HSF Transition from ISS to cis-lunar space
and
LEO Commercialization

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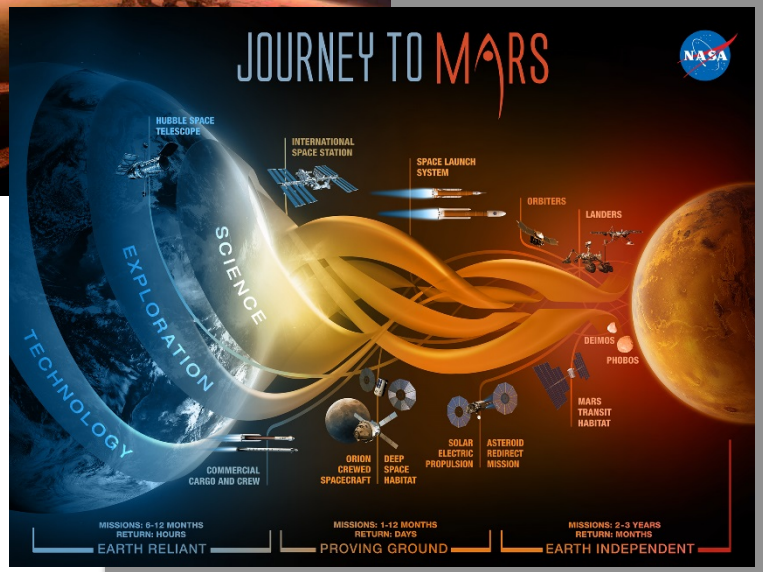
The Bigger Picture



Near-term execution

Strategic Principles for Sustainable Exploration

- Implementable in the ***near-term with the buying power of current budgets*** and in the longer term with budgets commensurate with economic growth*;*
- ***Exploration enables science*** **and science enables exploration***, leveraging robotic expertise for human exploration of the solar system*
- Application of ***high Technology Readiness Level*** (TRL) technologies for near term missions, while focusing sustained investments on ***technologies and capabilities*** to address challenges of future missions;
- ***Near-term mission opportunities*** with a defined cadence of compelling and integrated human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;
- Opportunities for ***U.S. commercial business*** to further enhance the experience and business base;
- ***Multi-use, evolvable*** space infrastructure, minimizing unique major developments, with each mission leaving something behind to support subsequent missions; and
- Substantial ***new international and commercial partnerships***, leveraging the current International Space Station partnership while building new cooperative ventures.

Principles provide the context for the next level framework definition…

Next level considerations

- What happens to LEO after ISS?
- What happens to the ISS platform after NASA's mission is complete in LEO?
- How do we take advantage of the research and technology development on ISS and apply that to next steps?
- How do we take advantage of the ISS Partnership, NASA institutional and industry capabilities?
- How do we prove we are ready to go to Mars or other destinations with humans that have return times to Earth on the order of months and years with tolerable risk to life?
- Beyond HSF objectives, what are some of the other objectives that could be accomplished?

Strategic Framework

- **HSF Transition from ISS to cis-lunar space**

  - NASA will focus on transition indicators and meeting ISS-specific requirements for human spaceflight and LEO commercial efforts instead of declaring a definite end date for Station
    - NASA will not transition from ISS until we are executing human deep space missions
    - Are there commercially available platforms and capabilities in LEO to conduct research and tech dev before ISS end-of-life
    - Exploration research and technology/system development activities requiring ISS as a testbed are complete

  - NASA will continue to work with stakeholders, International Partners and industry to develop plans for transitioning from ISS to cis-lunar space

  - NASA is exploring possible outcomes for the ISS platform at its' end-of-life
    - De-orbit, transfer responsibility, disassemble, others ideas

Strategic Framework

- **LEO Commercialization**
  - NASA is preparing to transition LEO post-ISS human spaceflight activities to the private sector
  - To do this, NASA will continue current LEO commercialization efforts. NASA will work with industry, academia and other government to establish long-term LEO investment and research/technology development activities
  - NASA is actively engaging other government agencies to assist, Department of Commerce, Department of Health and Human Services, and others are in work

- **Proving Ground**
  - Primary HSF goal is to prepare and develop all the crew-related capabilities for long duration transit missions to Mars
    - Culminating in one year crewed expedition(s) by the end of the 2020s
  - Nominally referred to as “shakedown cruise”
    - Directly measure preparedness in the relative safety of the lunar vicinity

Implications for the near-term

- **Having this goal of a "shake down cruise" (*or multiple cruises*) near the end of the 2020s provides an anchor for other HSF activities**
  - Provides the basis for acquiring long duration habitation systems (like ECLSS, EVA and other systems) for demonstration on ISS and Deep Space Habitat
  - Drive SLS/Orion performance and EM mission objectives
  - Provide the basis for International Partner discussions on what is beyond ISS
  - Provides the pull for shorter duration missions – particularly ARM and short duration habitation
  - Provides focus for near-term policy and budgets
  - Help drive requirements for other areas such as logistics, propulsion, etc.
  - Demonstrate the advantages of direct human presence in remote locations

Development Opportunities

- **There are many opportunities for public-private and international partnerships, and government-directed development within this framework – NASA also has extensive expertise and capabilities to be leveraged**
  - Short and long duration habitats
  - Crew tended platforms
  - Habitation systems (ECLSS, EVA, etc.)
  - Dissimilar redundancy
  - Logistical support
  - Communications
  - Navigation
  - Propulsion and re-fueling systems
  - Transportation
  - Integration, operations and planning
  - Other mission or scientific objectives

HSF Transition from ISS to cis-lunar space

Transitioning HSF from ISS to Cis-Lunar Space (Earth Reliant to the Proving Ground)

Earth Reliant

Goal at the end of the 2020s: Mars ready - One year crewed expedition(s) in cis-lunar space

Proving Ground

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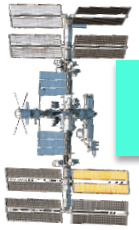
Earth Reliant



Long Duration Human Health & Habitation Research and Demonstrations

* Currently building a plan to demonstration on ISS the Mars habitation systems

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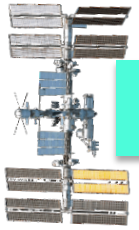

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Proving Ground

Learning how to be Earth Independent

- SLS/Orion performance validation
- Crew autonomy operations
- Crew health and performance research and validation
- Habitation systems performance validation including EVA
- Radiation shielding characterization and validation
- Guidance and navigation in deep space
- Prox ops and docking in deep space
- Breaking the logistics chain
- Reduced reliance on the ground control
- Validating other spacecraft system validation

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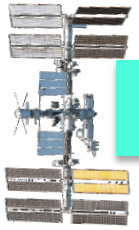

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Short Duration Habitation & Transportation system validation

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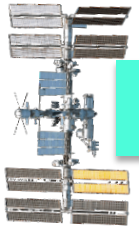

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Short Duration Habitation & Transportation system validation

Long duration human health & habitation Validation for Mars transit

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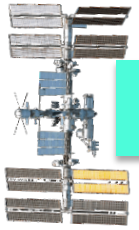

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Knowledge & Capabilities

Goal at the end of the 2020s: Mars ready - One year crewed expedition(s) in cis-lunar space

Proving Ground

Short Duration Habitation & Transportation system validation

Long duration human health & habitation Validation for Mars transit

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Habitation Systems Objectives

System	Includes	Today	Cis-Lunar Goal
Life Support	Air revitalization, water recovery, waste collection and processing	42% recovery of O2 from CO2; 90% recovery of H2O; <6 mo MTBF for some components	>75% recovery of O2 from CO2; >98% recovery of H2O; >2 yr MTBF
Environmental Monitoring	atmosphere, water, microbial, particulate, and acoustic monitors	Limited, crew-intensive on-board capability; rely on sample return to Earth	On-board analysis capability with no sample return; identify and quantify species and organisms in air & water
Crew Health	exercise equipment, medical treatment and diagnostic equipment, long-duration food storage	Large, cumbersome exercise equipment, limited on-orbit medical capability, food system based on frequent resupply	Small, effective exercise equipment, on-board medical capabilities, long-duration food system
EVA	Exploration suit	ISS EMU's based on Shuttle heritage technology; not extensible to surface ops	Next generation spacesuit with greater mobility, reliability, enhanced life support, operational flexibility
Fire	Non-toxic portable fire extinguisher, emergency mask, combustion products monitor, fire cleanup device	Large CO2 suppressant tanks, 2-cartridge mask, obsolete fire products. No fire cleanup other than depress/repress	Unified fire safety approach that works across small and large architecture elements
Radiation Protection	Low atomic number materials including polyethylene, water, or any hydrogen-containing materials	Node 2 CQ's augmented with polyethylene to reduce the impacts of trapped proton irradiation for ISS crew members	Solar particle event storm shelter based on optimized position of on-board materials and CQ's with minimized upmass to eliminate major impact of solar particle event on total mission dose

Human Health and Performance Research
Transition from ISS to cis-lunar space

ISS Goals for Space Exploration

- Fully utilize ISS to understand human health risks and verify capabilities to mitigate these risks
- Develop and test exploration biomedical technologies and tools
- Extend mission durations to one-year to validate six-month research and countermeasures
- Understand visual impairment/intracranial pressure risk and assess countermeasures
- Develop space radiation human protection & monitoring systems
- Investigate long-term spaceflight stressors and changes to the immune system and microbiome
- Develop and test exploration food system
- Develop, test, and verify crew habitation systems and models

Cis-Lunar Space Goals

- Validate advanced countermeasures against deconditioning for transit vehicle (bone, muscle, cardiovascular capacity)
- Validate crew performance, psychological well-being, and intervention toolkit under long-duration flight operations
- Validate integrated exploration medical capabilities (autonomous medical capability for diagnosis and treatment)
- Validate human health, performance, and environmental health in a closed spacecraft environment (immune system, microbiome)
- Validate exploration food system
- Validate space radiation human protection and monitoring systems for exploration
- Validate crew habitation systems for exploration
- Validate robustness and reliability of crew exploration exercise systems

What could we accomplish along the way with humans in cis-lunar space

- **Research objectives - origins of the universe**
  - Asteroid Redirect Mission – *currently in formulation*
  - Human/robotic Lunar exploration of far side and Shackleton crater
  - Some of the techniques and technologies/systems have been demonstrated on ISS already – more could be done
  - Human assisted Lunar sample return
  - Point of departure for human missions to asteroids in their native orbit
- **Research objectives - search for life**
  - Human/robotic construction of large diameter telescope at L2 (*18-20m, ATLAS, Space Telescope Science Institute*)
  - Some of the techniques and technologies/systems have been demonstrated on ISS already – more could be done
- **Earth/sun/moon environs monitoring**
- **Basic research for exploration**
  - Deep space radiation exposure characterization of materials and biological samples – extension of current ISS research
  - Long term zero boil off technology
- **Other basic research**
  - Astrophysics – *follow on to CREAM and AMS-02?*

Would require further study

LEO Commercialization


Vision:
Sustained economic activity in LEO
enabled by human spaceflight,
driven by private and public investments
creating value and benefitting Earth
through commercial supply
and predominately private demand

So what does this really mean?

In practical terms – it is NASA's intent to turn over LEO (supply and the demand) to the private sector before the ISS end of life

NASA is doing it's part to enable the vision –

- **Utilizing ISS to build the non-NASA demand in the private sector and other government agencies - National Lab and CASIS**
- **Developing and utilizing commercially based access to LEO**
  - **Commercial cargo and commercial crew**
- **Engaging stakeholders and other government agencies to establish a policy, investment, and legal framework for private industry in LEO**
  - **Agency letters to HHS-NIH, DOC-NOAA, NSF, others**
- **Changing ISS and NASA center processes from a government to commercial focus**

However, this vision also requires the supply industry to "own" the long term development and sustainment of the demand beyond NASA

Also means that as part of any public demand NASA will have to address its' long term research requirements for LEO…

In other words…

Commercial demand must be developed to utilize the private supply systems in work today…

…including other sectors of the economy beyond research including tourism, manufacturing and marketing


NASA

At the next HEO and full NAC we will be prepared to share the next level of decomposition of how ISS utilization and other NASA activities are aligned with this strategy