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AN INTEGRATED MISSION PLANNING APPROACH FOR THE SPACE EXPLORATION INITIATIVE

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FOR THE SPACE EXPLORATION INITIATIVE

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Abstract

A fully integrated energy-based approach to mission planning is needed if the Space Exploration Initiative (SEI) is to succeed. Such an approach would reduce the number of new systems and technologies requiring development. The resultant horizontal commonality of systems and hardware would reduce the direct economic impact of SEI and provide an economic benefit by greatly enhancing our international technical competitiveness through technology spin-offs and through the resulting early return on investment. Integrated planning and close interagency cooperation must occur if the SEI is to achieve its goal of expanding the human presence into the solar system and be an affordable endeavor. An energy-based mission planning approach gives each mission planner the needed power, yet preserves the individuality of mission requirements and objectives while reducing the concessions mission planners must make. This approach may even expand the mission options available and enhance mission activities.

INTRODUCTION

The direction of the American space program, as defined by President Bush, is to expand human presence into the solar system. Landing an American on Mars by the 50th anniversary of the Apollo 11 Lunar landing is the goal. This challenge has produced a level of excitement among young Americans not seen for nearly three decades. The exploration and settlement of the space frontier will occupy the creative thoughts and energies of generations of Americans well into the next century. The return of Americans to the moon and beyond must be viewed as a national effort with strong public support if it is to become a reality. Key to making this an actuality is the mission approach selected. Developing a permanent presence in space requires a continual stepping outward from Earth in a logical progressive manner. If we seriously plan to go and to stay, then not only must we plan what we are to do and how we are to do it, we must address the logistic support infrastructure that will allow us to stay there once we arrive.

If SEI is to be successful, a fully integrated approach to mission planning is needed. Only in this way can a permanent human presence in space be sustained. If SEI is to be affordable, careful consideration must be given to such things as "return on investment" and "commercial product potential" of the technologies developed. If SEI is to be acceptable, a relevant near-term focus with a clear, long-term vision must be adopted. A fully integrated approach to mission planning provides the pathway for the expansion of human presence into the solar system.

One area that lends itself to integration is power and propulsion. An integrated power and propulsion infrastructure based on energy would reduce the number of new systems and technologies requiring development. The resultatnt horizontal commonality of systems and hardware would reduce the direct economic impact of SEI, while an early return on investment through technology spin-offs would be an economic benefit by greatly enhancing our international technical competitiveness. It has the near-term focus that would help win Congressional support and help secure financial backing, thus ensuring that human expansion into the solar system becomes a reality

ENERGY-BASED APPROACH

Space initiatives range from the development and exploitation of near-Earth space to missions to the outermost planets. The National Aeronautics and Space Administration's (NASA) mission to planet Earth will use orbiting satellits to collect data on planetary conditions in support of studies of global climate change. The Department of Defense (DOD) plans to increase its number of surveillance, navigation, and communications satellites in Earth orbit to support military missions and objectives. The success of all of these efforts hinges on a single common need: the availability of power to operate the systems being proposed. Sufficient power must be available when and where it is needed. The power must be compatible with the various space systems being considered for deployment. Even more important, the method of power production and utilization must be acceptable from political, social, and economic perspectives and perceptions. These requirements all can be met by adopting a space power architecture based on directed energy transmission. Through directed energy transmission, the availability of abundant energy in space would be ensured. This would be a major step toward ensuring that U.S. space program goals are achieved and that the United States reestablishes and maintains its position of leadership in space.

ECONOMIC BENEFITS

Directed energy transmission is a cost-effective approach to meeting space power needs. Building on existing technology development, base-load space power needs could be met for about the same cost as solar, but with only one-half of the on-orbit mass. Coupling directed energy transmission with state-of-the-art electric propulsion technology, an energy beam-powered electric orbital transfer vehicle (EOTV) could deliver to geosynchronous Earth orbit (GEO) 80% of the mass initially placed in low Earth orbit (LEO) for about one-half of the cost of a chemical OTV (Coomes, Johnson, and Widrig, 1990). Chemical upper stages today deliver only 20% to 25% of the initial mass in LEO to GEO.

By separating the power system from the end-use application, a standard power transmission satellite design can be adopted. A standard design would simplify technology development and system requirements. The power satellite design could be optimized for power production and transmission independent of the end-use mission requirements, thus reducing development costs. Central-point power generation and distribution would reduce the total number of power systems needed and would greatly reduce or eliminate the need for on-board energy storage. The mass and volume savings on each satellite would allow the user to increase the satellite payload fraction, thus enhancing mission capabilities. This should increase the revenue-earning potential of each user satellite.

The commonality of power systems technology would support military, commercial, and civilian space activities, including advanced NASA missions to the Moon and Mars surface. The long-life continuous nuclear power sources developed for power satellites would also support nuclear electric propulsion for Lunar and Mars cargo transport spacecraft (Coomes and Dagle, 1992) and OTVs (Dagle 1991). As the manned development of space progresses and a Lunar base is established, refurbishment and upgrading of beam-power satellites could become a Lunar-based endeavor, providing increased economic incentive for Lunar development.

Adopting directed energy transmission does involve some economic uncertainties that must be addressed. As with any centralized system, the initial capital investment will be higher than that for smaller distributed systems. To keep power-user costs down, this higher initial capital cost must be spread over a longer operating time, thus increasing the need for long-life reliable systems. To ensure continuous power availability even in the event of a power satellite failure, the directed energy distribution grid must include excess generating capacity. Limited backup and/or keep-alive power may be required on each user satellite to accommodate temporary power loss.

Each power satellite represents a significant portion of the power grid assets, and each unit is a high-value asset. This increases the economic consequences of a system failure or loss at launch or transfer from LEO to high Earth orbit, even though significantly fewer launches are required. Operation from high orbit implies additional expense for transportation to get the beam-power satellite on station. Because each power satellite is a high-value asset, periodic maintenance and/or repair may be used to extend beam-power satellite lifetime. This could imply additional transportation costs or higher repair and maintenance costs, because the beam-power satellite is in high Earth orbit. These costs depend directly on the final operating scenario selected and must be factored into any deployment and operating analysis or evaluation that is performed.

Directed energy transmission is a different method of providing power in space. As such, it will require a change by mission planners in their approach to meeting space power needs. The economic impact of transition from the one-on-one, onboard power approach to a central-point generation and distribution power approach could range from a minimum level (involving only change in configuration of existing solar power systems from rectangular to circular geometries) to a maximum level (requiring totally new receiver systems). A more complete understanding of the commonality between solar and laser-beam receiver technologies is necessary before transition impacts can properly be assessed.

CONCLUSIONS

Central-point space power generation and distribution by directed energy beams is technically feasible and should be included in the U.S. space power program as an option that warrants serious consideration as the baseline approach to meeting this nation's space power requirements. Directed energy transmission is a true integrated approach to providing power in space. It can provide significant benefit to this nation's overall space efforts and offers an opportunity to greatly enhance U.S. space leadership. Directed energy transmission is a viable concept that allows power to be generated at one location and transmitted to a remote user at another location by energy beams, providing users with up to 10 times more power than a solar photovoltaic system for the same collector area. An energy-beam-powered EOTV would reduce the cost of satellite transfer from LEO to GEO to onle-half that for a chemical-based OTV, and would increase the payload capability delivered to GEO for existing launch systems lift capability to LEO. A space power architecture based on directed energy transmission would support both military and civilian space operations. It would be mission-enhancing, if not enabling, for manned activities beyond Earth orbit. Directed energy transmission would increase the acceptability and use of nuclear power in space, because it isolates the end-use satellite from the nuclear power source while providing significantly more power than a solar source.

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