FINDINGS and STRATEGIES for Enabling Human Habitation for Remote Destination Space Transit

Going Forward from ISS to the Proving Ground and Beyond

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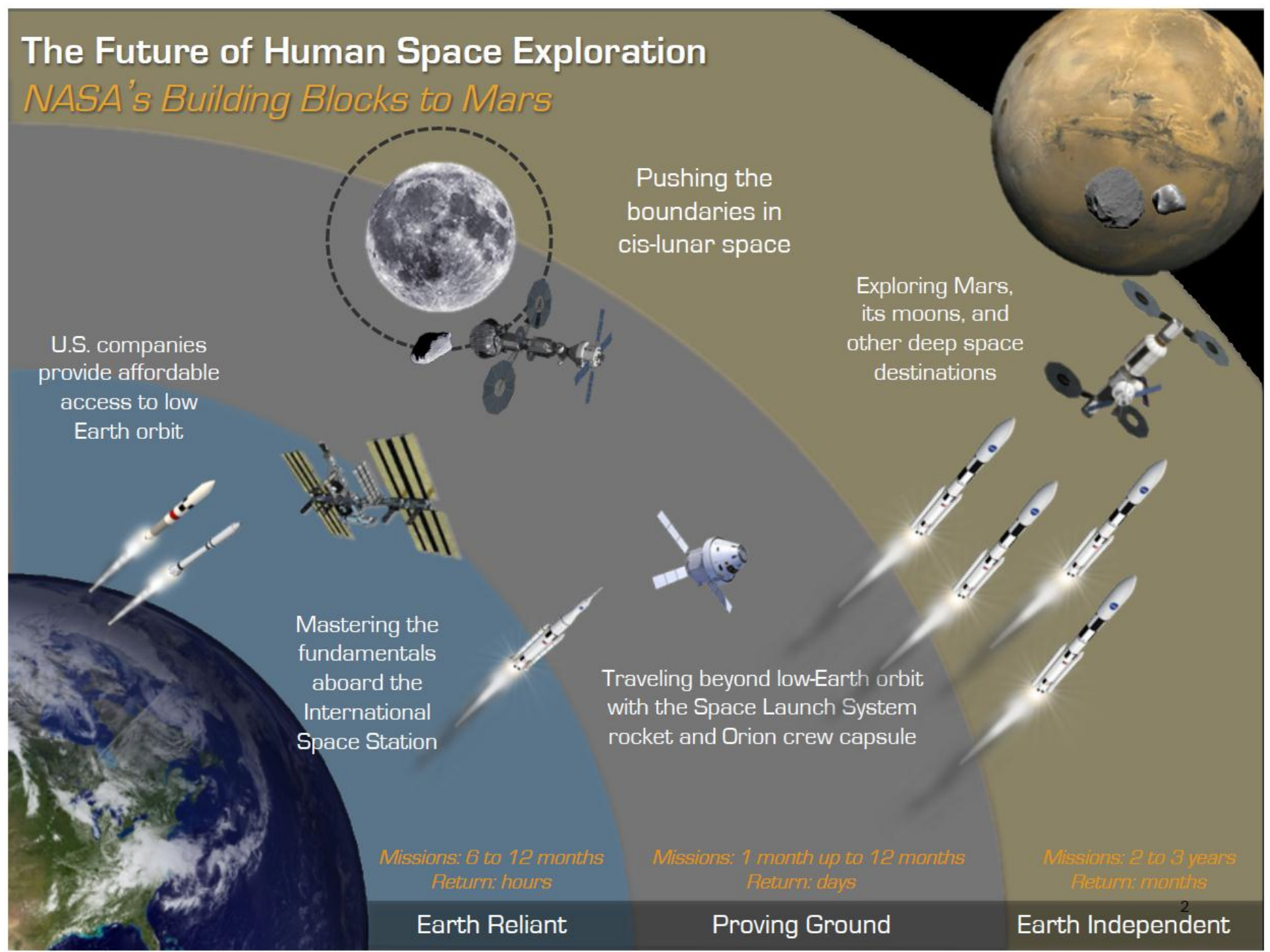
Today's Discussion

- What is the "Proving Ground" and EAM purpose?
- How can the EAM address both a "critical path" and an extensible path to Mars?
  - Closure of critical path Strategic Knowledge Gaps (SKGs) that address human health and performance in a deep space environment containing the combined effects of radiation → growing toward longer duration human presence at in lunar orbit as the path to wellness that precedes human long duration transit to Mars
  - Capability growth process from ISS → to EAM → to Mars transit vehicle

The Future of Human Space Exploration

NASA's Building Blocks to Mars



Let's Look at Two Transit Mission/Vehicle Types

- **The Asteroid Utilization Mission and other such lunar orbit missions can be classified as follows:**

TYPE 1: Short Duration (~1 mo., < 6), Close Proximity (Lunar vicinity) :

- Benefit of ready-return to address crew or equipment emergencies or repair issues
- Accommodates/promotes crew rotations/change-out for discrete, separate missions
- Benefit of logistics re-supply and immediate trash management, specifically catered for each short duration mission
- Convenience of similar communications and ground control that is familiar to our current operations and ways of conducting business
- Avoids the need for different measures for crew radiation beyond nominal storm shelter and monitoring (includes Galactic Cosmic Radiation up to 180 days)

- **A conventional mission to Mars (e.g. DRA 5) can be classified as follows:**

TYPE 2: Long duration (~900+ days), Remote (Interplanetary):

- No change-out of crew, no ready-return option
- No ready resupply -- presents a very different set of risk-reduction needs in terms of vehicle reliability, on-board logistics, spares, and repair equipment, and introduces need for on-board, automated vehicle monitoring and crew assistance
- Limited/no immediate ground control assistance (due to time delay) -- this is an uncharted/uncultivated operations model for crew and ground control
- Long duration crew exposure to microgravity, radiation (to include GCR), and unknown general behavioral and health effects

Overview of FUNDAMENTAL FUNCTIONS/CAPABILITIES NEEDED (not comprehensive list) for a given mission type

(Earth Reliant)
For a vehicle in LEO (ISS):

- Docking and airlock capability
- Emergency crew return capability
- Solar Power generation and distribution
- Attitude control and stationkeeping
- Heat rejection
- Communications
- SPE Radiation protection
- Micrometeoroid protection
- EVA/Robotics capability
- ECLSS
- Instrumentation/sensors
- Crew quarters, crew food/provisions
- Waste management/hygiene capability

(Proving Ground)
For Type "1"/lunar mission (Asteroid):

- Docking and airlock capability
- Emergency crew return capability
- Solar Power generation and distribution
- Attitude control and stationkeeping
- Heat rejection
- Communications
- SPE Radiation protection
- Micrometeoroid protection
- ~~EVA/Robotics capability~~ (based on DRM)
- ECLSS
- Instrumentation/sensors
- ~~Crew quarters,~~ crew food/provisions
- Waste management/hygiene capability
- Automated Rendezvous and Docking
- Improved radiation capability for equipment during manned/unmanned mission (outside Van Allen Belts)
- Advanced EVA capability

Vast Gap/Leap in Needs and Capabilities from Lunar Vicinity to Interplanetary

(Earth Independent)
For Type "2" / DRA 5 Mars mission:

- Docking and airlock capability
- ~~Emergency crew return capability~~
- ~~Solar~~ Power generation and distribution
- Attitude control and stationkeeping
- Heat rejection
- Communications
- SPE Radiation protection
- Micrometeoroid protection
- ~~EVA/Robotics capability~~ (based on DRM)
- ECLSS
- Instrumentation/sensors
- Crew quarters/crew food/clothing/provisions
- Waste management/hygiene capability
- Automated Rendezvous And Docking
- Improved radiation capability for equipment during manned/unmanned mission (outside Van Allen Belts)
- Advanced EVA capability
- Long Term On-orbit Cryo /Boil-off containment
- Nuclear Thermal Propulsion and Power Generation
- In-Situ Resource Utilization
- Automated Caution/Warning/Vehicle Health monitoring/prediction/repair capability
- Unmanned Long Duration Automated Vehicle Health and Self-Repair
- Repair/Maintenance Equip and Spares
- Crew radiation mitigation for GCR
- Crew health and countermeasures for 0g
- Automated Logistics Management
- Onboard-Crew Autonomous Ops

We need to prove out new/red Type "2" capabilities at our ISS and Type "1" missions

in black = use of readily-known/LEO/ISS methods and capabilities standard

in blue = requires use of a new capability for asteroid utilization mission in lunar orbit

in red = requires use of a new capability for long-duration, remote case

THE PROVING GROUND IN CISLUNAR SPACE:

Strategies and Development with EAM

Why go beyond LEO for the "Proving Ground"?

Some critical path items of note to progress us toward deep space exploration:

- **To address such strategic knowledge gaps, some fundamental, critical vehicle and human/crew-related evaluations are needed to be conducted beyond the Van Allen Belts, to include:**
  - Effect of Radiation on Human Health
    - Acute and late Central Nervous System effects on behavior and cognition
    - Altered immune responses
    - Degenerative tissue diseases
    - Increased cancer morbidity or mortality
    - Efficacy of countermeasures
  - Effect of Radiation and Deep Space Environment on the Food System
    - Food nutritive degeneration, food microbial controls, food consumption acceptability after irradiation, food processing and preservation controls acceptability, etc.
    - Long term storage of limited source food supply and affects on performance decrement, illness, or loss of mission
  - Unpredicted Effects on Medication Safety, Effectiveness, and Long-Term Stability
  - Effect of Isolation and Confinement on Behavioral Health, Net Habitable Volume
  - Environmental Effects on Virulence of Microbial Population and Microbial Mutation
  - Relationship between Tolerable Workspace/Space, Reconfigurability, Adaptation, and Customization
- **These evaluations should be conducted in a close (lunar) proximity location first for safety purposes, redesign/repair purposes, and operational autonomy / time-delay concept of operations**

EAM Objectives

- **Orion is the first component of human exploration beyond low Earth orbit and has capability of sustaining a crew of 4 for 21 days in deep space and returning them safely to Earth.**
- **After Orion, the next step for human spaceflight is the EAM which is to augment the Orion to sustain a crew of 4 for approximately 1 additional month initially and for a gradually growing duration over time. EAM is not specifically a single element and will likely be launched in a few pieces.**
- **The EAM will initially be used in cislunar space to support:**
  - Deep space systems demonstration and Strategic Knowledge Gap Testing to address Human Health and Performance in a deep space environment (that includes Galactic Cosmic Radiation)
  - Augment the Asteroid Redirect Mission (ARM) to allow asteroid sampling and possible ISRU testing
- **The EAM functions include:**
  - Habitation for crew of 4.
  - Ability for visiting vehicles to dock (Orion, logistics resupply, ARV, etc.) and an Airlock
  - Enabling Mars habitation demonstration
- **Be operational by 2021 (TBR) to allow for SKG experiments to impact Mars hab design**
- **Be launched on SLS or commercial vehicle**
- **Engage in partnership potential with international and commercial communities**

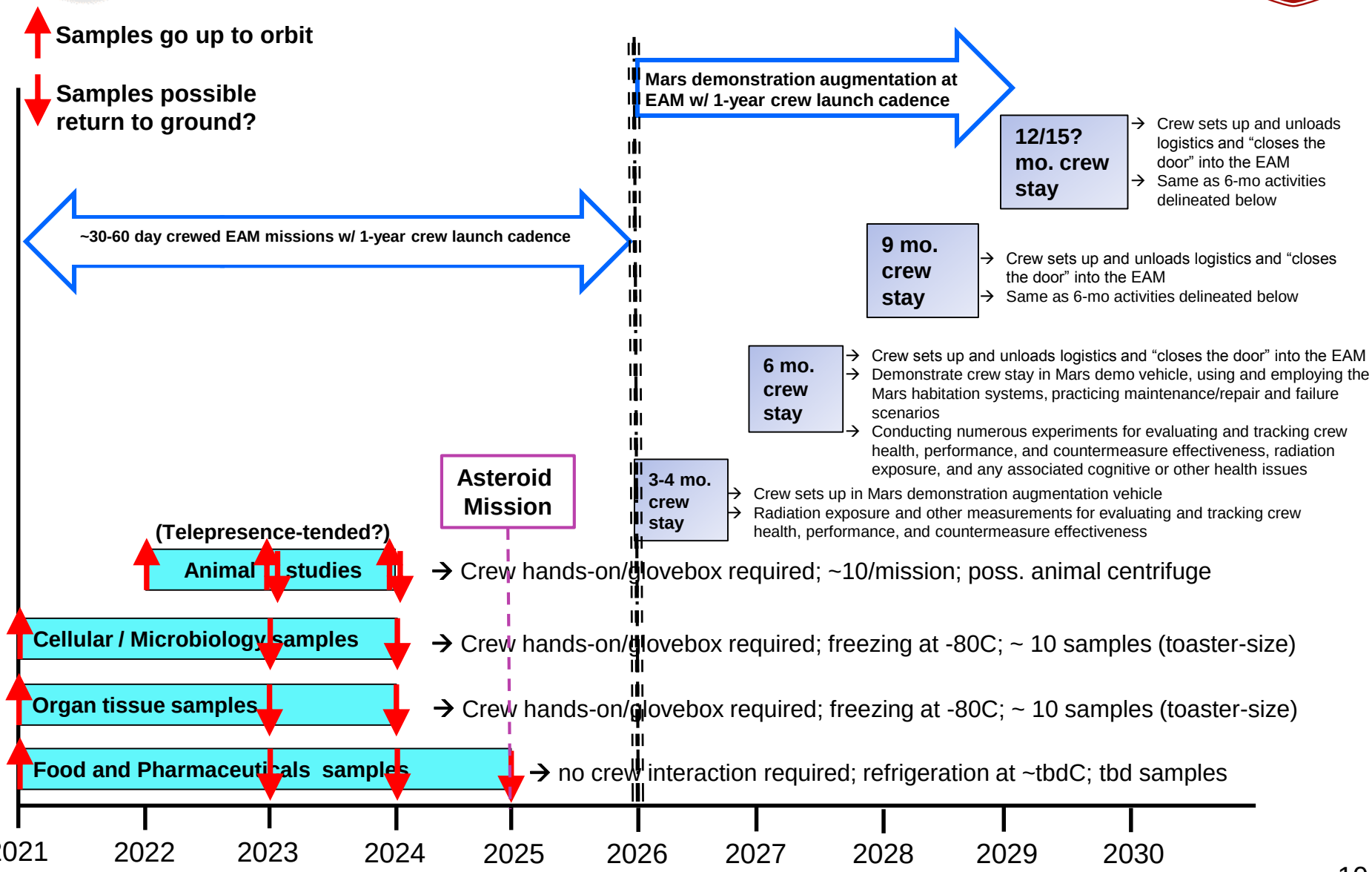
There are essentially two lines of action in defining the EAM :

1) Definition and assessment of “essential” vehicle design and capabilities of the EAM
   - ✓ Address fundamental design and vehicle capabilities required to arrive, live and operate in space (launch and on-orbit conditions) → covers the “avoid dying” requirements of living and working in space

2) Advancement of WHY we are in cis-lunar space
   - ✓ Address the Mars-enabling / deep-space SKGs for human health and performance → we want to properly map to HRP’s Risk Reduction Plan
   - ✓ Advance and test (new) Mars / deep-space vehicle capabilities
   - ✓ Support Asteroid Redirect mission → asteroid sampling/utilization
   - ✓ Serve as a platform to enable lunar missions, other asteroid missions, and/or Mars missions, etc.

EAM will always be Mars-forward, but is also available to enable additional exploration objectives

Notional Sequence of Mars-enabling human health and performance capabilities at EAM



Findings/Summary remarks

1) Advance forward in vehicle development/progression towards Mars by demonstrating Type 2 capabilities in a Type 1 mission

   - SKGs and vehicle capability changes/growth need to be addressed by testing on the ISS and some need to be addressed at the "proving ground" outside the Van Allen belts (at local/lunar vicinity) in order to promote critical path extensibility to Mars

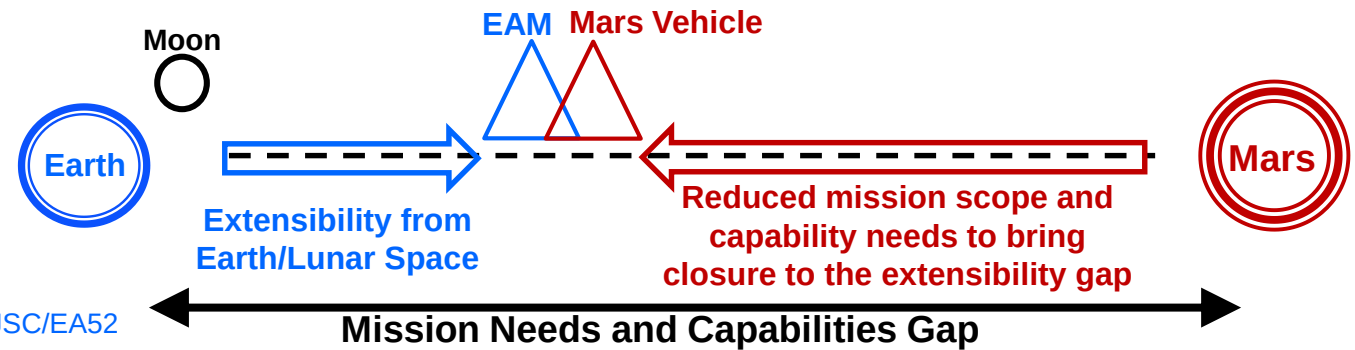
     → some need to be demonstrated at both locations

   - **EAM habitation serves as the "proving ground" / "go-to" location in lunar space to address strategic knowledge gaps for human exposure in deep space and to prove out exploration capabilities**

2) Encourage continued Mars architecture studies that reduce mission scope for the very first missions to Mars in order to provide moderation of the necessary new vehicle requirements/capabilities and hazard controls

   - This will also serve to give more time to work the long-pole technology items and other capabilities over a longer period to spread out the needs and costs

   - **Mars extensibility studies are in work that implement the utility of the EAM/proving ground as part of the effort to reduce the "leap" into smaller steps forward in Mars extensibility**



BACK UP

Deep Space Roadmap

❖ The current NASA HQ capability roadmap shows two next steps of note:

- **ARUM occurring ~ 2025 year timeframe (~ Type "1" class)**
  - Short duration, close proximity mission at a lunar distant retrograde orbit (DRO)
  - Currently includes an EVA from Orion to conduct the asteroid sample "mining"

- **Mars mission occurring ~ early to mid 2030s timeframe (Type "2" class)**
  - This could be an orbit, flyby, landing, or involving a Mars moon (IT'S NOT SPECIFIC)
  - In any case, it will be a long duration, remote mission

These two roadmap points are only few years apart…

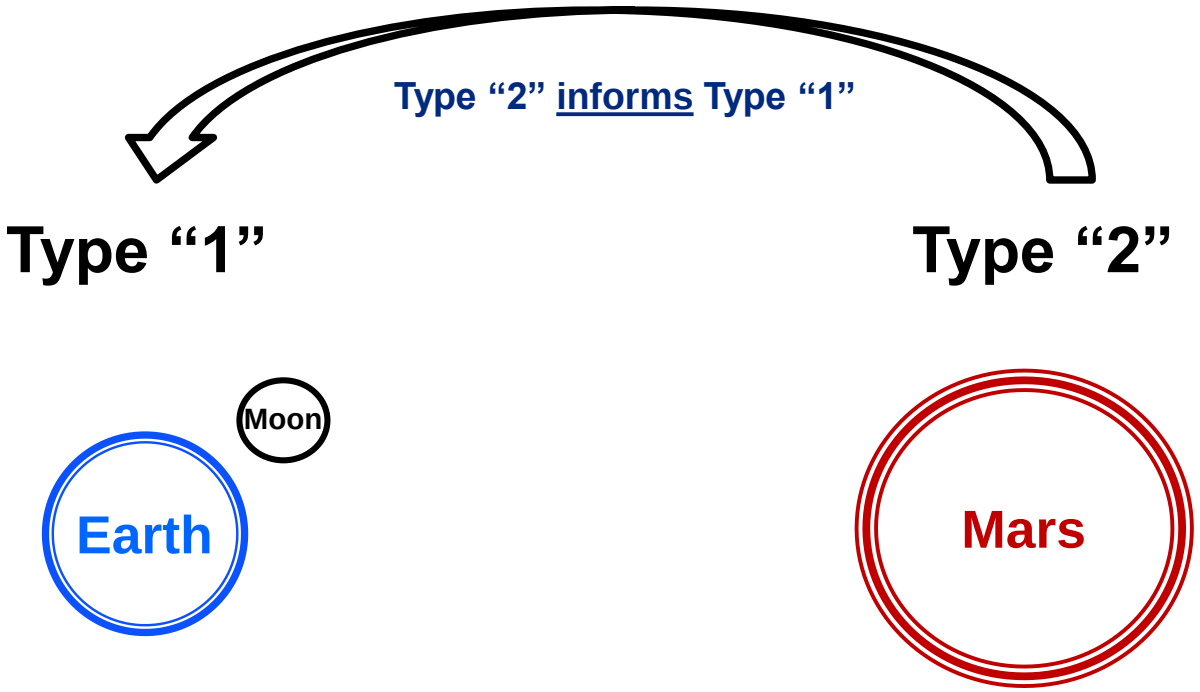
….so we need to have carefully thought out the extensibility path and scarred for or included otherwise unnecessary capabilities in the EAM in order to close strategic knowledge gaps

ISS → EAM → Mars

Deep Space Extensibility

Planning strategy of capability evolution:

Type “2” planning should inform Type “1”, from right to left



Planning for “Type 2” missions should dictate what our strategy is for developing our capabilities, utilizing ground test and near-earth flight missions (EAM!)

PROVING GROUND

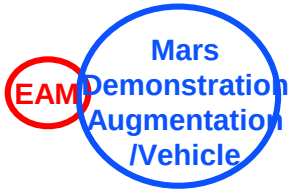
EAM at CisLunar Space

(2021 thru 2025)

- First on-board HRP experiments
- Augmentation habitation with Orion to support crew of 4 for 30-60 days
- First utilization of (some not all) on-board Mars-forward subsystem capabilities
- Enable arrival/departure of Orion on a one-year cadence
- Enable arrival/departure of logistics for crew annual arrivals
- Enable docking and outfitting for Asteroid mission
- Enable docking and outfitting for eventual Mars augmentation and demonstration

EAM at CisLunar Space

(2026 thru 2030+)



- First crewed extended-duration missions for enabling human health and performance capabilities for Mars (>6 mos to over a year)
- Enable docking and outfitting for Mars augmentation habitation (with/without EAM and Orion) to support crew of 4 for up to 1+ year
- Paradigm shift toward utilization of (most if not all) on-board Mars-forward subsystem capabilities
- Enable arrival/departure of Orion on a one-year cadence
- Enable arrival/departure of logistics for crew annual arrivals
- Enable continued arrival/departure and checkout of exploration vehicles (either going to the moon or Mars)

Reducing the Scope of Initial Mars Missions:

Mars Long Range Planning

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- Docking and airlock capability
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- Attitude control and stationkeeping
- Heat rejection
- Communications
- SPE Radiation protection
- Micrometeoroid protection
- EVA capability
- ECLSS
- Instrumentation/sensors
- Crew quarters, crew food/provisions
- Waste management/hygiene capability

For a cis-lunar mission (Asteroid):

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Vast Gap/Leap in Needs and Capabilities from Lunar Vicinity to Interplanetary

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Lora Bailey/JSC/EA52

Introduce Reduced Scope for First Mission(s) to Mars

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Modest Gap in Needs and Capabilities

Example: For a Lean Fast Mars mission:

- Docking and airlock capability
- ~~Emergency crew return capability~~
- Solar Power generation and distribution
- Attitude control and stationkeeping
- *Heat rejection to accommodate 0.7 AU
- *Communications
- SPE Radiation protection
- Micrometeoroid protection
- ~~EVA/Robotics capability~~
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For the NASA DRA 5 Mars mission:

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