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Testimony

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SPACE NUCLEAR
PROPULSION

History, Cost, and Status of
Programs

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Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to set the stage for a discussion of space nuclear thermal propulsion programs under development by the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) with the support of the Department of Energy (DOE). As you requested, my testimony will focus on the history, costs, and current status of these programs; and the roles and responsibilities of the major participants.

OVERVIEW

DOD and NASA are pursuing separate approaches to develop space nuclear thermal propulsion programs. The DOD program differs from the NASA approach primarily in the manner in which the nuclear fuel is packed in the reactor. NASA's approach, based on technology developed and tested from 1955 to 1972, involves the use of nuclear fuel encased in rods. DOD's approach envisions use of a nuclear fuel encapsulated in very small particles. If this particle bed reactor technology can be developed, it is expected to significantly increase the performance of future nuclear rocket engines.

DOD's nuclear thermal propulsion technology demonstration program was originally undertaken by the Strategic Defense Initiative Organization (SDIO), which studied the feasibility of using nuclear-powered rockets based on particle bed technology to launch heavy payloads into orbit and to intercept incoming enemy ballistic missiles. SDIO terminated its program and transferred the technology to the Air Force at the beginning of fiscal year 1992. While the Air Force has not yet identified a specific mission requirement for space nuclear thermal propulsion technology, it is pursuing the program as a technology demonstration. Air Force officials told us that some of their missions could be satisfied by nuclear propulsion systems, such as improved upper stage space launch and has suggested that the technology would be beneficial to NASA for space exploration missions.

The particle bed reactor program is still in the initial stage of component development and testing. The ability of the fuel particles to achieve desired performance objectives has not yet been demonstrated. No reactors have been built or tested. DOD has provided \$196 million through fiscal year 1992, and has requested \$39 million for fiscal year 1993 for the particle bed reactor program. Continuing the program through ground testing would require the construction of environmentally acceptable test facilities, currently estimated by the Air Force to cost about \$400 million.

NASA's nuclear thermal approach has a longer history. Nuclear rocket research and technology development in the United States started in 1955 under the program nicknamed ROVER jointly managed by the Atomic Energy Commission (AEC) and the Air Force. The Air Force role in the program was transferred to a newly established NASA in 1958. Early research under the ROVER program prompted the NERVA (Nuclear Engine for Rocket Vehicle Application) effort. The NERVA program developed and ground tested 20 reactors which provided confidence that a nuclear rocket engine could be used for space flight application. However, after an expenditure of \$1.4 billion, the program was cancelled in 1973, due to budget considerations and changing mission priorities.

NASA recently reestablished the need for nuclear thermal propulsion systems to support the President's Space Exploration Initiative (SEI), which seeks to return astronauts to the moon and place them on Mars in the next century. Following announcement of the SEI in 1989, NASA began a modest effort to determine the utility of NERVA derivative or alternative systems to meet SEI requirements, budgeting about \$3.5 million per year for studies and analyses of various nuclear thermal propulsion concepts.

DOE is supporting both DOD and NASA and is pursuing the joint planning, development, and acquisition of a ground test facility capable of testing the NASA and DOD programs. DOE is responsible for designing, developing, and testing nuclear power and propulsion technologies. DOE efforts can be self-initiated or in support of other agencies. Brookhaven and Sandia National Laboratories are the principal DOE laboratories participating in the SNTP program. Additional work is being carried out by Grumman Electronics Systems Division, Babcock and Wilcox, and other contractors.

Concerns about the use of nuclear power systems in space were heightened when a former Soviet Union satellite of the COSMOS series, which was powered by a nuclear reactor, disintegrated over Canada. The event resulted in development of non-binding international principles governing the use of nuclear reactors in space. According to Department of State officials, the principles, which are expected to be adopted by the United Nations General Assembly during its upcoming session, do not prohibit the use of nuclear propulsion systems in space.

With that overview, let me talk more specifically about DOD's program.

DOD's PROGRAM TO DEVELOP NUCLEAR THERMAL PROPULSION

DOD's work on nuclear thermal rocket propulsion systems was initially conducted under a classified program called TIMBERWIND by SDIO. SDIO's interest stemmed from its general interest in new launch systems that could enable rapid intercept of incoming enemy ballistic missiles, and provide a lift capability for deployment of

massive space-based antimissile systems. These requirements appear to be fading as SDI concepts now envision the use of ground-based interceptors and/or distributed arrays of smaller satellites such as BRILLIANT PEBBLES. SDIO formally terminated the TIMBERWIND program in fiscal year 1991. In 1992, the Air Force assumed program management responsibilities under the name of the Space Nuclear Thermal Propulsion Program (SNTTP).

Objectives of the DOD Program

The purpose of the SNTTP program is to increase lift capabilities by 200 to 400 percent over current chemical rocket engines. The increased performance would facilitate lifting payloads from low earth orbit, to mid-altitude orbit, and to geosynchronous orbit. Although the SDIO program had envisioned launching nuclear-powered interceptors from earth, the Air Force has stated that it does not intend to launch nuclear-powered rockets from earth or operate them within the earth's atmosphere.

Particle Bed Reactor Engine is the Key

The technical objective of the SNTTP is to develop and demonstrate a nuclear thermal propulsion engine based on the use of a particle bed reactor. Brookhaven National Laboratory, Babcock and Wilcox Grumman Electronics Systems Division, and other contractors have investigated particle bed reactor technology and have concluded that, although it is technically challenging, it has significant potential.

Nuclear thermal rockets use heat from a nuclear fission reactor to raise the temperature of a propellant, usually hydrogen, and then expel it through a nozzle to produce thrust. In a particle bed reactor configuration, extremely small nuclear fuel particles would be used to increase the ratio of surface area to volume of the nuclear material, thereby increasing the heat of the hydrogen fuel. Higher fuel temperatures would produce greater thrust which would improve mission performance over chemical rocket engines or the original NERVA reactors.

Initial efforts are intended to develop the particle bed reactor technology and demonstrate its safety, feasibility, and capability through a series of tests at a ground test facility. The tests would involve the evaluation of fuel samples, fuel elements, and nuclear rocket engines. Major steps in the program are, first, demonstrating a high-performance nuclear fuel element in existing and to-be-built fuel element test reactors; and second, qualifying a flight-capable engine at a ground test site.

Assuming these objectives can be achieved, the logical extension of the effort would be a demonstration flight test program. However, a flight test decision has not been made.

DOD Program Management

The SNTP Program Office resides within the Air Force's Phillips Laboratory in Albuquerque, New Mexico. Grumman Electronics Systems Division is responsible for integrating the system design, development, and fabrication activities of all other contractors for the Program Office. Grumman will be assisted by Garrett, Hercules, L-Systems, and General Dynamics Corporations. Babcock and Wilcox and Aerojet General Corporations will design, develop, and fabricate the particle bed reactor. Xerad Corporation will perform program support and independent review functions. DOE's Brookhaven National Laboratory has led the development of nuclear fuel particles for SNTP. Sandia National Laboratory is involved in developing plans and concepts for testing fuel elements and nuclear engines. These relationships are shown in appendix I.

Funding

SDIO spent \$131 million on the TIMBERWIND program from fiscal years 1988 through 1991. When the program was transferred, \$65 million that had been programmed for TIMBERWIND in fiscal year 1992 was transferred to the Air Force to fund SNTP. The Air Force has requested about \$38.9 million for fiscal year 1993 and plans to spend about the same amount each year through fiscal year 1996.

Let's turn now to NASA's program.

NASA'S PROGRAM TO DEVELOP NUCLEAR THERMAL PROPULSION

The nation's nuclear rocket program began in 1955 as a joint Atomic Energy Commission and Air Force effort called ROVER at Los Alamos Scientific Laboratory and the Lawrence Radiation Laboratory. The original objective of the ROVER program was to design a nuclear engine capable of powering long-range single stage ballistic missiles. The Air Force role in the program was transferred to a newly established NASA in 1958.

Early research indicated that flight data on a reactor was needed. This finding prompted the NERVA effort, which was intended to test a reactor in flight. In June 1961, the joint NASA/AEC office, the Space Nuclear Propulsion Office, awarded the NERVA contract to develop an in-flight test engine to Aerojet General Corporation and an associated contract to Westinghouse Electric Corporation. However, the successful development of the Saturn V chemical rocket engine made it unlikely that the NERVA engine would be used as an upper stage for the manned space program. As a result, in 1964 the NERVA program was redirected to technology development as opposed to a flight test program. From its inception until its demise in 1973, the NERVA program included ground tests of over 20 reactors with a cumulative test time of 17 hours.

Space Exploration Initiative

NASA's interest in nuclear propulsion has been revived with the administration's Space Exploration Initiative (SEI), which calls for NASA to return to the Moon and go to Mars early in the 21st century. Nuclear propulsion could offer greater mission flexibility, reduced mass and cost, shorter transit times, and growth capabilities for new space exploration transportation systems. If transit times can be reduced, the exposure of astronauts to solar and galactic radiation could also be reduced.

After examining the pros and cons of chemical, solar electric, nuclear thermal, and nuclear electric propulsion technologies for the Mars mission, NASA recommended development of nuclear thermal technologies. NASA's Lewis Research Center in Cleveland, Ohio, is considering a nuclear propulsion program with the goal of building and ground testing a rocket engine that would allow flight qualification to begin by the year 2006. NASA has examined three nuclear thermal propulsion rocket concepts: solid core, liquid core, and gas core. It determined that the solid core concept would best meet its mission requirements because the liquid and gas core concepts may not be mature in time to fit the initial Mars mission time frame. Both the NERVA and SNTF concepts represent solid core reactor technologies.

Although NASA is considering SNTF for its space exploration requirements, it has not contributed any funds from its budget toward development of the particle bed reactor. NASA believes the NERVA derivative systems could be available sooner than the particle bed reactor because NERVA reactors have already been tested, while no particle bed reactor has yet been built. NASA officials told us that the increased performance particle bed reactors might offer is not really needed for the space exploration missions NASA currently envisions.

Funding

In 1992, NASA spent about \$3.5 million on nuclear thermal propulsion program concept and technology development studies, systems engineering, and project management efforts. NASA has requested the same amount for 1993 and proposes to spend it for similar functions.

I will now turn to the role of DOE in supporting the DOD and NASA programs.

DOE'S ROLE IN DEVELOPING NUCLEAR THERMAL PROPULSION

DOE designs, produces, and delivers nuclear power sources--from fuel to complete reactor assemblies--that will be used in space transportation systems conceived and produced by its customers: NASA and DOD. DOE works with both agencies in designing,

developing, and testing nuclear power source technologies. DOE also develops nuclear technology concepts as a part of its responsibilities to further nuclear research. DOE is pursuing the joint planning for development and acquisition of a ground test facility capable of testing both the NASA candidate and SNTP.

Brookhaven National Laboratory

DOE's Brookhaven Laboratory conceived and began developing the idea of building a reactor using nuclear fuel in the form of loose particles in 1960. Early concepts were based on the use of a fuel particle similar to the kind that had been developed for gas cooled nuclear power reactors. At first the work was devoted to experimenting with ways to hold the particles in place. The work was not continuous, but in 1983 Brookhaven began development of a particle bed reactor.

Two applications for the particle bed reactor were analyzed during the 1983 to 1987 time period, one for producing large amounts of electrical energy for use by SDI systems in space, the other a propulsion system that could be used to move a satellite from a low earth orbit to a geosynchronous earth orbit. A model of the orbit transfer vehicle was built, but a nuclear-fueled system was never built or tested. In 1987, Brookhaven participated in SDIO's study that focused on the utility of the particle bed reactor in a propulsion system under its then classified TIMBERWIND program.

Sandia National Laboratory

DOE's Sandia National Laboratory is primarily responsible under the SNTP program for testing nuclear fuel elements and engines. Sandia has developed an Integrated Test Plan for this purpose. The fuels testing and evaluation objective is to qualify coated particle fuels for nuclear propulsion concepts. This will require determining the performance limits of the fuel, its operational and safety characteristics, and design improvements needed to increase performance and safety levels.

As SNTP is presently envisioned, tests of the fuel particles would be followed by a series of tests of prototype fuel reactor elements. A series of five or six Particle Bed Reactor Integral Performance Element Tests (PIPET) are contemplated. Objectives of the PIPET series are to (1) demonstrate fuel element performance, stability, and operability under SNTP conditions; (2) develop reliability data suitable for support of engine test programs; and (3) generate a database from which fuel element design models and computer codes can be verified and/or refined.

If the PIPET series is successful, SNTP would contemplate a series of full power ground tests to verify performance. The PIPET reactor could also be used to test other nuclear rocket fuel elements that might be useful to NASA.

A new testing facility operated by DOE would be required because no reactor facility currently in existence in the United States can accommodate the test conditions needed to fully evaluate SNTP fuel elements. The Air Force estimates that constructing the new test facility and completing the PIPET series would cost \$407 million. However, DOE has estimated the cost of a test facility that would satisfy both DOD and NASA requirements at \$.5 to 1.0 billion.

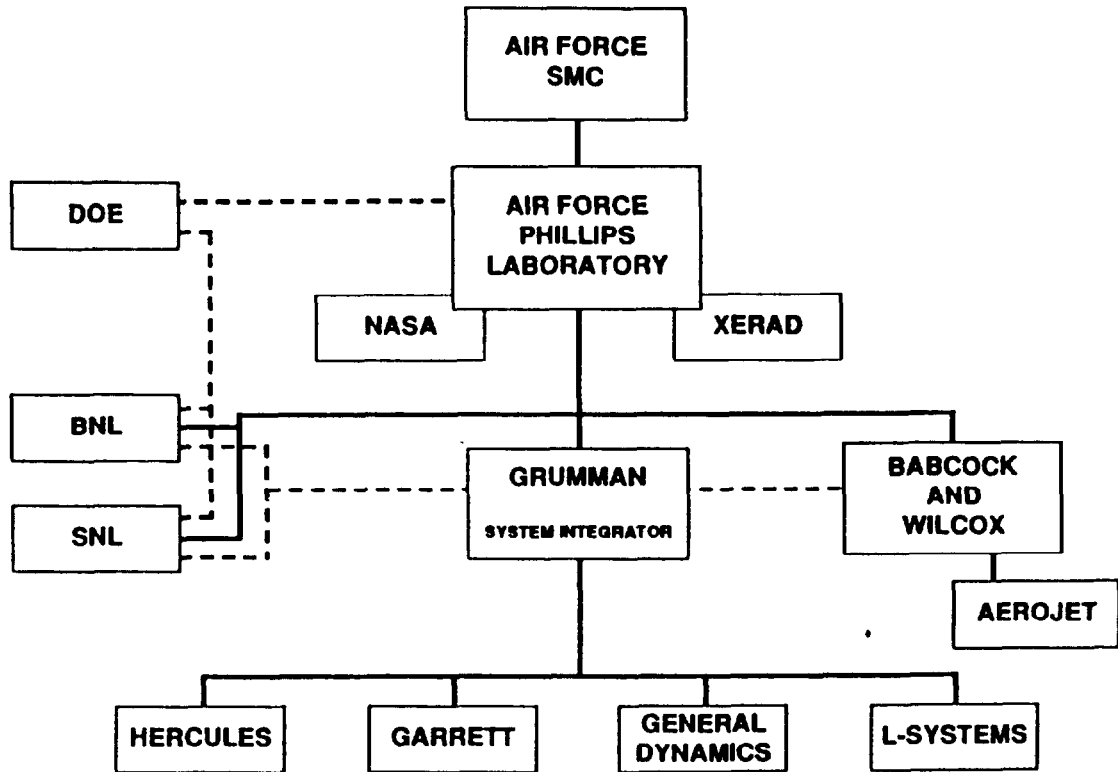
Funding

Because the DOE laboratories receive funding from multiple sources, we were unable to quantify how much AEC and DOE have spent on developing nuclear thermal propulsion systems since 1955. In fiscal year 1992, DOE is spending about \$3 million for Program Research and Development Announcements; university grants; and various concept development, test and facilities planning; and environmental impact studies activities related to nuclear thermal propulsion concepts.

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Mr. Chairman, this concludes my prepared statement.

DOD, DOE and Industry Relationships for the SNTP.



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