by about $700 million and the time required for the technology to be proven by about 9 years. The costs, benefits, and risks associated with this potential mission are discussed later in this statement. The predicted cost and time savings, however, are unofficial, and the mission is only in the early stages of discussion by program officials.

DOD officials decided that because of requirement changes, growing cost estimates, and schedule delays in the SP-100 program, they would make a more significant investment in a thermionics conversion system development program and eliminate their funding for SP-100. Although the United States has had a joint DOD/DOE thermionics research program since 1986, funding for it has been limited in comparison to the SP-100 program. Only about $37 million has been spent to date.

The former Soviet Union, now the Commonwealth of Independent States, has made great strides in thermionics research. In 1989, the Soviet Union offered to sell the United States an unfueled Topaz thermionic reactor for ground testing by U.S. scientists. Subsequently, Strategic Defense Initiative Organization officials expressed interest in purchasing the Topaz. Officials told us that they are interested in building on the Commonwealth's thermionics technology and stated that they expected the Topaz to be delivered soon. However, an official from the Office of the Secretary of Defense told us that DOD had not yet decided to proceed with the acquisition of the Topaz. The potential purchase is currently undergoing detailed policy reviews.

The joint DOD/DOE thermionics program is expected to produce between 5 and 40 kilowatts--the levels needed to run potential DOD missions. In addition to the cost and schedule factors affecting the SP-100 program, DOD officials viewed the potential availability of the Topaz reactor as an opportunity to build on technological progress made by the Soviet Union. DOD officials believe that space qualification of a U.S. thermionic reactor will cost about $451 million and can occur by 1999. They based their cost and schedule savings estimates primarily on contractors' preliminary estimates. Associated launch and launch vehicle costs are not included in this estimate. DOD assumed that space qualification for the SP-100 would not occur until about 2009 and would cost more than $2 billion.

DOE officials told us that the predicted cost and schedule savings for developing a thermionic reactor are not realistic. In addition, the thermionic program is aimed at developing a less powerful reactor with a shorter lifespan than the reactor system to be developed under phase II of the SP-100 program. Furthermore, some NASA and Jet Propulsion Laboratory officials expressed doubts about the usefulness of studying the Topaz and concerns about the pursuit of two different space nuclear power programs when funds are limited. They believe that SP-100 technology development is further along than thermionic technology development and a thermionic reactor program will therefore have to catch up. Specifically, they cited SP-100 advances in safety, increasing the reactor's lifetime, and reducing its mass.

In January 1992, the Office of Management and Budget asked that DOD and NASA jointly submit a report by March 1, 1992, that identifies the most likely potential applications for space nuclear power systems from 2000 to 2010. In addition, DOE, NASA, and DOD are to submit a joint report identifying program options for developing space nuclear reactor power systems to be used in these applications. As of March 9, 1992, these reports had not been submitted.

SEVERAL OPTIONS ARE AVAILABLE CONCERNING SP-100's FUTURE

Recent events have led us to believe that the future of space nuclear power systems is at a crossroad. Where do we go from here? We believe that several options need to be considered. The preferred option or options may, however, depend on the Office of Management and Budget's assessment of potential applications for space nuclear power systems and alternatives. Three options for consideration follow.

Option 1. Continue phase II of the program under the current schedule at an estimated cost of $2.1 billion for completion in 2004. Continuing phase II offers assurances that the power system will proceed through the full testing and development program. However, it is a costly and lengthy way to proceed. We believe, given the program's funding history, that the current cost and completion estimates are overly optimistic. If this option is pursued, a decision to continue with phase III could be made at or near the completion of phase II.

Option 2. Terminate the program. The obvious benefit of this option is that the remaining costs to complete phase II--over $1.6 billion--could be saved. The obvious disadvantage is that by terminating the program, the United States will lose the technology expected to be produced by the program. Also, SP-100 officials estimate that termination and storage costs could be about $15 million to $20 million in fiscal year 1992 dollars. This estimate is based on system contractor termination costs of $8 million to $10 million, fuel storage costs of $3 million to $4 million, and national laboratories' termination costs of $4 million to $6 million. If the program were terminated now or at some point before phase II were completed, some of the built-up learning curve would be lost. The costs for recapturing the learning curve are impossible to predict at this time. In addition, development work-in-process would stop, and archiving of research results could be affected. This becomes important should it be decided at some future time to restart the program. It is unlikely that the teams of people currently associated with the SP-100 program would be available to restart the program in the future.

Option 3. Some program officials thought that a fast-track approach, or an early demonstration mission, could be pursued for the late-1990s. We believe that this option, in general, requires further scrutiny and detailed assessments of costs, suitable missions, and technical risks. This option includes identifying a demonstration flight to be launched, powered by SP-100 technology. SP-100's development plans would probably need to be altered to eliminate the nuclear assembly test and go directly from component development to a demonstration flight. Also, certain components would not be fully matured or developed if this option were pursued. One result of this would be that the system would be heavier than expected. Also, full lifetime testing of components would be conducted on the ground rather than in space.

While this option does not yet have an official cost estimate, the SP-100 project manager at the Jet Propulsion Laboratory indicated that such a mission could be accomplished in the late-1990s for an estimated $1.4 billion, or about $700 million less than the current phase II cost estimate. This estimate includes component development, flight demonstration, fabrication, and test facilities but not associated launch and launch vehicle costs. According to NASA officials, these other costs could range between $65 to $286 million if either an Atlas or Titan launch vehicle were used.

The range of these options is very wide and warrants substantial deliberation. The costs are too high and the potential missions too important to postpone a complete review of the options.

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This concludes my prepared statement. I would be pleased to answer your questions.

PROPOSED AND ACTUAL FUNDING, BY AGENCY, FOR THE SP-100 PROGRAM

Dollars in millions

Fiscal year	Memorandum of agreement[a]	President's budget request[b]	Appropriation[d]
1986			
DOE	$16.6	$16.6	$16.0
DOD	16.0	20.0[c]	10.7
NASA	4.0		0
1987			
DOE	30.0	30.0	27.6
DOD	51.0	55.0[c]	36.5
NASA	4.0		0
1988			
DOE	79.0	70.0	59.0
DOD	82.0	85.0[c]	25.0
NASA	4.0		10.0
1989			
DOE	83.0	58.0	56.0
DOD	73.0	62.0[c]	10.0
NASA	4.0		9.9
1990			
DOE	55.0	43.0	29.3
DOD	43.0	35.0[c]	20.0
NASA	4.0		9.9
1991			
DOE	51.0	51.0	31.3
DOD	20.0	40.0[c]	9.0
NASA	20.0		9.9
1992			
DOE	56.0	52.0	36.0
DOD	25.0	51.0[c]	0
NASA	22.0		10.0

[a]Memorandum of Agreement, dated November 1985, and amendments where applicable.
[b]DOE funding for the SP-100 program is a specific congressional budget line item. In contrast, DOD's and NASA's funding of this program is contained in a broader program budget line item.
[c]The amount shown is what DOE anticipated would be contributed by DOD and NASA.
[d]The amount shown is what DOD and NASA actually contributed to the program from appropriated funds.

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