A Strategy for Revolutionizing Access to the Mars Surface:

Frequent. Affordable. Bold.

A report out from A Keck Institute for Space Studies Workshop: Revolutionizing Access to the Martian Surface

3 February 2022 MEPAG Virtual Meeting

Chris Culbert (JSC), Bethany Ehlmann (Caltech), Abigail Fraeman (JPL), Elizabeth Frank (First Mode)

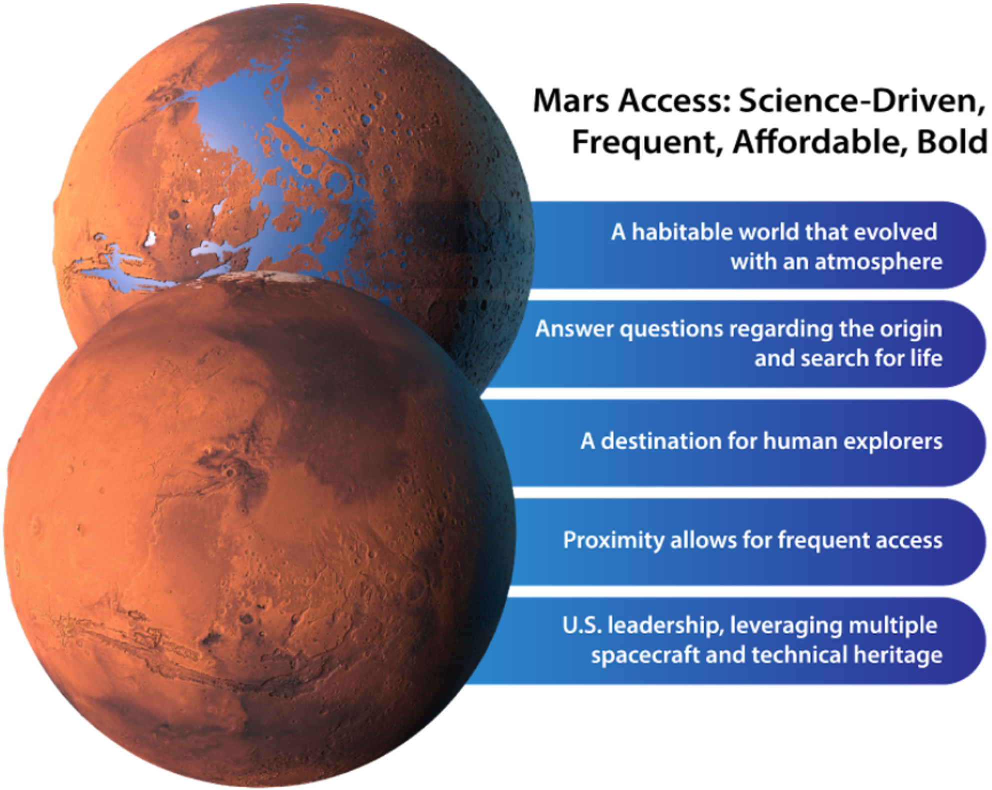
Full report Advance Review Copy at https://www.kiss.caltech.edu/final_reports/Access2Mars_final_report.pdf

Abigail Fraeman

Jet Propulsion Laboratory, California Institute of Technology

Access to Mars' Surface: Why Needed Now?

- **Key science questions require in situ access–see MEPAG Goals, MASWG report**
- Mars Sample Return has primary importance as the next mission and nothing in this strategy is intended to replace or delay MSR
- We believe there are opportunities to augment and expand on the critical MSR investment at a relatively low cost with high potential for community engagement
- Important to maintain continuity of progress and presence of U.S. leadership at Mars (human, robotic)



Keck INSTITUTE FOR SPACE STUDIES

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A Keck Institute for Space Studies (KISS) Workshop

We convened a broad group of workshop participants (next slide) to study how to substantially reduce the cost associated with landed missions to Mars

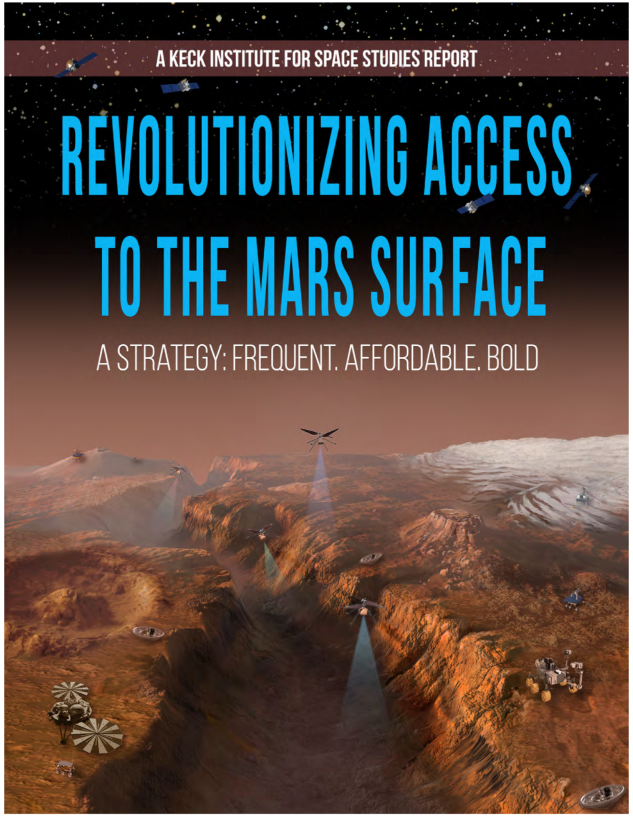
https://kiss.caltech.edu/programs.html#access2mars

Workshop 1: April 2021, including recorded half-day short course

3-month summer study period; working groups addressed specific programmatic, cultural, and engineering factors

Workshop 2: September 2021

Final report posted at the link in slide footer.



Workshop Participants

Representing multiple NASA Centers, industry (old space and new space), and academia
Participants represented a mix of scientists, engineers, and costing/business development leaders.

- Sam Albert - University of Colorado Boulder
- Don Banfield - Cornell University
- Jon Bapst - JPL
- Dave Bearden - JPL
- Kevin Bonnet - University of Colorado Boulder
- Joel Burdick - Caltech
- Wendy Calvin - University Nevada, Reno
- Barbara Cohen - NASA Goddard Space Flight Center
- Tim Crain - Intuitive Machines
- Chris Culbert - NASA Johnson Space Center [study co-lead]
- Charles (Chad) Edwards - JPL
- Bethany Ehlmann - Caltech [study co-lead]
- Giusy Falcone - University of Illinois
- Abigail Fraeman - JPL [study co-lead]
- Elizabeth Frank - First Mode
- Andrew Horchler - Astrobotic
- Mark Johnson - Lockheed Martin
- Brett Kennedy - JPL
- Laura Kerber - JPL
- Rob Manning - JPL
- David Masten - Masten Space Systems
- Larry Matthies - JPL
- Michelle Munk - NASA Langley Research Center
- David Murrow - Lockheed Martin
- Paul Niles - NASA Johnson Space Center
- Mark Panning - JPL
- Zachary (Zach) Putnam - University of Illinois
- Eva Scheller - Caltech
- Rachel Sheppard - JPL
- Nathan Stein - Caltech
- Skylar Wei - Caltech
- Ryan Woolley - JPL
- Paul Wooster - SpaceX

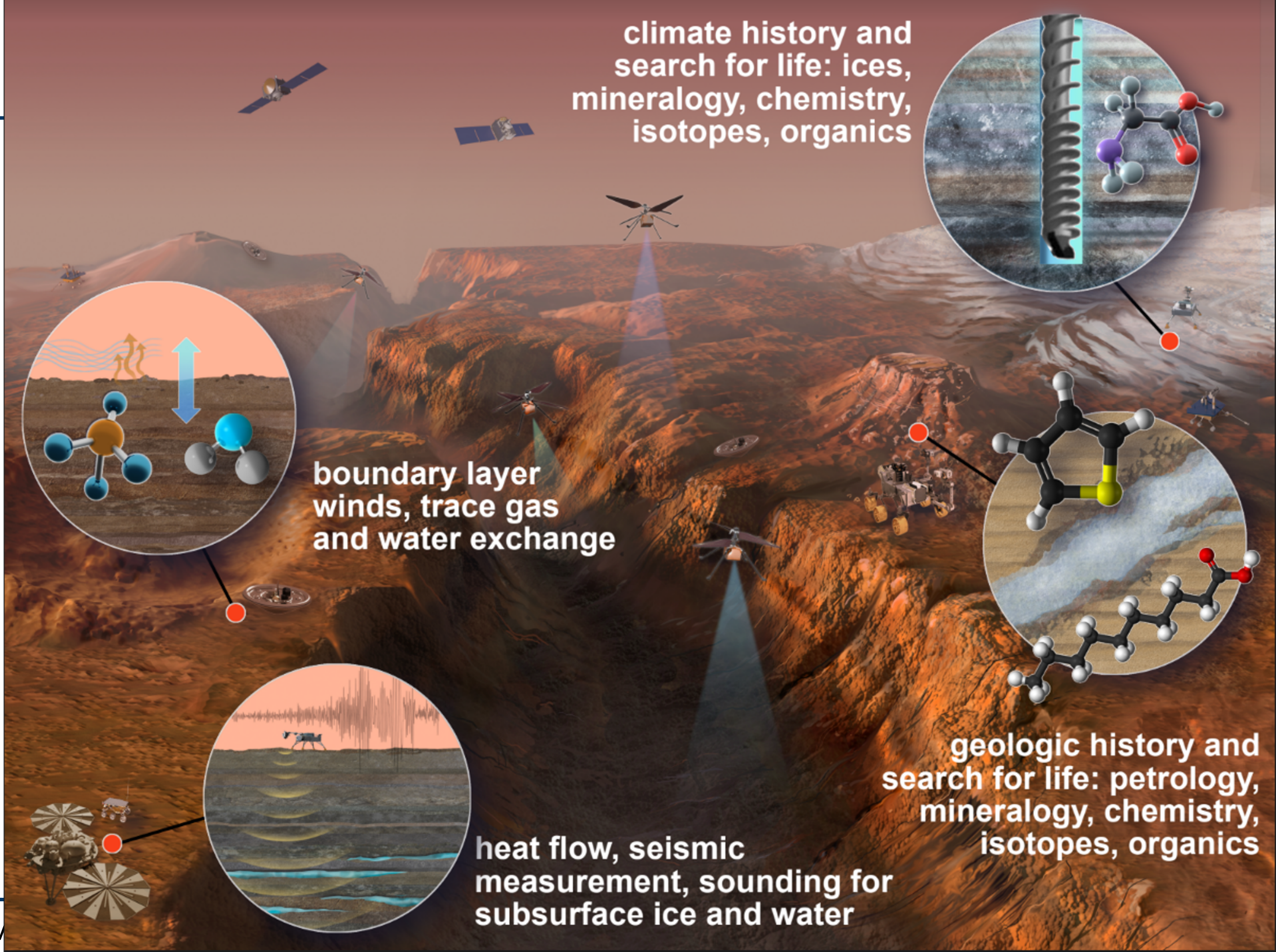
KISS Revolutionizing Access to Mars Wkshp1 Team Photo

Bethany Ehlmann

California Institute of Technology

Identified Priority Science **Requiring** Surface Access

- Traced to MEPAG goals
- IDed shared system-level requirements



Identified Shared Mission Types for Landed Science

- **Key: different types of science share systems-level requirements**
- **Realization that in a programmatic, multi-mission approach, one could leverage this for cost reduction**
  - Standardizing to a few (~5) mission types
  - Standardizing payload interfaces
- Expected to enable a diversity of instrument payloads without the need of a unique design for each platform

Mission Science Objective	Lander	Lander Network	Aerial Mobility	Rover mobility	Large Landed Mass
Surface-atmosphere boundary layer interactions (incl. trace gases)	X	X	X	X	X
Geophysics (subsurface ice/water, seismology, magnetism)		X	X	X	X
Polar layered deposit climate record			X	X	X
Geology for ancient habitable environments, environmental change			X	X	X
Geochronology for Martian and solar system chronology				X	X
Life/organics detection in Martian ice, deep subsurface				X	X
Mid-latitude ice sampling for characterization					X

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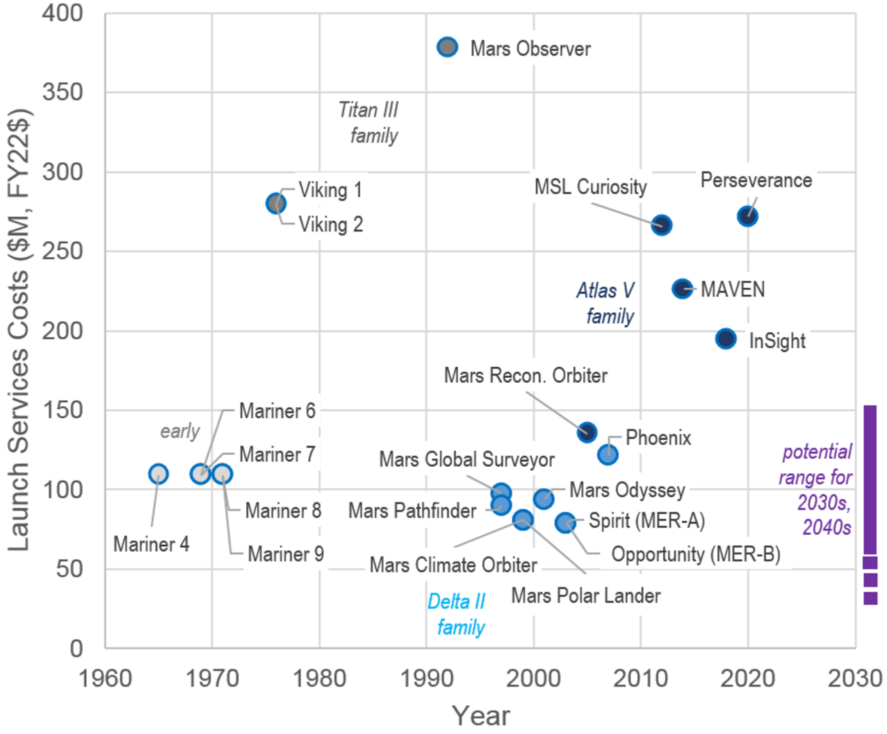
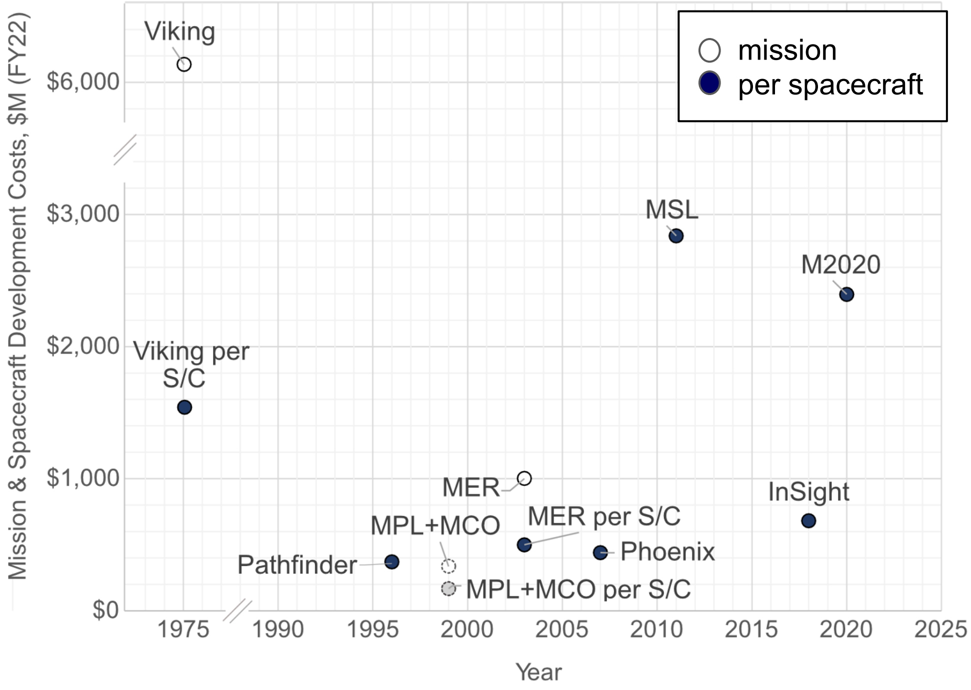
The Challenge - Cost per landed mission

Historical Launch Services Costs



Historical Development Costs for Landed Mars Missions

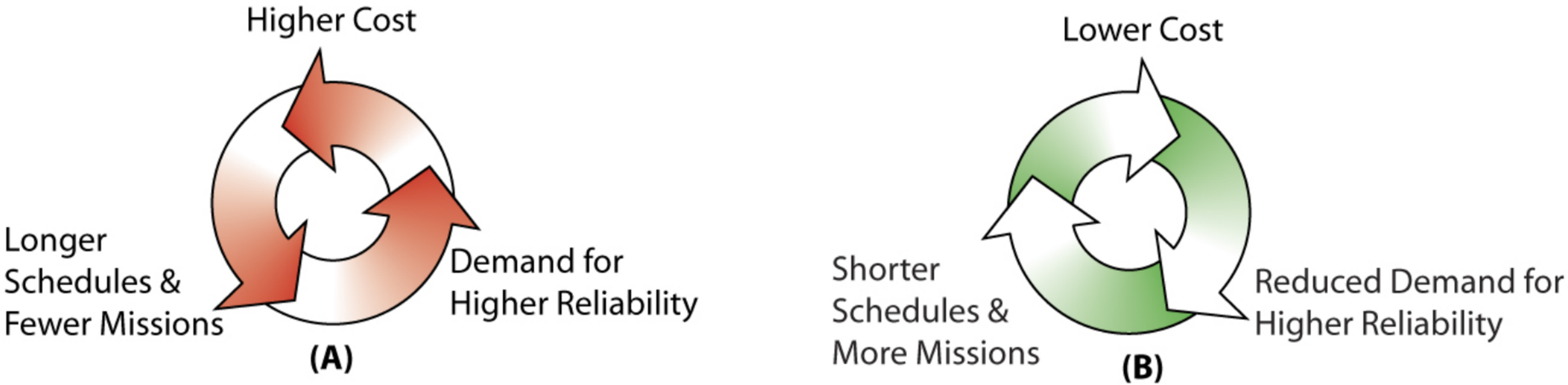


compiled from Planetary Society database https://www.planetary.org/space-policy/planetary-exploration-budget-dataset

Elizabeth Frank

First Mode

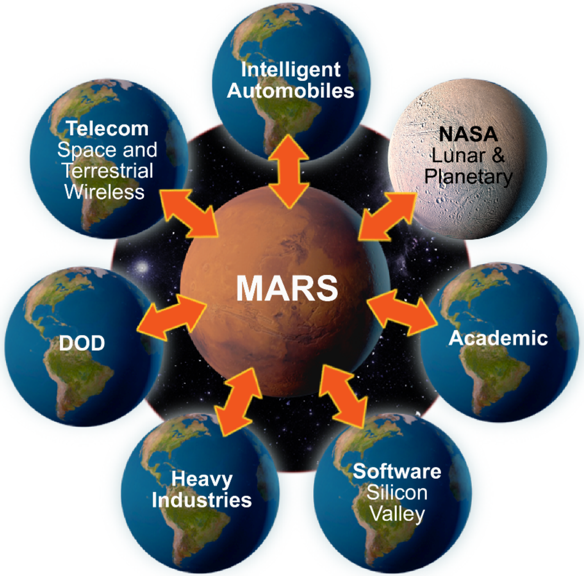
Avoiding the Space Spiral



after Wertz et al., 2011

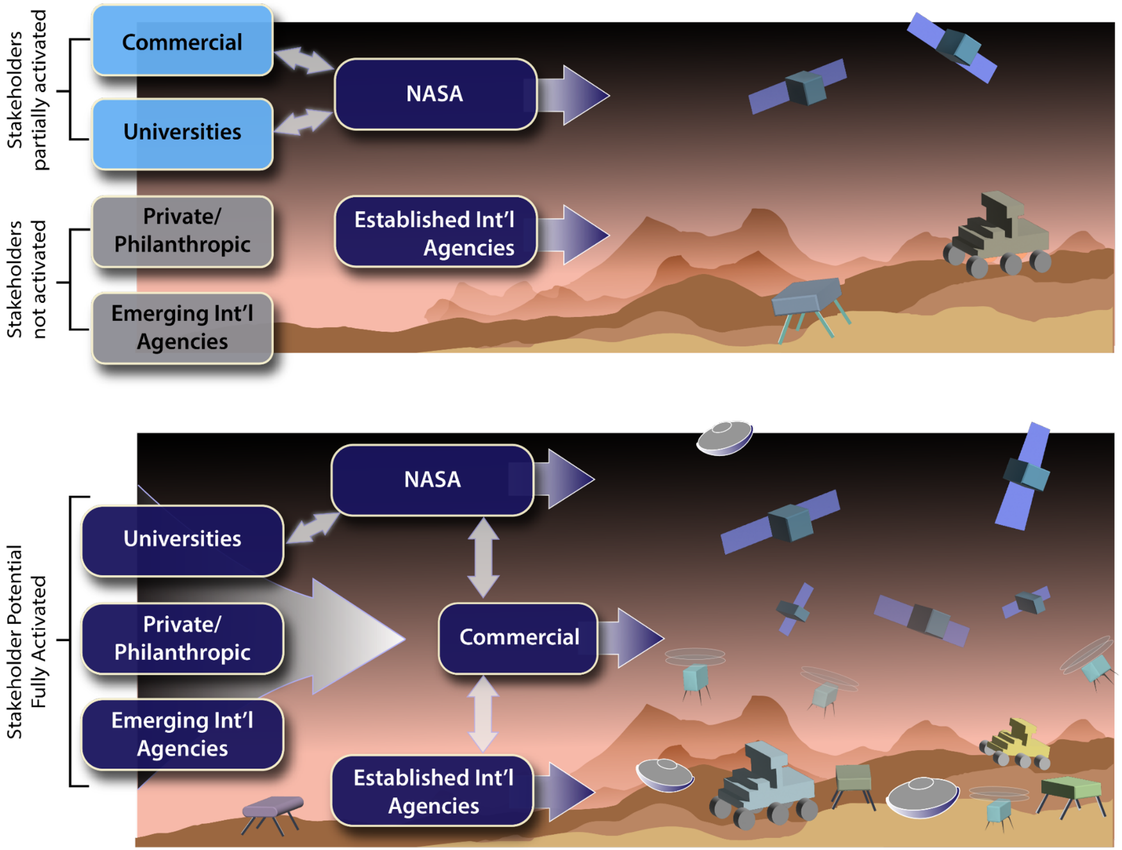
Elements of the Solution

- **We are at a natural juncture to leverage innovation in the space and technology sectors to enable a program of Mars surface access that grows the U.S. commercial space sector**
  - **Lessons from commercial cargo, commercial crew, CLPS**
- Reduce launch costs (piggyback, rideshare, new LVs) to save $10s-$100M/mission
  - Also emerging potential for lower launch cost at high mass (e.g., Starship)
- Seeking reductions in labor that dominate current mission costs
  - e.g., simplicity, standardization, reuse, modularity/automation in testing, multi-/simultaneous builds
- Thinking across multiple missions, types of spacecraft, and target bodies can
  - maximize benefit for technology and cost by reducing non-recurring engineering and using parts common across missions
  - adopting a program-level risk posture



Incentivizing Partnerships

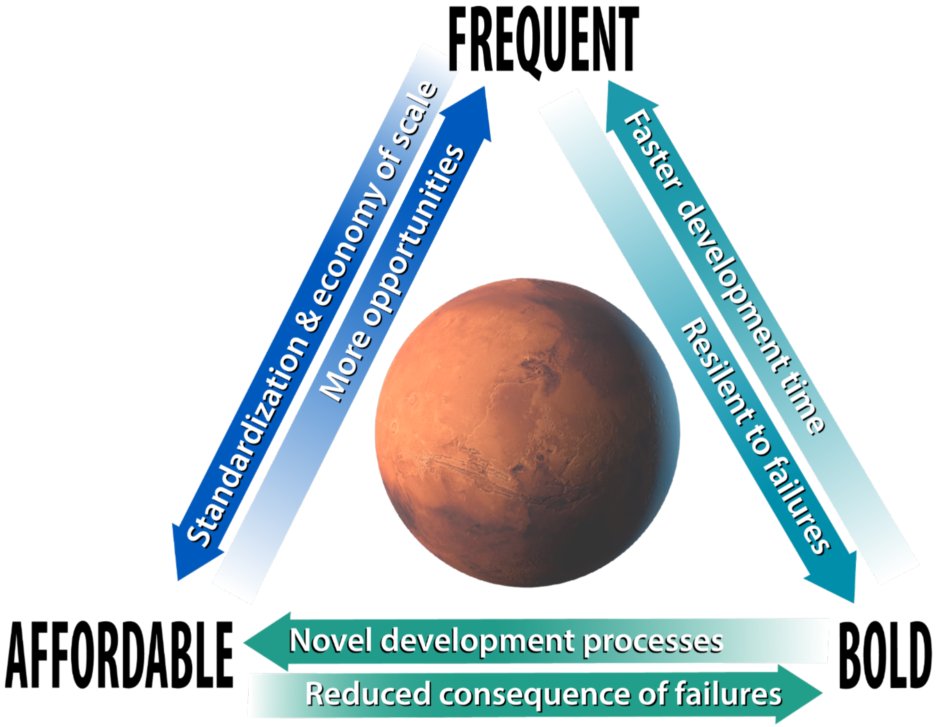
- **Changing role of commercial spacecraft builders to a services model can activate more stakeholders**
- Opportunity to enable additional partners who have motivations in addition to science objectives (teaching/research curriculum, prestige, workforce/tech development) but budgets smaller than those of large national space agencies
- Recognize NASA's unique role in creating opportunity but resist the desire to control all aspects of the missions



Chris Culbert

NASA Johnson Space Center

Key Elements of the FAB Mars Exploration Strategy



- **<u>Frequent</u>:** Two missions to Mars at every opportunity
- **<u>Affordable</u>:** Initial focus on low cost, smaller missions that can fit in a moderate extension to MSR budget.
- Take advantage of emerging commercial capabilities and interests, international partners
- **<u>Bold</u>:** Be aggressive defining mission timelines, goals, capabilities, and budgets
- Balance mission cost, complexity, pace, and risk in a measured manner programmatically that relies upon multiple frequent missions to achieve goals rather than risk-averse posture

Near-Term Programmatic Steps

1. Identify where early science mission activities align with commercial interests while also supporting the longer term goals of FAB.
2. Start a process to identify the technical capabilities that might be readily available commercially for near-term Mars missions and those that might be available in the mid-term with modest investment.
3. Fund an instrument development/adaptation track to align instruments with near-term science mission activities/technical capabilities
4. Fund a number of short term study/analysis activities partnered with commercial companies to more deeply assess feasibility of the commercial concepts and relevance to program needs, including consulting technical support from NASA.
5. Work with entities such as MEPAG to develop a science roadmap and landing sites list
6. Create agreements (contracts, grants, Space Act Agreements, cooperative agreements, etc.) for partnering with one or more entities to develop, deliver, or provide services for FAB activities.

Missions Programmatic Plan

- FAB at $100-150M/yr during MSR and $250-350M/yr after fits within a robust Mars Exploration Program (~$500-600M/yr) framework
- FAB Missions start from a "minimum viable product" (e.g., small hard landers, comm+science sats), and evolve desired capabilities in new risk environment (SSc: $150M)
- Investments in commercial technology "close the gap" to enable mobility, soft landing, and higher mass after several years (SSc+ $250M; Discovery+secondary $825M).
- Funding must be consistent and committed over a set number of years; the program should be renewable beyond that timeframe, based on overall program performance.
  - An annual budget of $250-350M per year is in line with the CLPS Lunar plan)
  - Progress can commence at a lower level even during sample return.
  - The 2x/opportunity competed FAB-style missions do not preclude traditional flagship and higher class directed missions, also within MEP