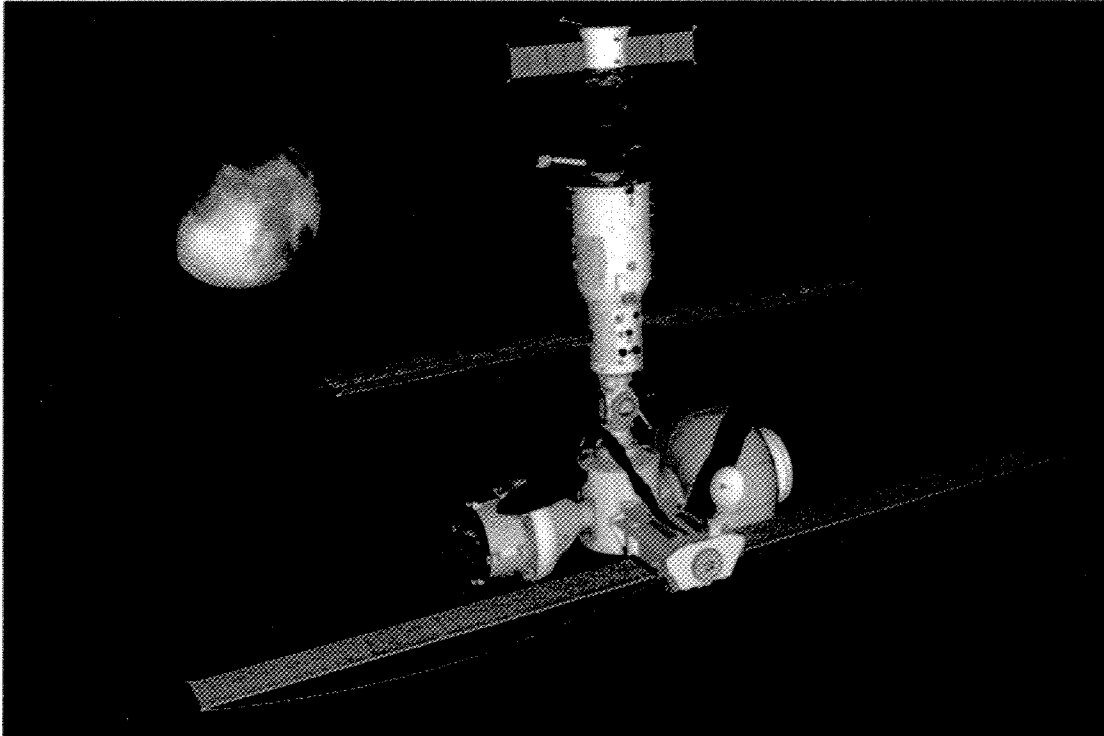


# THE SPACE REVIEW

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*Human voyages beyond LEO may be possible in the near future by using existing or undeployed elements of the International Space Station. Shown here is a concept for a habitation system at the Earth-Moon  $L_1$  location using ISS-heritage or legacy components. [courtesy: M. Raftery (Boeing Corp.)]*

## ACCELERATING THE FUTURE: HUMAN ACHIEVEMENTS BEYOND LEO WITHIN A DECADE

*In the near future you can explore beyond LEO with the systems that you have or wait for the systems that you wish you had.*

*by Harley Thronson, Dan Lester, and C. A. (Skip) Hatfield*

Human space flight in the US and other space-faring countries is faced with a twin challenge that is likely to persist for many years: flat or declining budgets along with an expectation of continuing, significant achievements. A partial solution may involve increased participation by multiple commercial competitors with the promise – albeit yet to be fully demonstrated – of much-reduced costs. That said, most commercial goals are concentrated on low-Earth orbit (LEO) for the time being, leaving human trips beyond Earth orbit (BEO) as governmental initiatives.

The past decade, beginning with the 1999/2000 Decadal Planning Team (DPT)/NASA Exploration Team (NExT) human space flight studies for the White House Office of Management and Budget (<http://history.nasa.gov/DPT/DPT.htm>), can arguably be described as a Golden Age of engineering design, strategic planning, technology capability prioritization, and development programs on the International Space Station (ISS). However, cynics have criticized the same period as little more than PowerPoint presentations, and unfocused technology investments with only limited progress toward a goal of human space flight beyond the immediate vicinity of the Earth.

We disagree with the cynics. Experience with the ISS on increasingly sophisticated capabilities have prepared international partners to deploy a major “stepping stone” for human space flight: a habitation system in free space beyond low-Earth orbit. Such an achievement would be a major milestone in human space flight and, very likely, an essential demonstration site for subsequent, very ambitious exploration missions such as to Mars. Developing critical capabilities for human voyages beyond LEO, such as Earth-Moon libration points, offers, as just one example, easy return to Earth within days (see, e.g., Farquhar 1971 (Aeronautics & Astronautics, July, p. 59ff), Thronson, Lester, and Talay 2011 (<http://www.thespacereview.com/article/1756/1>), and Lester 2010 (<http://www.thespacereview.com/article/1650/1>)). Use of Earth-Moon libration points as sites for early demonstrations of capabilities necessary for human missions to Mars, for example, contrasts sharply with using missions to near-Earth asteroids (NEAs) for that purpose.

Not only is a cis-lunar habitat beyond LEO a major “stepping stone” in advance of human missions far beyond the Earth-Moon system, we believe that such a system should be a priority for *near-term deployment* (i.e., within about a decade), particularly as the majority of truly necessary development and design programs are already well

underway using ISS. The justifications include (1) taking advantage of the experience gained with the ISS development program before it is lost; (2) learning and applying early lessons via actual space operations that cannot be duplicated by engineering design or terrestrial prototypes alone; (3) building upon existing international agreements; and (4), in a constrained financial environment, deploying a limited, affordable habitat in the near term to free up resources necessary for development of advanced systems required *only* for the most ambitious human missions.

These issues were the topic of a recent workshop in Galveston, Texas sponsored by NASA's Human Exploration and Operations Mission Directorate (HEOMD). About 80 individuals from within NASA, industry, and academia were invited as community representatives to critically assess cis-lunar BEO habitat design and development plans. The workshop goal was to identify the essential development activities to enable a BEO habitat system within a decade. Presentations and background materials, as well as a final report of the workshop, may be found at: <http://nasainvitation.com/revise> .

### **Employ Experienced Talent, Proven Capabilities, and Lessons Learned from ISS Design and Deployment**

With the ISS nearing the end of its development and deployment phase and one day facing the end of its operational life, the managers, executives, engineers and technologists will quickly retire or transfer to other programs. That is, experience in engineering design and management of the only long-duration, in-space human operations site will be lost, unless there is a program underway that can effectively apply the hard-won creativity that made the program successful. Moving beyond LEO will certainly benefit from the lessons learned and skills honed on ISS.

Fortunately, there has been extensive design work in the past few years on future habitation systems, operations, and relevant development investments on ISS. Thus, NASA and international partners could make a decision in the near future to build a basic habitation system in time to take advantage of engineers and managers experienced with ISS development while such experts are still available.

Success with the ISS offers an additional opportunity, as depicted in the image that opens this article: extensive use of existing ISS hardware that has been designed and, to some degree, already tested

for space operations with which current ISS staff is familiar. Moreover, a modular system of this type might be upgraded over time as lessons are learned and technology improves. However, there may be some compromise in extensibility. That is, a habitat that can be developed quickly and launched within a decade using experienced personnel and proven components may not, however, be a straightforward “stepping stone” for *subsequent* systems necessary for longer very long-duration human voyages. But a voyage to Mars decades in the future that we have posited here will be more feasible to the degree that it can build upon the experience with cis-lunar habitation systems that precede it.

Another specific example of valuable lessons learned from ISS operations – lessons that will be quickly lost when ISS development concludes – is sustaining the logistics of space operation: crew, cargo, experiments, and disposal. Very significant improvements have been made over several years of ISS support, improvements that must continue when transport to the operations site is measured in several days or more, rather than a day and a half to a LEO site.

Nevertheless, there appear to be opportunities in a constrained budgetary environment should policymakers conclude that a habitation system must be developed beyond LEO before ISS reaches the end of its development period and experienced personnel are quickly lost.

### **Learning by Doing, Sooner Rather than Later**

There are extensive development efforts on – or proposed to be on – ISS, as well as using terrestrial facilities, that are relevant to human voyages beyond the immediate vicinity of the Earth-Moon system. This is important work. At the same time, a great deal can be learned no other way than by actual deployment of a habitation system. The sooner that such a facility is deployed, the more promptly can these lessons be learned and incorporated. This is certainly the case, even if the facility does not support the longest-duration voyages, although may be extensible or upgradable to such a capability.

As one example, a great deal is known about protection from solar particle events (SPEs) via shielding by water and/or a suitable plastic. However, how such shielding is deployed in practice within even a simple habitat design is a significant challenge. For example, does the shielding impede ready access throughout the habitat, can the shielding be used to physically support spacecraft systems in zero g, or what protection is necessary against damage to the shielding due to wear and tear in actual operations lasting many months?

As another example, thermal control on ISS uses a dual-liquid system. A goal is to replace this with a more simple, single-liquid system. A future cis-lunar habitation system similar to those described in the Galveston workshop presentations (<http://nasainvitation.com/revised>) will require substantial reduction in mass and volume, with an increase in reliability. Demonstrating advancement in this technology on orbit seems an attractive activity in advance of other capabilities that could well be deployed later.

In these and other ways, essential understanding about how to operate in space can *only* be learned in many cases by actual deployment and operation on site. And the sooner that this is accomplished, the further ahead can be human voyages beyond the Earth-Moon system. This is the philosophy, for example, behind the Bigelow Aerospace series of *Genesis* prototype inflatable habitat systems, which have been in LEO now for some years as examples of new lightweight and economical strategies to achieve significant habitat volume.

### **Demonstrating in the Near Future the Capability to Reach Destinations Beyond LEO**

A successful long-duration habitat is one of the generally recognized small number of *essential* capabilities necessary for long-duration human voyages beyond the Earth-Moon system, such as to Mars. According to current national planning, the Space Launch System (SLS) and MPCV will be available in the time period that we discuss here, thereby providing deep-space human transportation capability. A near-term cis-lunar habitat could well be one of the first facilities deployed and supported by SLS and MPCV.

Operating with humans beyond LEO for weeks or months at a time will also be an unambiguous *political* demonstration of a growing capability for longer-duration human destinations that could include Mars. This will be an important element in sustaining the funding necessary for even more ambitious subsequent missions.

Related to this, it is reasonable to expect that a successful cis-lunar habitation system beyond LEO will have the additional desirable effect of sustaining funding for other key technologies. Advances in in-space propulsion, for example, another critical capability to be mastered for long-duration human space flight, may be more *politically* sustainable

if a cis-lunar habitation system beyond LEO is already operating or in advanced development. The reverse may not, however, be true: space propulsion without a successful habitation program may be politically problematic. Similarly with other major elements of human travel beyond LEO: how politically tenable are major entry, descent, and landing (EDL), astronaut EVA capabilities of any kind, or in-situ resource utilization (ISRU) investments without the habitation architecture for astronauts to operate effectively and comfortably on their way to their destinations?

It is for these reasons that we refer to habitation systems beyond LEO in cis-lunar space as a "lynch pin" for human missions to Mars. That is, it is prudent to move incrementally into space beyond LEO to locations where it is possible to return to Earth within a few hours or days at the most. Human missions beyond the Earth-Moon system that have limited or non-existent easy returns are questionable as the next "stepping stones" for sustained exploration.

### **Build on Existing ISS National and International Agreements**

It is the policy of NASA to engage with international partners in the exploration of space. Coordinating international partners over decades has been at the core of the success of ISS in engineering and management. Considerable effort has been expended to establish and maintain these international partnerships, agreements are in place, and the senior managers from the contributing countries are familiar with one another. As such, we should build upon these agreements for the programs that follow the ISS. Indeed, a superficial examination of the agreements among the ISS partners suggests that an international cis-lunar habitat beyond LEO can be coordinated among partners following closely the model of ISS.

### **Accept Judicious Compromises for an Early Habitation System**

Significant compromises in performance, with concomitant major cost and schedule savings, can be made by developing a habitation system that does *not* from the start have all the capabilities that will ultimately be necessary. For example, the capability for "anytime EVA" or extensive astronaut-robotics collaboration may be delayed while essential lessons are learned by actual on-orbit habitation. Similarly, solar particle radiation protection may not be necessary for more than that required for a few months of occupation by any individual. On the other hand, the environmental control and life support system (ECLSS) on ISS is part of a development plan that seems deployable to a

beyond-LEO habitat within a decade. Similarly, avionics systems, for example, which were under development for the Constellation Program's *Orion* vehicle, now being applied to the MPCV, seem well suited to a near-term habitation system.

It *is* critical for such capabilities to be developed if humans are to travel beyond the Earth-Moon system, but more limited performance seems worthwhile, if it results in near-term experience that can be gained no other way. Waiting for the development of systems required, say, for a mid-2030s mission to Mars, although unnecessary for a mid-2020s demonstration mission beyond LEO, seems to be an expensive, slow, not very instructive, and consequently politically very problematic strategy.

*This work is based on a presentation at the AIAA Space 2011 Conference. Dr. Harley Thronson is Senior Scientist for Advanced Concepts in the Astrophysics Division at NASA Goddard Space Flight Center. Dr. Dan Lester is an astronomer at the University of Texas. He is active in NASA strategic planning activities and writes regularly on space science policy. Mr. Skip Hatfield is Manager of Program Projects Integration in the International Space Station Program Office.*