AM V Breakout Group 2
Semi-Permanent Mars Surface Science Field Station
COSPAR 2018

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Architecture Group 2: Mars Surface Science Field Station

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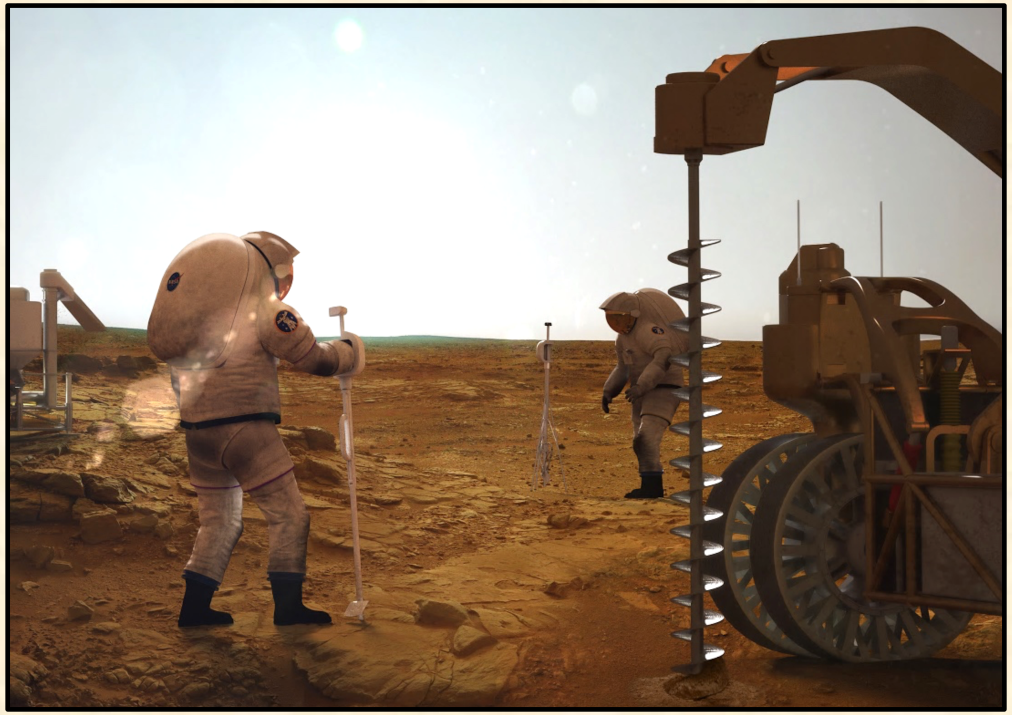
- **Goal:** To learn how to live and operate on Mars in preparation for continuous human presence on Mars, via the deployment of a temporary Mars surface field station that is visited by multiple crews over the lifespan of the infrastructure

- **Activities:**
  - **Engineering testing** of surface hardware (e.g. ISRU, ISM, civil engineering, pressurized rovers, etc.)
  - **Environmental monitoring and characterization** (e.g. ground-truthing of orbital recon datasets such as water mapping and surface winds, better informing planetary protection practices)
  - **Understanding long-term human health impacts** of long duration deep space and surface missions and demonstrating appropriate countermeasures
  - **Learn how best to do in-situ science** with human crewmembers as a resource (e.g. to address MEPAG goals)

- **End State:**
  - When sufficient knowledge and operational experience is gained to **decide on the location** and architecture of the **first continuously occupied permanent base on Mars**.
  - Chosen to occur at the same time that Mars surface equipment wears out (thus avoiding the need for system recertification and/or replacement)



Architecture Group 2: Guiding Principles

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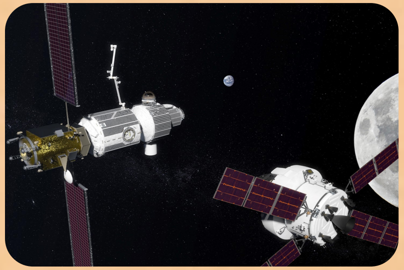
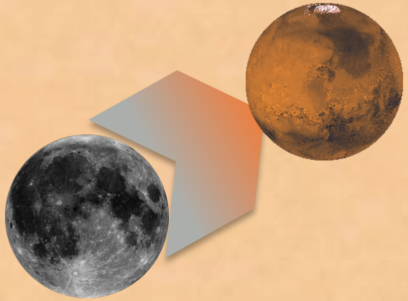
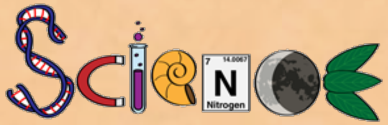
- Architecture should be achievable and sustainable **within a budget only increasing with inflation**

- Incorporate **commercial and international partnerships** as much as possible
  - to distribute costs, increase system robustness (diverse system options), and increase enterprise sustainability





- Assumes the presence of **a cis-lunar gateway facility**
- **Lunar surface system and technology development activities** need to be directly **traceable to achieving Mars missions**
  - For example, a **common lunar and Mars lander/ascent vehicle** would use the same propellant combination, deep-space transit system testing, etc.
  - The **timeline for lunar surface** activities will require some decisions on the Mars architecture to be made earlier than others (e.g., ascent vehicle propulsion combination)



- **Scientific investigations** are part of any human exploration mission

Architecture Group 2: Key Features

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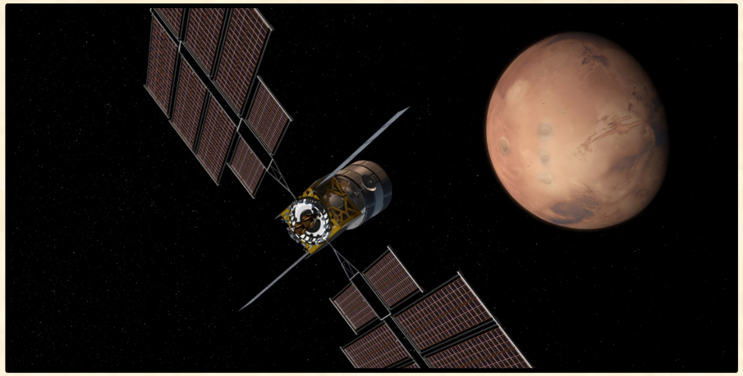
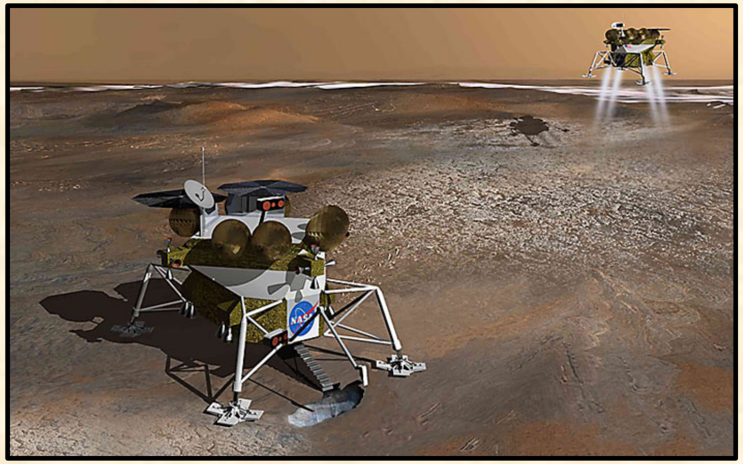
- Built upon **NASA's Evolvable Mars Campaign (EMC) study** (2014-2016) with additional options considered to increase program sustainability
  - **Conjunction-class missions** with gradually increasing time spent on the Martian surface as more surface capabilities are delivered and more experience is gained
  - **Baseline atmospheric O_2 ISRU** with water-based ISRU considered within the trade space depending on selected landing site and precursors/field station activities
  - **Reuse of Transit Habitat and in-space propulsion** for crew and cargo transit, which are sent back to lunar gateway for refurbishment
  - **Reuse** of **Mars Surface Habitat**
- **Modular build-up** of in-space and Mars surface assets (incl. human habitat and laboratory modules) using **multiple commercial and international providers**
- **Small/mid-size Mars landers derived directly from lunar surface program**
  - Develops experience base and **distributes cost** for Mars program across longer timeline
  - Smaller, modular payloads (~10mT) allows for **increased commercial / international participation** (e.g. launch vehicles, landers, and payloads)
    → increases cost sustainability and political sustainability
  - Allows deployment of **larger science payloads** (than currently considered)
    → increased opportunities for scientific discovery and public engagement
  - Increases **system flexibility and robustness** by allowing individual components to be repaired and/or upgraded as they degrade, or as more experience is gained in their operations





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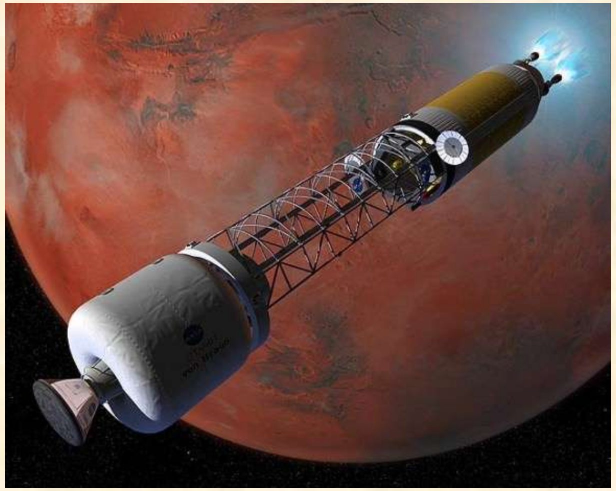
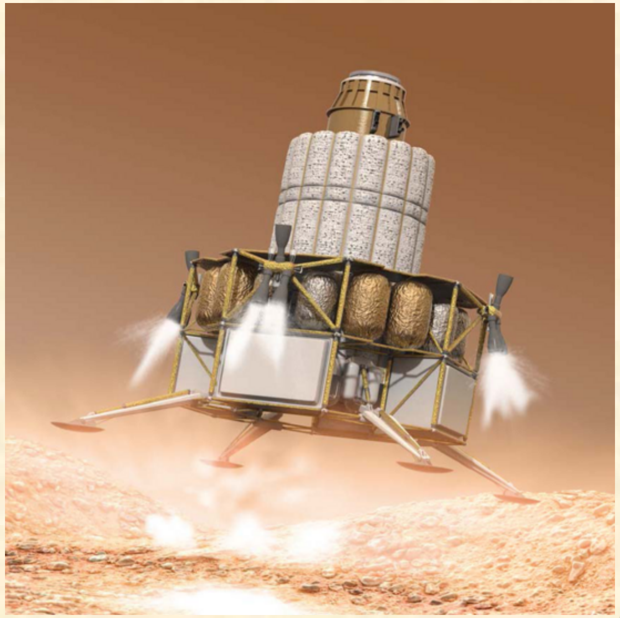
Architecture Group 2: Technology Impacts

- Include **Nuclear Thermal Propulsion** (NTP) **in the propulsion trade space**, along with SEP-chemical and hybrid architectures, to understand potential performance improvements, such as:
    - Additional mass margin, potentially providing payload capability for additional commercial/international providers
    - Lower transit times
    - Expanded mission abort options
    - Enabling both conjunction and opposition class missions, thereby providing additional architectural flexibility
- Explore **reusable Mars ascent vehicle**, which
    - Requires exploration of **crew size** (4 - 6), number of crew transported per vehicle (2 - 6) and whether or not they are transported at the same time
        - As population size increases, crews will likely not all arrive and depart in the same vehicle at the same time
    - Exploits element reusability where feasible to reduce cost
    - Leverage/encourage development of reusable lunar surface lander and ascent vehicle technology





Comparison of Mars Architectural Philosophies

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DRA 5.0	EMC	AM V Team 2
Minimize risks and exposure of crew/cargo to the deep space environment with short duration transits separated by a long surface stay. Three crewed missions in 10 years with overlapping pre-deployed cargo missions.	Progressive expansion of capabilities through the cis-lunar "Proving Ground" to a sustainable human presence on Mars with reasonable extension of ISS, SLS, Orion and DSG. Emphasis on affordability and sustainability.	Looked for ideas to enable an "enterprise sustainable" architecture for an initial human Mars Field Station. Do not necessarily represent completed trades.
Key Architectural Similarities		
• Conjunction Class – 900-1000d	• Conjunction w/ depart & arrival windows to 1200d	• Conjunction Class
• Pre-deployment of cargo	• Pre-deployment of cargo	• Pre-deployed cargo on a range of lander sizes
• ISRU (O_2 for ascent)	• ISRU (O_2 for ascent)	• ISRU O_2, but also include H_2O as early as possible
• Long surface stay	• Evolve to long surface stay	• Long surface stay
• Round-trip crew vehicle	• Round-trip crew vehicle (hybrid SEP/Chemical option)	• Round-trip crew vehicle
Key Architectural Differences		
• Crew of 6	• Crew of 4	• Examine crew of 6
• Cost profile – high peak	• Cost profile – long medium	• Cost profile – long medium
• In-space prop: fast transit, NTR	• In-space prop: Minimum energy SEP/Chemical, Chemical, NTP	• In-space prop: NTP, Minimum energy SEP/Chemical, Chemical
• All crew to surface	• 1^{st} crew to orbit, 2^{nd} to surface	• No orbital only missions; All crew to surface
• Vehicle assembly in LEO	• Vehicle assembly in cis-lunar, HEO departure and arrival	• Vehicle assembly in cis-lunar, HEO departure and arrival
• Max launch cadence – 6/yr.	• Max launch cadence – 2/yr. (1 crew and 1 cargo)	• Launch cadence depends on commercial landers
• Crew trip to Mars each opportunity	• Crew trip to Mars every other opportunity	• Aim for frequent opportunities
• Minimize crew space exposure	• Crew 1100 days in space ok	• Minimize crew space exposure (surface stays + NTP)
• Redundant surface systems possible	• Single string of elements	• Modular habs and labs likely have redundancy
• Each landing site different for science	• Single site build-up infrastructure	• Single site with broad science exploration
• All systems expended	• Reuse of habitat, transportation, surf. Sys.	• Reuse of habitat, transport, and surface & examine MAV reuse

Notional Mars Surface Field Station Architecture

Illustrating Maximized Technology Infusion

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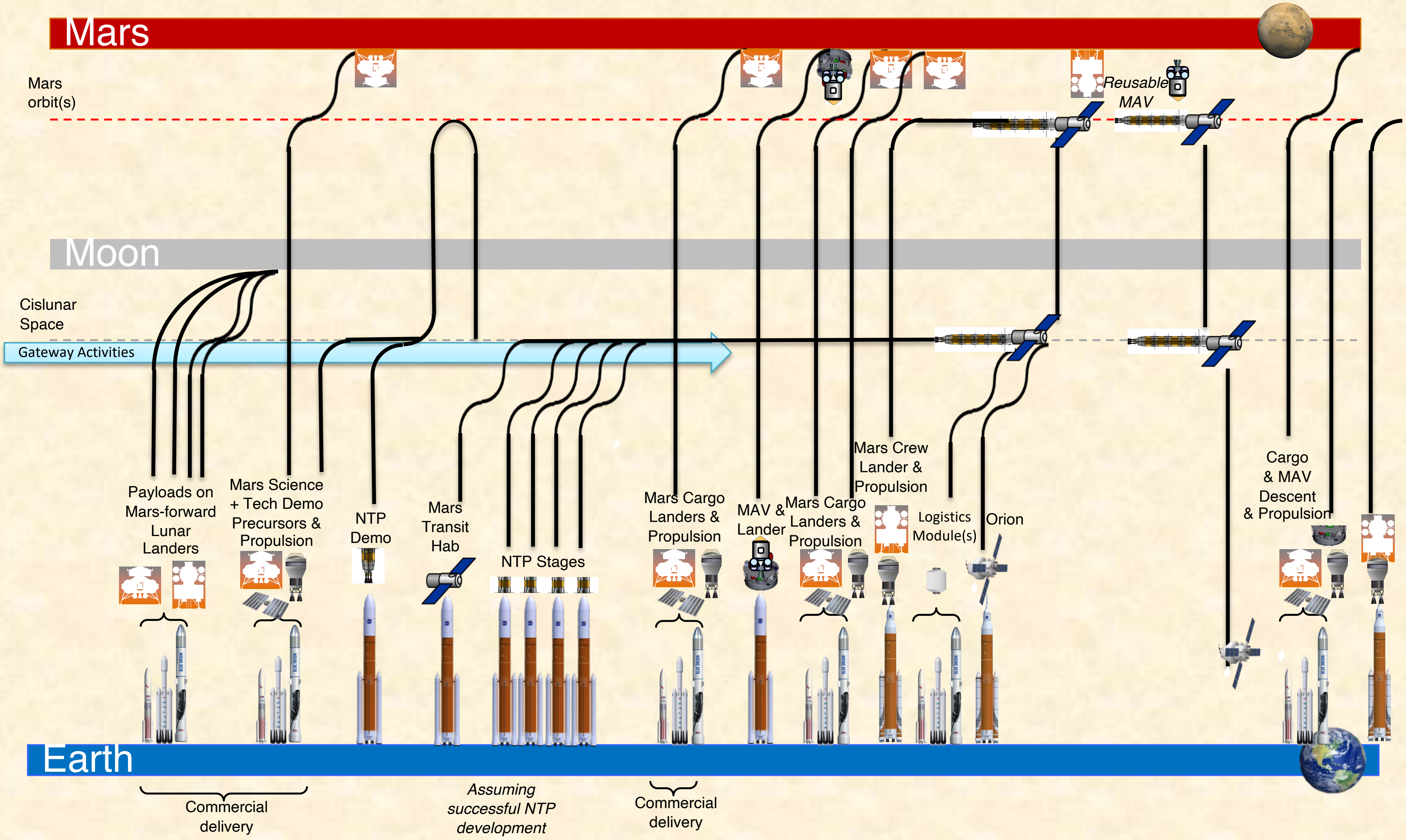

Thank You!

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