Enabling Sustained Deep Space Exploration with a Broad Vision

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ABSTRACT

For almost five decades the U.S. has led and inspired the world in the arena of space exploration. However, human exploration of deep space has languished since the end of Apollo, and key robotic exploration capabilities are at risk. Sustaining U.S. leadership in this arena will require completion of a new launch system, a human exploration vehicle, restoration of fuel production for deep space power systems, and reconstitution of supporting life science capabilities. More synergistic human/robotic operations and international collaborations are also essential enablers.

ISSUE BACKGROUND

Space exploration is a modern extension of the human aspiration to discover new places, explore them, and eventually benefit from them. Since the 1960s, the U.S. has been a leader in pushing both the robotic and human boundaries of space exploration into deep space, first to the Moon, and subsequently throughout the solar system. Those achievements have inspired people throughout the world, stimulating many brilliant Americans and immigrants to pursue technical careers in the United States. The resulting technological advances have been numerous and the economic benefits have been large.

However, U.S. leadership in deep space exploration has been degraded, and is threatened. Clarity of purpose has been lacking for over twenty years with frequent changes in interim objectives usually driven by transitions in the Administration and Congress. The lack of consistency has led to numerous programmatic direction modifications, and the loss of significant investments in many development initiatives when they were cancelled prior to completion. Moreover, technology development investment, which represented about 6% of the NASA budget during the Apollo era, has slipped to a small fraction of that. Basic capabilities necessary for deep space exploration, such as heavy lift and thermoelectric power, were considered mature technologies in the past, but now have to be reestablished. Advanced capabilities essential to extending deep space exploration, such as more efficient in-space propulsion and enabling safe, extended human habitation in low gravity and ambient radiation environments, are getting very limited attention.

Human exploration beyond Earth orbit has suffered the most. The U.S. capability to send humans into deep space ended with the Apollo program. A variety of programs to create new launch systems capable of sending a vehicle large enough to support humans beyond Earth orbit have not been realized. The Space Launch System (SLS) now under development (Figure 1) has the prospect of success, but it is a resource constrained program. Its initial test flight is now planned for 2017, with its second test flight (the first with a crew) not expected before 2021 due to budget constraints. Even at the currently projected level of funding (which is at risk of reduction), specific plans for the SLS program beyond an initial piloted mission are not yet defined. The spaceship that the SLS would carry to deep space, the Orion Multi Purpose Crew Vehicle (Figure 2) follows a series of Space Shuttle successor programs that did not achieve realization. Orion development is also a resource constrained program. An initial un-crewed test of the Orion crew capsule is planned for 2014 on its first in-space and reentry flight test. An agreement with the European Space Agency (ESA) has just been established to develop a supporting Service Module (SM) needed for deep space Orion missions launched on the SLS. That agreement currently only encompasses delivery of one SM and spare components with capabilities specific to those needed for the initial Orion/SLS test flight. That Orion SM arrangement is significant, marking the first commitment of an international partner to this human exploration program, but it is yet to be determined if future SMs will be supplied by the ESA or NASA.

Figure 1. The planned initial SLS configuration with a 70 ton lift capability.

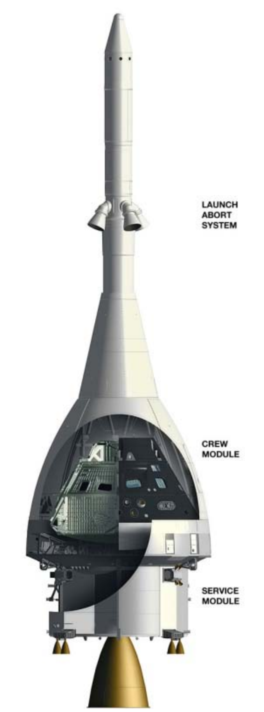

Figure 2. The MPCV as configured for launch on the SLS.

Meanwhile, other nations – most notably China – are seeking to independently establish leadership in these areas. Over the past two decades, these countries have rapidly advanced their capabilities for human space operations, and could surpass the United States in the foreseeable future.

In the robotic exploration arena, the U.S. continues to achieve major accomplishments, based on past investments from which we are still benefitting. Orbital and landing missions to Mars, including the Mars Reconnaissance Observer and Curiosity Rover, have greatly advanced our knowledge of that planet and have identified conditions that could have allowed precursors to life to exist in the past. Exploration of the outer planets has been a unique U.S. capability to date, with remarkable findings about the moons of Jupiter and Saturn, some of which have materials essential to life. However, even in this arena, U.S. leadership is at risk. Resources are not available to pursue new “flagship” missions that break new ground.

Figure 3. A self-portrait of Curiosity on Mars with labeling of its RTG in the back of the vehicle

Since the 1960s, Radioisotope Thermoelectric Generators (RTGs) using non-weapons-grade plutonium (Pu-238) have enabled long-term operation of science missions where power by other means was not practical or even possible. The Voyager missions have operated continuously since the 1970s using this technology, and are still transmitting science data while departing the outer reaches of the solar system. The Curiosity Mars rover uses this power source day and night. The Cassini mission has used RTG power to explore the Saturn system since its 1997 launch. However, the U.S. has stopped producing Pu-238. In recent years the U.S. relied on buying it from Russia, which is now running out of a supply to sell. There are now Stirling cycle RTGs that can produce comparable amounts of power with a fraction of the Pu-238 used by older devices, but any RTG still requires some Pu-238 supply. Resolving this issue requires full collaboration of the Department of Energy with NASA, and some supporting resources to both to resume production of some Pu 238.

Visionary science and human exploration objectives can help focus the direction of supporting programs. However, sustained support by the American public requires that each generation believes the nation’s space programs are important. Achieving major milestones each decade on the path to visionary objectives would inspire ongoing public support. Specific technical and capability advances could also be consolidated with accomplishment of each major milestone.

Progress in human deep space exploration cannot be assured without achieving an operations capability of essential transportation infrastructure. The current schedule for SLS and Orion completion risks U.S. human deep space exploration leadership. Accelerating completion of those systems will facilitate new human exploration success.

As already demonstrated by the new European participation in the Orion program, sharing resource contributions through international collaboration can be a critical space exploration enabler, and should be aggressively sought. However, some specific space exploration technology is essential to leadership, and critical to national security needs. Development of space capabilities that serve those special roles needs to remain within the U.S. portfolio.

As demonstrated by the Dawn mission (where a single spacecraft is using ion propulsion to perform detailed scrutiny of two widely separated asteroids), advances in space propulsion are enablers of new exploration capabilities. However, this specific operational advance is based on technology developed over several decades. The risk to humans traveling to destinations such as Mars that results from space radiation may best be mitigated by very high performance propulsion technologies that can greatly reduce transit times. This fact has been known for decades, but serious work in this arena (with nuclear thermal propulsion) was last pursued in the 1960s. Enabling safe and successful human missions to Mars and beyond will require ongoing investment in advanced in-space propulsion systems.

Amazing advances in data processing capabilities and avionics component miniaturization have facilitated development of robotic spacecraft with major gains in operational capabilities as well as autonomy and independent decision making. These robotic spacecraft capabilities enable pursuit of exploration goals where risk to humans remains excessive. With major parallel advances in Human Systems Collaboration capabilities, it is now possible to conceive advanced exploration missions with highly synergistic human and robotic roles. If humans are in the vicinity of advanced robots, effective telepresence is possible (avoiding long radio communication delays). Using this approach, robotics can scout many regimes to identify the few that warrant more direct scrutiny and assessment by humans.

Life science research into the long-term effects of partial and micro-gravity, as well as consequences of extended exposure to space radiation is essential to understanding the resulting risks to the health and mission-performance effectiveness of humans, and to find methods for mitigation of adverse effects. However, support for applicable life science research has plummeted over the past decade. The sponsorship cuts have been so severe, that it has drastically reduced the pipeline of graduate students who could lead in this realm of expertise in the future. Successful advancement of human deep space exploration will require that applicable life science research and associated work-force sustainment go hand in hand with exploration systems development.