ISS Transition and Deep Space Gateway Concept

Committee on Biological and Physical Sciences in Space
Irvine, CA
November 2017

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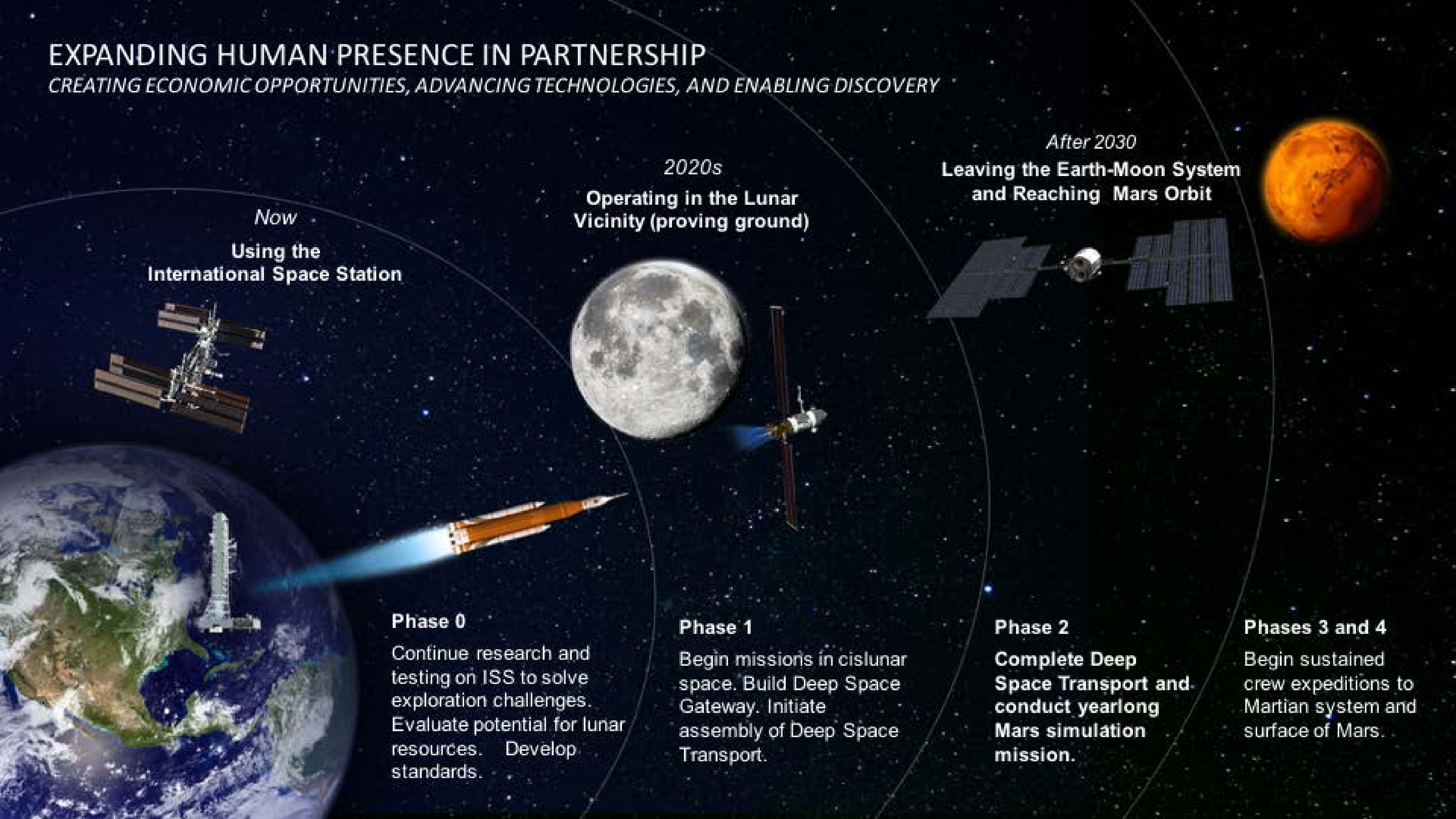
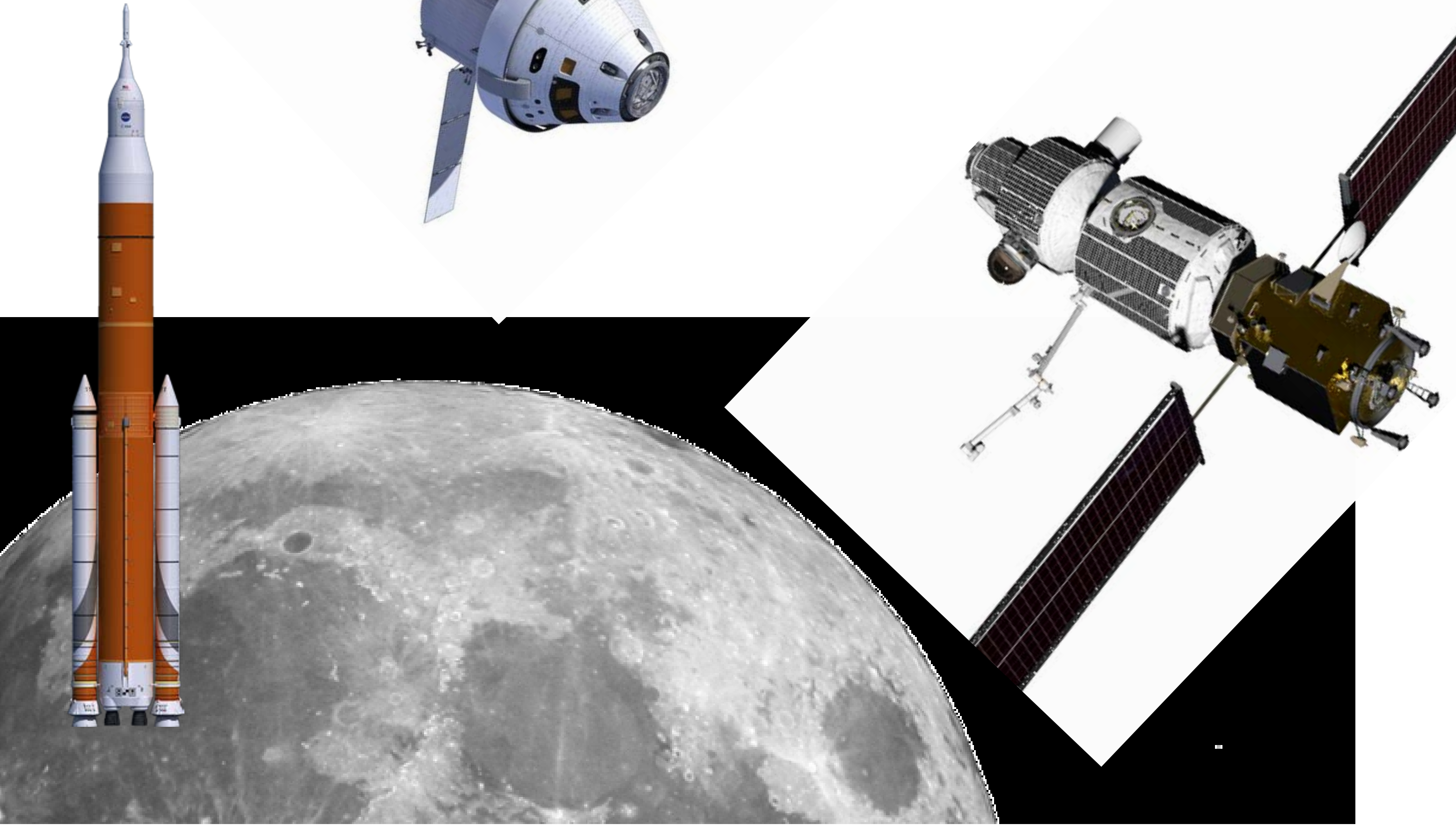

EXPANDING HUMAN PRESENCE IN PARTNERSHIP
CREATING ECONOMIC OPPORTUNITIES, ADVANCING TECHNOLOGIES, AND ENABLING DISCOVERY
Now
Using the International Space Station
2020s
Operating in the Lunar Vicinity (proving ground)
After 2030
Leaving the Earth-Moon System and Reaching Mars Orbit
Phase 0
Continue research and testing on ISS to solve exploration challenges. Evaluate potential for lunar resources. Develop standards.
Phase 1
Begin missions in cislunar space. Build Deep Space Gateway. Initiate assembly of Deep Space Transport.
Phase 2
Complete Deep Space Transport and conduct yearlong Mars simulation mission.
Phases 3 and 4
Begin sustained crew expeditions to Martian system and surface of Mars.

Phase 0: Utilizing the ISS

Focus on realizing long-term deep space human missions beyond the Earth-Moon System

- **Human health and performance research and countermeasure development**
- **Long-term deep space life support systems development and demonstrations**
- **Sustaining human existence beyond LEO**
- **Relevant exploration technology development and demonstration**

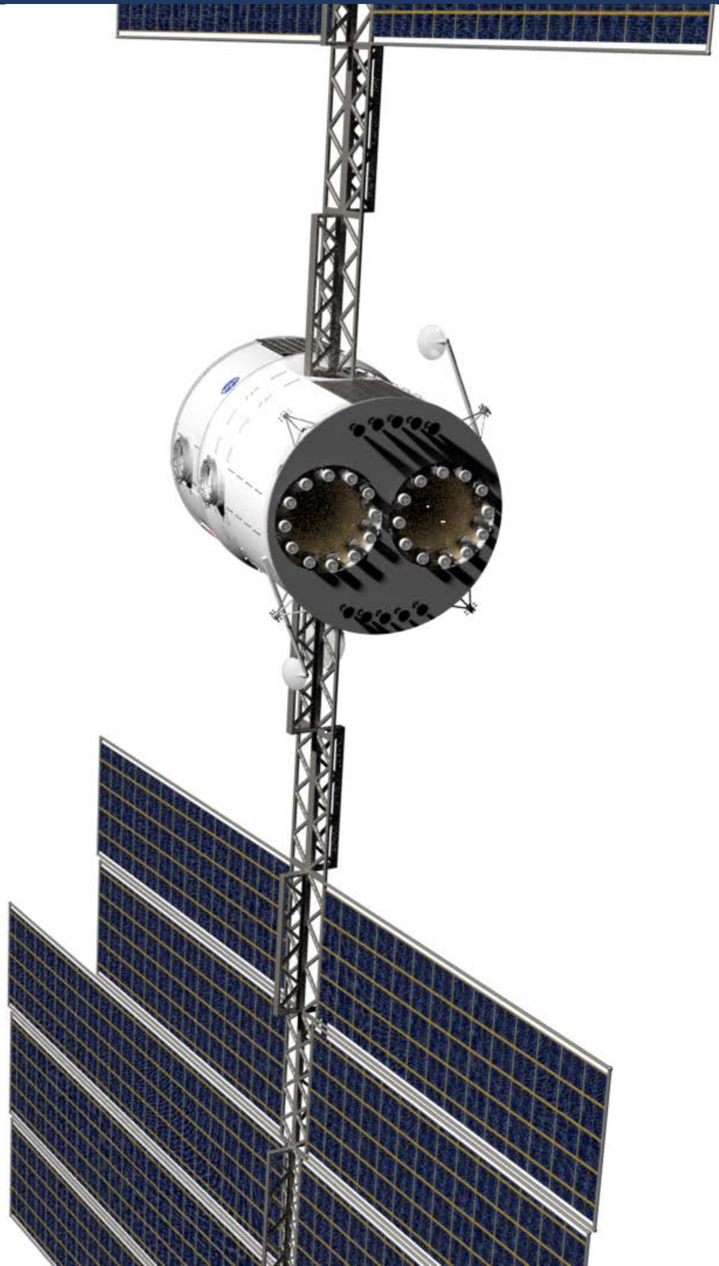
Phase 1 – Missions around the Moon - SLS, Orion, and the Deep Space Gateway



- With the Moon only 3-5 days away, the area around the Moon “cislunar space” is our next destination

- Building upon the ISS International Partnership
- Building and flying the large systems to get humans beyond LEO – SLS and Orion
- Deep Space Gateway supports multiple NASA, International and commercial objectives beginning with 30 days of docked operations

Phase 2 - Testing the Mars spaceship in cislunar space



- **Deep Space Transport provides habitation and transportation needs to be able to send humans to Mars**
    - Crew of 4 for 1,000 day-class missions in deep space that supports a Mars orbit mission
    - Launched on one SLS 1B cargo vehicle - resupply and minimal outfitting to be performed in cislunar space

- **Emphasis on supporting a year long *shakedown cruise* by 2029 in the lunar vicinity**
    - Validates all the vehicle and crew systems necessary to go beyond the Earth-Moon system
    - Utilizes deep space interfaces and common design standards

Exploration Health & Performance Risks

Altered Gravity Field

1. Spaceflight-Induced Intracranial Hypertension / Vision Alterations
2. Renal Stone Formation
3. Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Space Flight
4. Bone Fracture due to spaceflight Induced changes to bone
5. Impaired Performance Due to Reduced Muscle Mass, Strength & Endurance
6. Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity
7. Adverse Health Effects Due to Host-Microorganism Interactions
8. Urinary Retention
9. Orthostatic Intolerance During Re-Exposure to Gravity

Concerns

1. Concern of Clinically Relevant Unpredicted Effects of Medication
2. Concern of Intervertebral Disc Damage upon and immediately after re-exposure to Gravity

Radiation

1. Risk of Space Radiation Exposure on Human Health:
   - Acute solar events
   - Cancer
   - CNS impairment
   - Tissue degeneration (cardio)

Distance from Earth

1. Adverse Health Outcomes & Decrements in Performance due to inflight Medical Conditions
2. Ineffective or Toxic Medications due to Long Term Storage

Isolation/Confinement

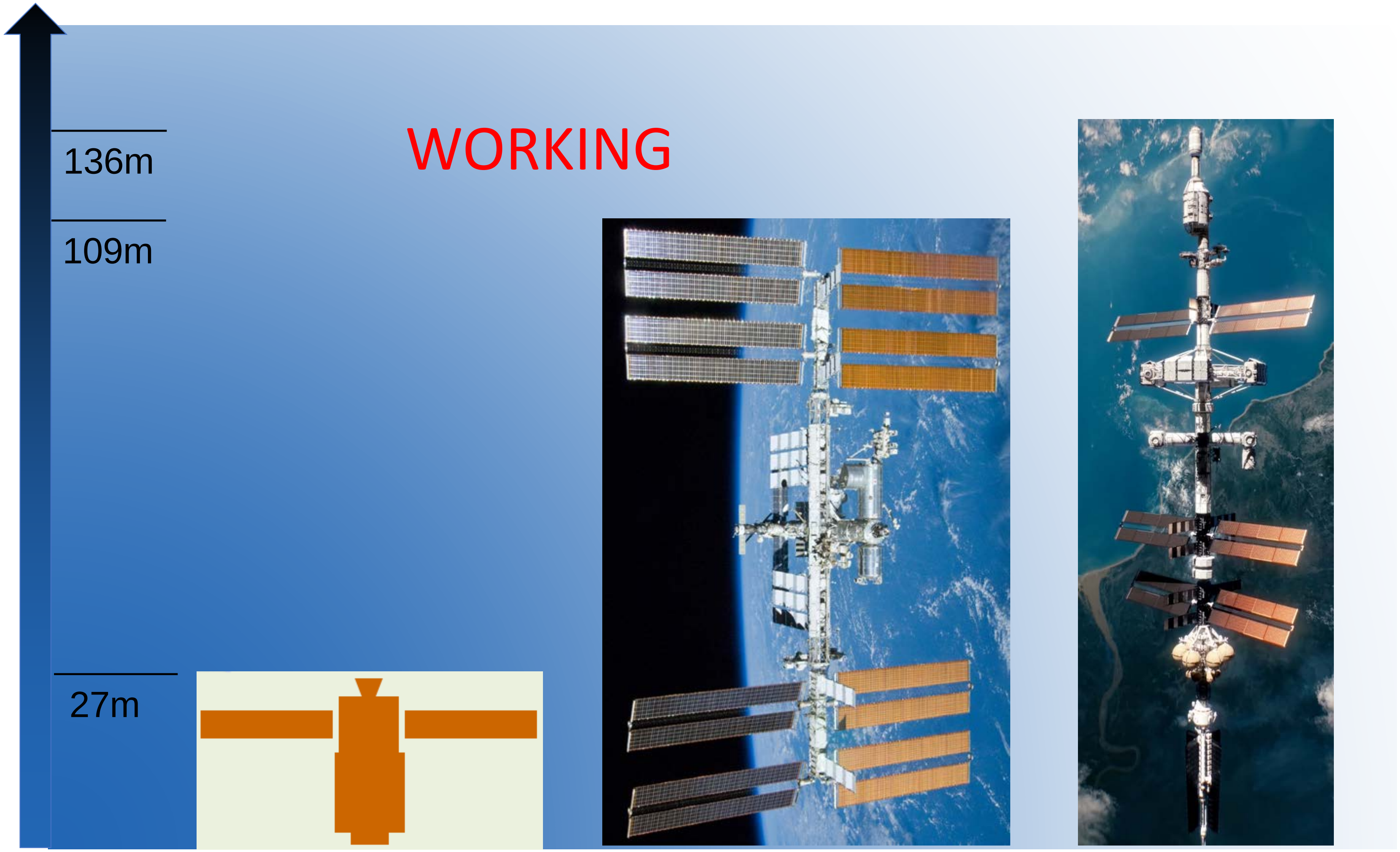
1. Adverse Cognitive or Behavioral Conditions & Psychiatric Disorders
2. Performance & Behavioral health Decrements Due to Inadequate Cooperation, Coordination, Communication, & Psychosocial Adaptation within a Team

Hostile Closed Environment

1. Acute and Chronic Carbon Dioxide Exposure
2. Performance decrement and crew illness due to inadequate food and nutrition
3. Injury from Dynamic Loads
4. Injury and Compromised Performance due to EVA Operations
5. Adverse Health & Performance Effects of Celestial Dust Exposure
6. Adverse Health Event Due to Altered Immune Response
7. Reduced Crew Performance Due to Hypobaric Hypoxia
8. Performance Decrements & Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, & Work Overload
9. Reduced Crew Performance Due to Inadequate Human-System Interaction Design
10. Decompression Sickness
11. Toxic Exposure
12. Hearing Loss Related to Spaceflight

NASA Human Systems Risk Board: Red Risks for Mars DRMs

DST / ISS / Hermes

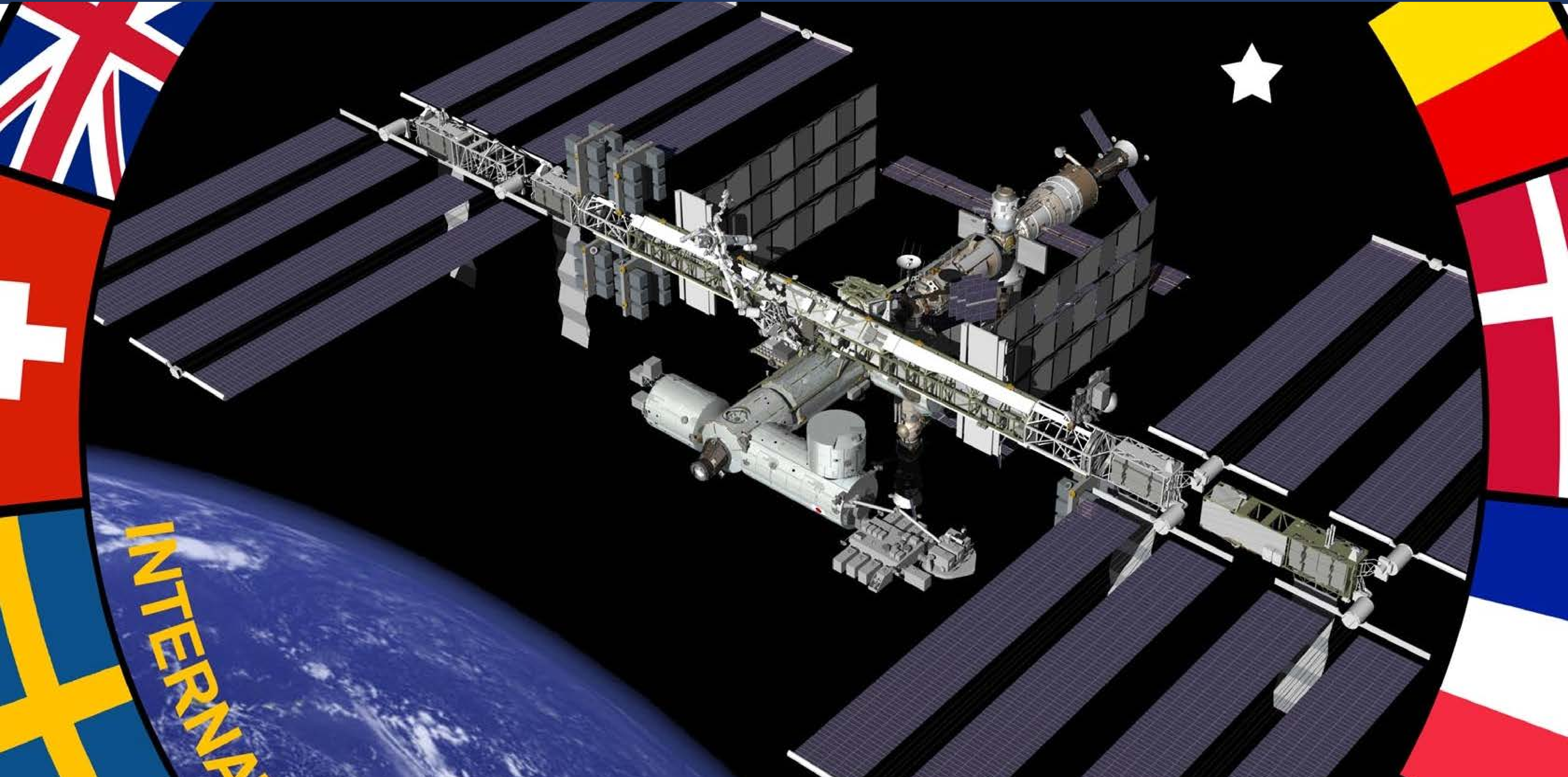


DST *ISS* *Hermes*

DST / ISS / Hermes

	Pressurized Volume	Habitable Volume	Total Mass	Crew Capacity	Habitable Volume per Crew	# Launches based on 130 MT SLS (Block 2)	Years to Assemble Based on 2 130 MT SLS Flights/Year
DST	427 m^3	142 m^3	75MT	4	36 m^3	4	2
ISS	916 m^3	388 m^3	420 MT	6	65 m^3	10	5
Hermes	2,032 m^3	677.52 m^3	733 MT	6	151 m^3	18	9

International Space Station – Moving into the future



Partnership Investments in ISS and Low Earth Orbit Enables the Following

- **Continuous human presence in LEO**
- **Mature international partnership**
- **Development of commercial markets in LEO**
- **Deep space long duration exploration research**
- **Broad based research and development activities**

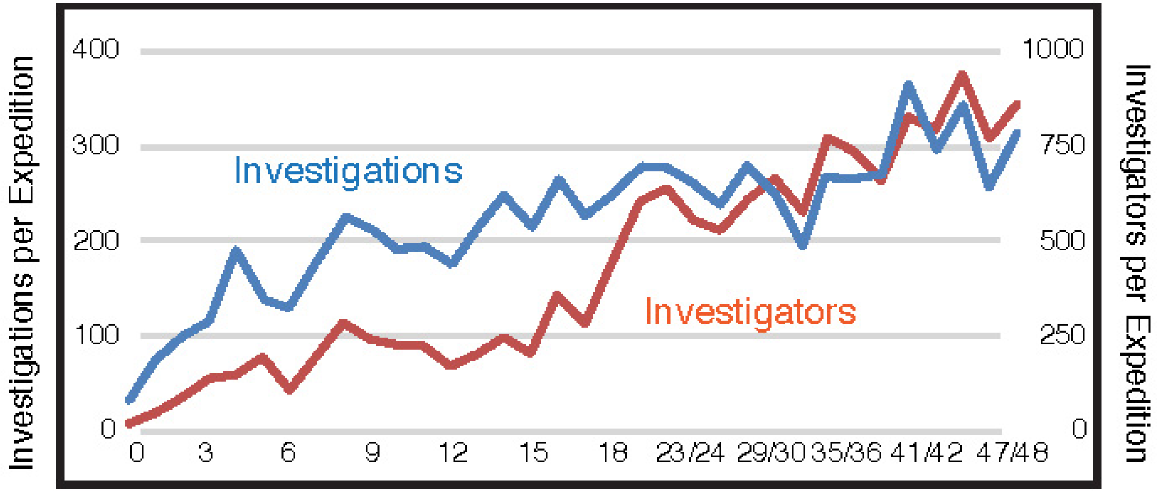
ISS hitting our research and utilization stride

Top 20 Journals with ISS Results* (Number of Publications)
PLOS ONE (38)
Nature (1)
Proceedings of the National Acedemy of Sciences of the United States of America (3)
Science (3)
Physical Review Letters (26)
Journal of Biological Chemistry (2)
Chemical Communications (1)
Journal of Neuroscience (1)
Advanced Materials (1)
Journal of Geophysical Research (5)
Physical Review D - Particles, Fields, Gravitation and Cosmology (1) ‡
Otics Express (2)
Scientific Reports (10)
Chemistry - A European Journal (1)
Geophysical Research Letters (1)
NeuroImage (1)
Journal of Chemical Physics (4)
Langmuir (2)
Physical Review E - Statistical, Nonlinear, and Soft Matter (12) ‡
The Astrophysical Journal (2)

*Journals are listed in Eigenfactor® order. Eigenfactor® is an estimate of the percentage of time users spend with a journal, with citations from influential journals ranked higher.

‡ Denotes a new Journal to the top 20 list since the Expedition 0-46 report.

	ISS Expeditions 45/46	ISS Expeditions 47/48	ISS Expeditions 0-48
Number of Investigations	257	312	2179
New Investigations	39	77	--
Completed/Permanent Investigations	22	49	1572
Number of Investigators with Research on the ISS	776	864	3145
Countries & areas with ISS Investigations/Education Activities	42	48	98



Development of the commercial and non-NASA government demand

ISS

U.S. NATIONAL LABORATORY

NASA CASIS

POWERED THROUGH PARTNERSHIP

Current State

- **Continuous human presence in LEO**
  - Continuous human presence has been sustained over the past 16+ years
    - Commercial crew will add an additional crew member
    - ISS is now part of human spaceflight and space culture around the world

- **Basis for International cooperation in human spaceflight and exploration**
  - Current ISS Inter-Governmental Agreements (IGA) have been in place for nearly 20 years and provide treaty-level agreements between U.S., Russia, Canada, Europe and Japan

- **U.S. development of commercial markets in LEO**
  - Cargo and crew already supplied by private industry
  - Commercial crew and cargo support commercial launch industry
    - ~14% of world launch market goes to ISS
  - Research and tech dev demand development via National Lab/CASIS

Current State

- **Deep Space - Long-Duration Exploration**
  - Requirements for human health and performance research and technology/system demonstrations for habitation systems, and other exploration systems are currently planned to be completed by 2024/2025

- **Research and Development**
  - NASA sponsored research across life and physical sciences, human health, astrophysics, Earth sciences, space science, many others
  - National Lab (NL) users have been greatly expanded into private industry and other government agencies via CASIS
    - Pharma, materials, manufacturing, human health, model organisms, consumer products
    - NASA continues to fund NL activities at $15M/year + transportation, crew time, power, data, etc. for no cost

Considerations

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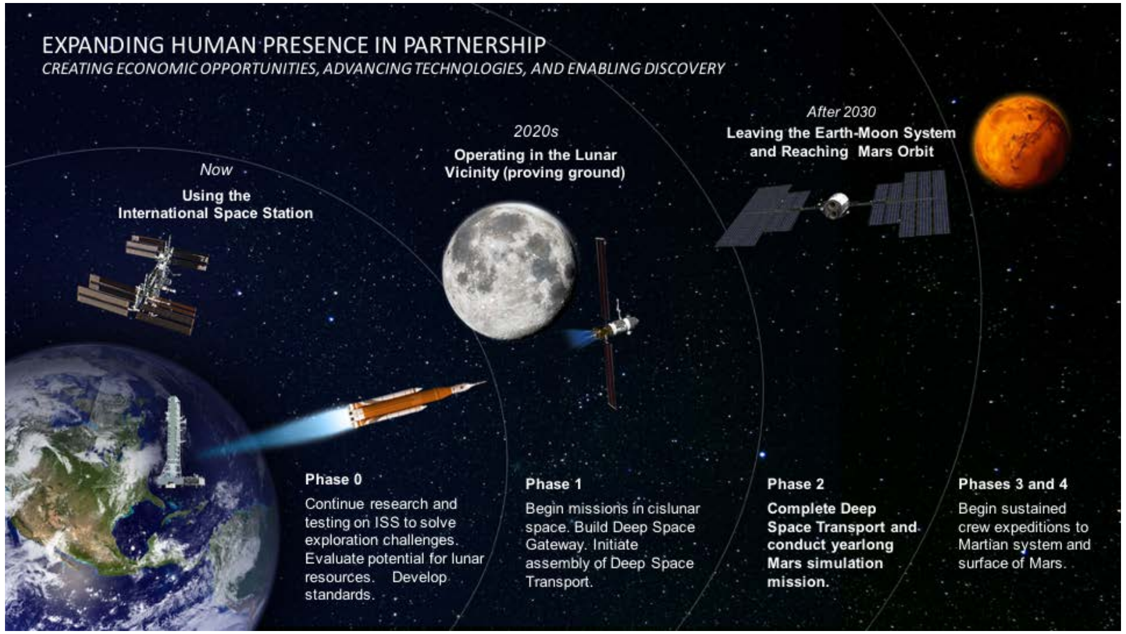
➢ **Transition indicators**

- Completion of exploration-related research and technology development requiring ISS
- Demand from government and private industry including research and for-profit motivated activities, and whether that demand will support private LEO platforms and associated transportation costs
- Establishment of cislunar Gateway capabilities and execution of missions beyond LEO

➢ **Affordability in the larger HSF Exploration context**



Considerations

- **Future of the National Lab**
  - Role of the government in fostering R&D across private industry and non-NASA government agencies

- **Re-use of on-orbit ISS elements**
  - Many ISS elements will have considerable structural life after 2028
  - Some systems, including the solar arrays, will need to be replaced by the end of the 2020s in order to maintain the current configuration
  - Maintenance levels less than originally anticipated
  - Value of the nation's investment is considerable

Element	Year Launched	+30 years
FGB/Node 1	1998	2028
US Lab	2001	2031
Node 2	2007	2037
Columbus/JEM	2008	2038
Node 3/Cupola	2010	2040
Truss segments	2000-2009	2030-2039

- **Long-term NASA requirements for LEO research and utilization**
  - NASA is currently assessing its LEO long term requirements and utilization needs

- **Scope of public-private partnership models**
  - There is a large range of private partnership arrangements that could be considered
    - Proper role of the government vs. private industry would need to be explored
    - Ability for private industry to do business outside of government constraints

Thoughts to Wrap-up