INTERNATIONAL SPACE STATION AS AN EXPLORATION PLATFORM FOR DEEP SPACE.
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Introduction: The International Space Station (ISS) is a cornerstone for the world's most advanced space programs. We will introduce concepts for how ISS could be fully utilized to support exploration. Increased pressure on space program budgets will only intensify the need to use existing assets to their fullest extent. Meaningful progress on exploration can be made using ISS that will pave the way for dramatic achievements in the future.

Background: The management model for ISS can be characterized as a balance between cooperation and competition. While international cooperation is a well known hallmark of the program, competition has also been a significant contributor to ISS success.

Cooperative Development - In 1998, fifteen national governments signed a treaty establishing a framework for cooperation on the ISS program [1]. This intergovernmental agreement (IGA) provided the basis for how the contributing partners would develop and operate the ISS. Fundamental issues such as program funding, cross waivers for liability, data rights and intellectual property are all addressed by the IGA. Details of management cooperation are further defined in bi-lateral memoranda of understanding (MOU) that fall under the umbrella of the IGA.

Competing Technologies - The ISS management model provides a natural means to accomplish dissimilar redundancy through "competition at the technology level" as each participating nation is free to decide how they will implement a particular function. "Competition at the technology level" represents a significant strength for the program because while redundancy of function is provided, common mode failures are avoided. Many examples of this are available from ISS but perhaps the most visible was crew transportation where both Shuttle and Soyuz were capable and used to transport crew. With Shuttle retired, work is progressing in the US to provide the new compliment to Soyuz crew transport capability.

Supporting Commercial Opportunities - Cargo service contracts have been established for ISS that offer the potential to lower the cost of logistical re-supply. This model stimulates innovation and, when successful, will significantly reduce operating costs. New exploration initiatives should be structured to enable and encourage commercial innovation that could produce similar reductions in cost.

ISS as Base Camp: Existing ISS assets can be used to advance exploration objectives both in low earth orbit (LEO) and in higher orbits as well.

Base Camp ISS – Departure Point for Exploration ISS in LEO provides a natural base-camp for missions to higher orbits or the moon. First, the transit through the Earth's atmosphere is one of the most hazardous legs of the journey and it is prudent to pause in LEO for a system check while still close to home. The second benefit of a base-camp at ISS: if repairs to the exploration spacecraft are necessary, they could potentially be made at ISS thus avoiding the loss of an expensive mission. Third, supplies for the journey can be pre-staged at ISS having been delivered there through various, presumably lower cost, means. Fourth, since ISS is an international endeavor, partner participation in the exploration mission is more easily accommodated from there. Finally, a LEO base-camp at ISS simplifies and promotes an incremental approach to exploration by allowing an orderly build-up and testing of new capabilities.

Lagrangian Points as a Gateway for Exploration - The Earth-Moon Libration (EML) system represents a series of five points where the gravitational and centrifugal forces are in balance. The idea of a gateway at one or more of these points is not new. The innovation we propose is to build this gateway as a part of the ISS infrastructure using ISS designs and residual equipment. We call it an ISS Exploration Platform (ISS-EP) because it would be part of the ISS program but its focus and purpose would be to support exploration objectives. Control of the ISS-EP would be done from the ISS mission control centers and logistical support for the ISS-EP would be done using ISS systems.

Best Early Destination Beyond LEO- NASA is hard at work building the Multi-Purpose Crew Vehicle (MPCV) and the Space Launch System (SLS). These new capabilities will enable missions beyond LEO. The MPCV can support missions up to 21 days on its own. Longer missions will involve docking with another spacecraft that can provide additional on-orbit stay time capability. In its full-up configuration, SLS will be capable of launching an additional 20t of payload to high Earth orbit along with the MPCV. The question is: where to go? EML points provide many mission advantages. EML points act like a GEO-stationary orbit in that it remains at a relatively stable location. EML1 also provides the potential to perform an Earth or Lunar fly-by to increase spacecraft delta-v for departure, a methodology that provides benefits similar to the highly elliptical orbit. For lunar surface missions, EML1 or 2 offers mission planning flexibility and ready access to most of the lunar surface. EML1/2 are well clear of the Earth's radiation belts and offers a true "deep space" environment which will typify what must be mastered before long trips to Mars.

System Benefits: ISS provides an ideal platform for the construction of the ISS-EP. In the same way that ISS itself was built, the ISS-EP construction is done incrementally through a series of deliberate steps. Using existing launch systems, each element of the ISS-EP is delivered to ISS so that they can be integrated together and tested as a system. ISS expedition crews gain operational experience with the ISS-EP during this test phase and help to ensure that it will be ready to perform its intended function for exploration missions.

Benefits to this approach – 1) Several years of operation at ISS are possible prior to deployment (2016 to 2020). In this time, any issues with the systems could be resolved which would improve the probability of mission success. 2) The presence of the ISS-EP directly enhances the capabilities of ISS. The docking module provides additional docking ports to ISS which will enhance flexibility when dealing with visiting vehicle traffic. The utility module can generate power which could be used by other ISS systems when it is not needed for ISS-EP tests. The utility module also has RCS and Hall thrusters which could be used to augment ISS attitude control. The habitat module provides additional volume which could be used by the ISS crew. 3) The systems used to launch the ISS-EP modules to ISS would have other benefits as well. The US ability to launch large pieces of structure was lost with the retirement of the Shuttle and won't be available again until SLS is complete.

Transport to EML1/2 - The ISS-EP must be relocated from LEO to EML1 after its build and test is complete. We have evaluated two different ways of accomplishing this task. The first approach uses a 400KW solar electric propulsion (SEP) tug to relocate the platform. The second approach would use the upper stages of the SLS to perform the function. In this approach, the ISS-EP would separate from ISS with a crew on-board and the systems would be prepared for departure. A fully fueled SLS would be launched to ISS without a payload. The ISS-EP would dock to the SLS upper stages; arrays and radiators would be retracted and the crew would depart. Adequate fuel remains in the SLS upper stages to boost about 50t from ISS to EML1. While both methods are viable, the SEP tug approach is preferred because of its long term usefulness as a deep space propulsion system. ISS-EP deployment would occur in the 2020 timeframe, so this plan would require that either the SLS or the SEP tug be available by then. If ready, the SEP-400 tug could then be used to ferry supplies back and forth between the two parts of ISS as a cargo cycler. Valuable operational experience would be gained which would increase confidence in its use for long duration missions beyond cis-lunar space.

Reusable Lander - One of the most exciting uses of EML is as a base for a reusable Lunar Lander. ISS-EP provides a perfect base for a small lander which could be refueled and used for multiple missions. This reuse of expensive spaceflight hardware is an essential element of an affordable space program. Consumables such as fuel, air, lithium hydroxide canisters and water are provided as well as the ability to make small repairs necessary to keep the lander operational. The EVA and robotic capabilities of the ISS-EP allow the lander to be serviced both internally and externally based on mission requirements. The placement of the ISS-EP at an EML point allows the lander to access any site on the lunar surface thus providing tremendous flexibility in the lunar science program.

Telepresence from EML Gateway - Telerobotic capability has been identified as an important policy mandate, and telepresence capabilities are considered by the agency to be one of several "grand challenges" for space technology [2]. We invite the lunar science community to consider the priority scientific tasks that such on-orbit operations might enable. While human visits to the lunar surface provide optimal opportunities for field geologic research, onorbit telerobotics may provide attractive alternatives at lower cost and with less human risk in the short term. Telerobotic geology of this sort would be especially valuable precursor activities in advance of human exploration campaigns. See paper by Lester et. al this session.

Conclusions: In summary, EML points are an excellent location for placing the ISS-EP both in the near term and also in the long run. Once established, the ISS-EP can be used as a near term destination to fully characterize the deep space environment. As we gain experience, it can then be used as a base camp for missions to the moon, and near earth asteroids as well as a repair site for large space telescopes. Its primary long term purpose would be as an assembly site for human missions to asteroids and to Mars.

References: [1] Civil International Space Station Agreement Implementation Act; S.C. 1999, c. 35; http://lois.justice.gc.ca/en/C-31.3/. [2] Lester, D. et. al. (2011) LEAG 2011, Abstract #2012.