Nuclear Space Initiative:
A Planetary Society White Paper

In 2002 The U.S. Administration proposed a "nuclear space initiative" for the propulsion and power of deep space probes. This included the development of new radioisotope thermoelectric generators (RTG) and nuclear reactors for future planetary missions. The Planetary Society analyzed the proposal and drafted a response. One year later the initiative was organized within NASA as Project Prometheus, a program to develop the technology with goals of first mission use for a new RTG on the Mars Surface Laboratory mission (scheduled for 2009) and for propulsion for a very large and ambitious mission, Jupiter Icy Moons Orbiter (JIMO) for the middle of the next decade. JIMO has now been indefinitely postponed and a new first mission for nuclear electric propulsion technology is being sought. The following is an update of our original 2002 White Paper, including consideration of the recent (2005) JIMO postponement. We invite our readers' comments, and we will take them into serious consideration in formulating our final position on the initiative.

The Planetary Society supports the continuing exploration of the solar system including missions to Mars, Pluto and Europa now in development. Such exploration is limited by the difficulties of supplying power for deep space applications. We support the President's proposal for a Nuclear Systems Initiative, and the resultant Project Prometheus for deep space applications. Nuclear power is needed for future exploration of the planets. Nuclear propulsion however will not be ready for many years and we believe that a cautious approach is required both in its development and in satisfying public environmental and safety concerns. Thus, while supporting Prometheus we specifically recommend against relying on the readiness of Nuclear Electric Propulsion for any mission of high science priority in the near term or by any particular launch date. Conversely we urge the development of the improved RTG (radioisotope thermoelectric generator) for a 2009 Mars mission.

The following explains our position.

***What* is Project Prometheus?**

The President's proposed budget for the fiscal year starting in October 2002 included a program, to be conducted jointly by NASA and the Department of Energy, known as the Nuclear Systems Initiative (NSI). In 2003 this program was organized as a NASA project, Prometheus. This multi-year endeavor is aimed at developing advanced means of power and propulsion to enable long lived, highly capable spacecraft to intensively explore the outer reaches of the solar system and the surface of Mars.

Prometheus has two components: Development of more effective Radioisotope Thermal Electric Generators (RTGs) that generate hundreds of watts, and development of nuclear power reactors generating tens of kilowatts of electric power. The latter can propel spacecraft to great distances from the Sun, and is referred to as Nuclear Electric Propulsion (NEP).

The NEP development program was expected to take about a decade to produce technology that can then be turned into operational systems. It is now expected to take longer. The RTG improvements would take less time. Together they will require an investment of over $2 billion to achieve these goals.

Why was it proposed?

Outer planet and Martian surface exploration have always been handicapped by scarcity of power. The traditional means for powering long-lived space vehicles, solar energy converted to electricity, becomes rapidly ineffective as one travels further from the Sun. Solar intensity diminishes with the square of the distance from the Sun, so that at Jupiter, the nearest of the outer planets and five times more distant from the Sun than the Earth, the solar intensity is only one twenty-fifth its value at Earth. Similarly, on the Martian surface, the severe cold combined with nighttime conditions sharply limit landers and rovers using solar power alone.

The very distance of the outer planets make for very long transits, often taking ten years or more before the objectives of the mission can be accomplished. While more powerful launchers can shorten trip time, they are expensive and highly inefficient for this application. And some goals, i.e., orbital reconnaissance of the far outer planets, cannot be accomplished at all without nuclear electric propulsion or more exotic means.

These handicaps can be overcome by employing nuclear power. From a technical standpoint, nuclear material contains more extractable energy for a given mass than any other substance. Nuclear energy, converted to electricity, eliminates the need for solar panels whose size is impractical beyond Jupiter. Nuclear power can provide both electricity and heat for Martian explorers anywhere on the surface of the planet, whereas solar panels are most effective around the equator and in low latitudes. Furthermore, the use of solar panels limits the possibility of subsurface exploration because of the limited power available for drilling. Note that RTGs have been successfully and safely used on the Apollos, Vikings, Pioneers, Voyagers, Galileo and Cassini space missions. Nuclear electric propulsion can substantially increase payloads and lower launch vehicle requirements, for missions to the outer planets, in some cases with shorter trip times.

In general, nuclear power facilitates intensive exploration of remote regions of the solar system such as a multi-objective tour, the major satellites of Jupiter, some of which are thought to harbor subsurface oceans, and sophisticated mobile laboratories on Mars, which could penetrate well below the surface. In the long run, nuclear power and propulsion will likely be needed for missions to carry humans to Mars and back.

What's _good_ in it?

The major questions facing scientists engaged in exploring our universe include how the solar system formed and how life began. People have always wondered about the uniqueness of life -- is it only confined to Earth, or can we find it elsewhere in the universe? In recent times humankind has acquired the tools to address these questions. We have sent our machines, as surrogates of ourselves, to probe the nearby planets in search of clues that will get us closer to the answers.

But our tools are limited. More capable tools will allow us to probe deeper and further, and to carry more sophisticated instruments. Among those tools is the employment of nuclear power and propulsion. If this technology is developed and employed, we can expect a more vigorous program to explore environments that may harbor extraterrestrial life. It would then be possible to probe the most promising of these, deep beneath the surfaces of Mars and Europa. It would also make possible sending probes to the outer solar system, which may contain the record of the early history of our part of the universe.

In the near term, the advancements in RTGs will increase the size and range of Mars landers, as well as their surface and subsurface science capabilities. It will also allow for missions capable of exploring Jupiter's moon Europa from a close orbit later in the decade. In short, improved RTGs *enhance* current capabilities.

NEP will open a whole new category of mission possibilities, including deep penetration of the icy surface of Europa, an extensive tour with deployed landers in the Jupiter or Saturn system, and orbiters about objects farther out in the solar system, such as Neptune's moon Triton. In short, NEP could enable us to build more capable spacecraft and fly more ambitious missions.

What's *bad* in it?

Environmental concerns: Nuclear power has a unique handicap: It is categorically opposed by some. Their position is that nuclear material, in any form and in any place, is a danger to the population of the Earth and that no benefits are worth the risks that it imposes on mankind. They are particularly alarmed by employment of nuclear energy in space where, in principle, it might be diverted to weapons or other military systems, and where deadly radioactive material might be accidentally spread over large areas.Their position has been loudly articulated and lent some credence by the disasters at Chernobyl and Three Mile Island. NASA and the Department of Energy acknowledge that nuclear technology involves risks and therefore takes stringent steps to manage those risks, but those steps have been seen as inadequate by the critics ideologically opposed to nuclear power.

Delaying exploration that can be done now: Introduction of an initiative to develop new technology inevitably slows the current pace; better is the enemy of good. NASA deleted plans for near-term missions to Pluto, the Kuiper Belt, and Europa and delayed a very capable Mars lander with the expectation that a successful nuclear power and propulsion system will enable better missions later. But what if it isn't successful? The opportunities to search out these bodies will be delayed many years at best, and, in the case of Pluto and the Kuiper Belt totally lost for generations. In 2003 a New Horizons mission to Pluto and the Kuiper Belt was finally approved by Congress, over NASA's objections, in part, because of strong Planetary Society member support. But a Europa mission, which was receiving study as a conventional, chemical propulsion mission, was dropped from consideration and its objectives organized into a proposal for a large, Prometheus-based Jupiter Icy Moons Orbiter. The subsequent delay of JIMO proved the prescience of our concern about delaying exploration.

Risks of long- term technology developments: New technologies have almost always appeared more attractive and less costly when started, than a few years down the road. As costs grow, the program stretches out, the performance is not as great as originally thought, priorities change and programs get canceled. An example is the multi-agency, ill-fated SP-100 space nuclear power program that ran for nearly ten years, consumed about $1 billion and was ultimately terminated well short of a working product. Looking back, that money, talent and time would have produced far greater scientific advances had it been applied directly to flight missions than invested in an unsuccessful technology development program. Few decade-long technology development programs have ended up where they were pointed at the outset; our perceptions change, the political/technical/fiscal environment changes, and the technical challenges are more formidable when engaged than in the conceptual phase. Might Prometheus suffer the same fate? It is fate. Then NASA Administrator, Mr. O'Keefe, had great confidence in this program, based partially on the success of the U.S. Navy in employing nuclear power. But a successful space reactor culminating in flight missions is far from a sure thing, and letting go a small bird in the hand to reach for a more attractive bird deep in the bush is always risky.

The JIMO proposal was a huge one – the reactor was based on Navy experience where weight is not a major concern. More efficient reactors would take advanced technology and more years to develop – and NASA was in a rush to tie the technology to a near term mission objective. But the mission was so large (it would have taken at least 3 or 4 of America's largest rockets just to launch it) and expensive, that it now raises the question whether more advanced, higher efficiency and lighter weight reactors should be developed for space applications.

The Planetary Society position

While an unabashed advocate of a vigorous planetary exploration program, The Planetary Society is fully aware of the potential hazards, both programmatic and physical, associated with this initiative. The Society is solidly behind the Prometheus program objective to enhance the exploration of the solar system and probe deeper into the questions that so intrigue us. We are also cautious: It remains to convince the public that this technology is both safe and can be developed reliably. We support the start of the nuclear systems initiative but urge concomitant study of safety, reliability and risk. In the meantime, we oppose delaying any missions to the Mars surface and/or the outer planets while awaiting more capable nuclear systems that may or may not materialize. Since Nuclear Electric Propulsion cannot be ready for 10-15 years at the earliest, we specifically opposed delaying the proposed Pluto/Kuiper Belt Mission, and now oppose delaying Europa exploration. We urge consideration of a Europa mission before JIMO (or any nuclear electric mission).

We do support continued Prometheus development, though with significant changes. The project should investigate the development of more efficient nuclear electric systems, which might be available for relatively low weight missions. In place of the ambitious JIMO, the first nuclear electric could, for example, be the deflection of an asteroid on a collision course with the Earth. Such a mission would not have the near-term high priority of JIMO, but would nonetheless be important for long-range development. This would preserve the central role of nuclear propulsion for future planetary exploration, without hindering current projects that can be accomplished with existing technology.