Achievable Human Exploration of Mars

Highlights from The Fourth Community Workshop (AM IV)

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Senior Editors

Future In-Space Operations Seminar

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Why *Community Affording, Achieving, and Sustaining Human Exploration of Mars* workshops?

About a half decade ago, several professionals working mainly in industry on scenarios for initial human exploration of Mars together recognized that, under generally similar assumptions, there was a fair degree of similarity among these scenarios.

Moreover, opportunities should be sought for greater community input into NASA's own scenario-building for the future of human space flight.

A series of focused community workshops were considered to be effective to assess these scenarios and involve more directly the science community, including planetary protection, with industry.

Four workshops to date each involve about sixty professional scientists, engineers, technologists, and strategists from NASA, academia, aerospace corporations, the National Academies, consulting organizations, and potential international partners.

Each workshop produced a series of presentations and reports briefed to NASA leadership and other stakeholders and may be found at **http://www.exploremars.org/** [AM IV intended to be posted at end of March.]

AM IV MAJOR CONCLUSIONS (DRAFT v0.9)

The estimated length of time to retire the long poles strongly supports the view that a human mission **to the surface of Mars** could be accomplished in the in early to mid-2030s with sufficient funding. *That is, engineering and technology development are not the limiting factors.*

A human **orbital mission** to Mars does not require retiring as many long poles to be closed and could be attempted as early as 2026 or 2028. Such a mission could substantially inform subsequent missions.

Entry, descent, and landing systems were identified as the major long pole, requiring about 13+ years to retire, although are not a pre-requisite for orbital missions.

Robotic reconnaissance over the next two decades is an essential element of preparing for human missions, as well as a source of priority science discoveries.

The role of logistics support, supply nodes, refueling and aggregation needs to be studied in more detail and could be enabling of sustained human missions.

There are significant interdependencies among the two habitation modules (in-space transit and surface). The value of modularity needs to be assessed as a priority.

Surface power looks very promising with the advent of small nuclear fission reactors.

Operations with astronauts on the lunar surface were not identified as offering value to initial human missions to Mars.

Previous Three AM Community Workshops

AM I (December, 2013 at The George Washington University)

Community-based critical assessment of the claimed affordability of several non-NASA scenarios for initial human missions to Mars.

AM II (October, 2014 at The Keck Institute, Pasadena)

Community-based critical assessment of updated non-NASA scenarios for human exploration of Mars. Introduced scientists and priority science goals into scenarios.

AM III (December, 2015 at the Space Policy Institute, GWU)

Integration of priority science goals with increasingly detailed human space flight scenarios: modify science goals and/or elements of human exploration. Included planetary protection.

Achieving & Sustaining Human Mars Exploration

December 2016 at DoubleTree Hotel, Monrovia

With substantial critically reviewed work supporting the contention that initial human missions to Mars by the mid-2030s is affordable, our workshop turned toward assessing <u>achievability</u>:

What major goals (i.e., “long poles”) must be achieved – and how – before initial human missions?

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N.B.: Affiliations throughout this document are for identification purposes only. Findings and observations in this document are consensus and not intended to imply unanimity in all cases.

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Nine “Long Poles” Assessed at AM IV

- Mars System Reconnaissance (D. Beaty, C. Whetsel, *et alia*)
- Aggregation/Refueling/Resupply (R. Davis *et alia*)
- Transit Habitation and Laboratory (J. Baker *et alia*)
- Entry, Descent, and Landing (J. Cassady *et alia*)
- Surface Habitation and Laboratory (L. Hays, S. Hoffman, *et alia*)
- Surface Power (R. Zucker, L. Mason, *et alia*)
- Mars Ascent Vehicle (B. Drake, T. Polsgrove, *et alia*)
- Human Health/Biomedicine (P. Norsk, G. Scott, *et alia*)
- Sustainability (M. Craig *et alia*)

AM IV Ground Rules and Assumptions

- As presented and assessed at AM IV, there are a modest number of common elements among the handful of plausible scenarios for human Mars exploration.
- Early and focused technology investment, including precursors and demonstration missions, is essential for the timescale adopted here.
- Technical/engineering solutions exist for landing and long-duration operations on the martian surface.
- Partnerships (international, industrial, commercial, academic . . .) will be an essential component of human Mars exploration.
- Research and development will continue on ISS at least through the mid-2020s.
- SLS and Orion will be available during the time period considered here, so will not be assessed in depth in this workshop.
- The budgets for space agencies will be approximately flat at least for the next few years. Budget growth is possible in response to an international commitment to travel to Mars.

Content of Each “Long Pole” Assessment

Major elements of the “long pole” (for a long-stay surface mission) and key characteristics:

- Basic description: “sub-poles,” key technologies/capabilities
- Why this is a “long pole” and why does this need to be developed
- Why this is challenging and why this is achievable (with substantive reasons: e.g., high TRL/SOA, advanced SOA, few or no “miracles” required, scheduled demonstration or precursor activities)

Development plan(s) or options, if any, to make this achievable:
Milestones, investment strategy and priorities,

- Precursor and demonstration site(s), where is this being developed (US aerospace, NASA, academia, internationals)
- Time to close “long pole,” including “sub-poles” and related “long poles”
- Creative alternatives, if any, for accelerating closing

Are Lunar Surface Operations Necessary in Advance of Initial Human Missions to Mars?

Operations with astronauts on the lunar surface has been claimed to be a necessity (or highly desirable) in advance of initial human missions to the martian surface.

It seems plausible that professionals who have spent many years developing designs, architectures, and technologies for human exploration of Mars are in an excellent position to evaluate the value of lunar surface precursors or demonstration missions.

This topic was discussed at all four AM workshops in plenary, which consisted of ~150 professionals. These discussions did not assess the value of astronauts on the lunar surface for other purposes, such as scientific exploration, nor was the relative value of sustained human occupation of the Moon versus Mars discussed. Assessment at the AM workshops was focused <u>solely</u> on the assertion that lunar surface operations with astronauts were necessary in support of initial human missions to the Red Planet.

Although the participants at the workshops appreciated contrary opinions expressed by a small number of colleagues, the overwhelming consensus of each workshop was that there was no discernable value to human missions to Mars by preceding them with human missions to the lunar surface.

ABBREVIATED EXAMPLE

AM IV Long Pole 1. Mars System Reconnaissance in Advance of Astronaut Missions (I)

The Long Pole

Certain datasets are needed to guide architecture and engineering design of a long-stay mission to the Martian surface, which require reconnaissance activities *at Mars*, specifically: Ground truth for resources, surface mapping, and linkage to orbital data; knowledge of atmospheric dynamics; surface dust environment; health considerations (toxicity, extant biological potential); mapping of "special regions" for potential forward planetary protection/contamination concerns; demonstration of proof-of-concept hardware systems (e.g., ISRU production) in the relevant environment interacting with indigenous materials.

Major Elements of the Long Pole

- Biological, geochemical, and atmospheric reconnaissance to retire strategic knowledge gaps
- In-situ resource utilization, including
  - *Reconnaissance to determine where minimally acceptable resources are located and their attributes*
  - *Development of technology needed to use those resources*
- Reconnaissance to establish/optimize astronaut-enabled science program (now largely complete)
- Landing site selection

ABBREVIATED EXAMPLE

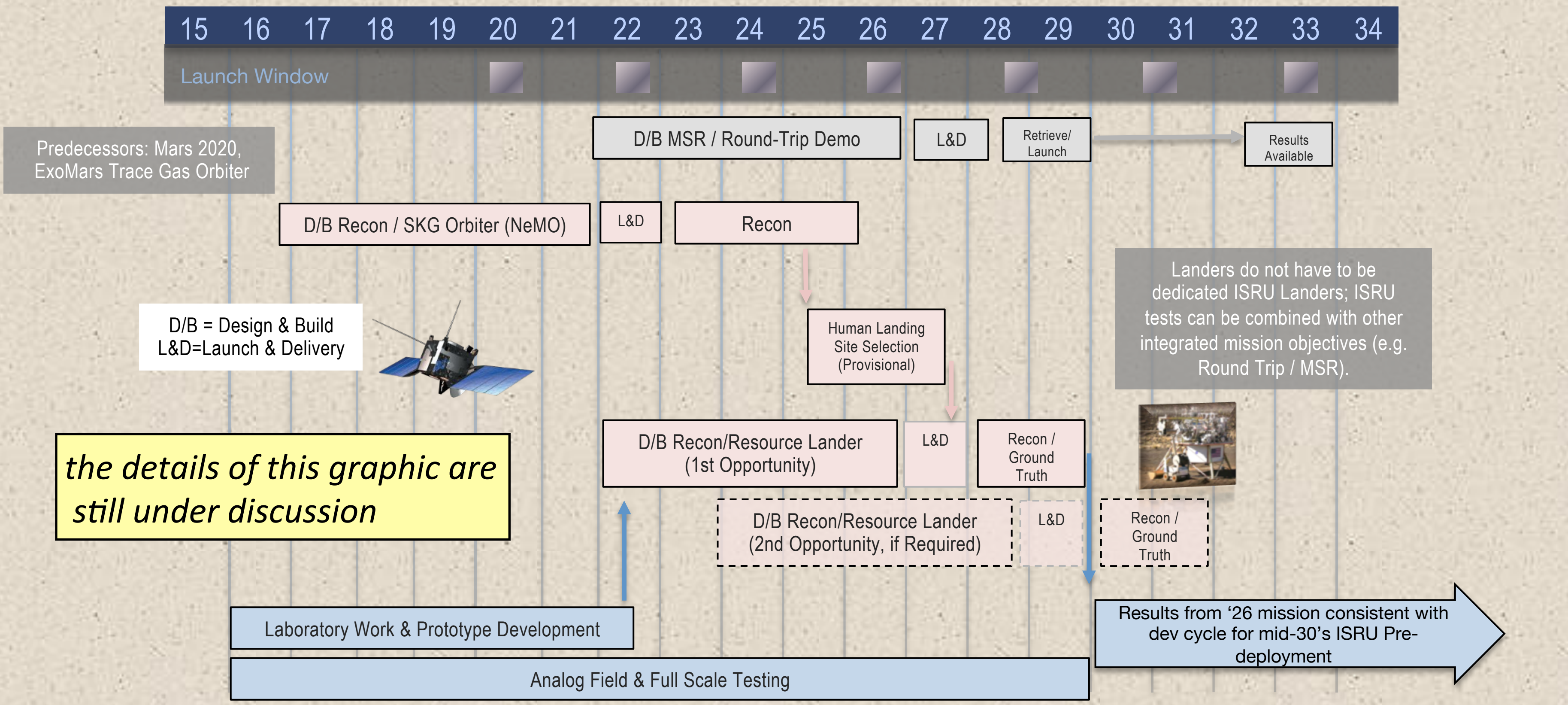
AM IV Long Pole 1. Mars System Reconnaissance in Advance of Astronaut Missions (II)

Primary challenge to closing long pole: Identify from orbit and characterize/demonstrate resource extraction feasibility from surface sites with adequate resource potential to support long-term sustained exploration operations.

Secondary challenges to closing long pole: (1) Demonstration of ISRU and off-Earth mining techniques and technologies. (2) Filling of other strategic knowledge gaps required to enable design of the crew landing and surface systems.

Time to close long pole: 10-12 years: 6-8 years for orbital asset to identify sites and 4-6 years for surface ground truth from robotic precursor from landing site. This assumes missions that enable analysis of returned samples, if needed (e.g. dust characteristics, toxicity, particle size distribution, etc.), occur in parallel over similar time frame.

Mars System Reconnaissance & Supporting Engineering Developments



Length of recon periods is dependent on amount of data to be collected, data processing capabilities onboard the spacecraft and/or lander, other users of Deep Space Network as well as relay transmission rates back to Earth. SAR and high resolution stereoscopic imaging are heavy data generators

ABBREVIATED EXAMPLE

AM IV Long Pole 4. Mars Entry, Descent, and Landing (EDL) (I)

The Long Pole

The EDL long pole for a crewed Mars mission is the selection, development, and qualification of an architecture capable of precisely landing payloads over an order of magnitude heavier than present capability allows that also fit within possible launch vehicle fairings. The first long-duration (~300 days) Mars human surface missions will require delivery of nearly all supplies necessary for survival. Total payload mass estimates are on the order of 80 t, which is not feasible to deliver in a single lander. Therefore, current concepts divide the total payload into four 20 t units that must be delivered in close proximity (~1 km) of one another with high precision (<50 m). Current technology can only land payloads of approximately one ton within a landing radius of approximately 20 km.

The Challenge

Simply scaling current designs to the larger masses required by human missions requires capsule diameters larger than those that can be accommodated by current or planned launch vehicles. Thus, effective atmospheric entry technologies that can be packaged into a more compact and efficient form are being explored. Similarly, present supersonic parachute technology is near its scale limit and cannot be extended to the deceleration of payloads in the mass range required for a human mission. Supersonic retro propulsion is the present descent mode of choice, but very limited Mars descent developmental analysis and test has been performed for this technology. The development and qualification of the EDL systems required for human Mars missions will take significant time to complete.

ABBREVIATED EXAMPLE

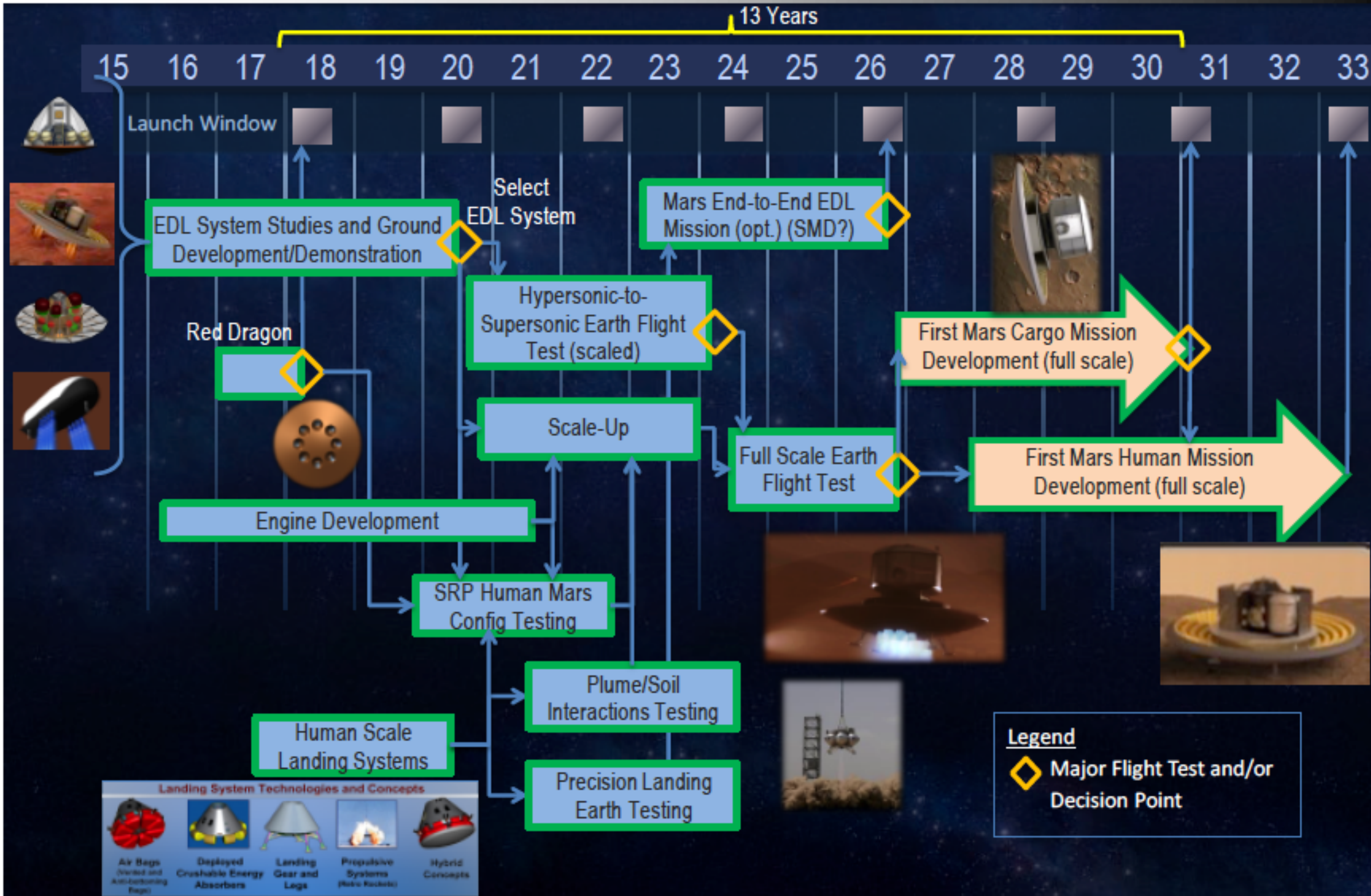
AM IV Long Pole 4. Mars Entry, Descent, and Landing (EDL) (II)

Statement of Achievability

Although EDL of human class missions for crew and cargo to the surface of Mars represents a significant tall pole to future Mars missions, the challenges can be mitigated with proper and timely decision making, planning, and funding. As can be seen in Figure 1, it was estimated that approximately 13 years is required to have landed a human class cargo mission on Mars. The challenge of landing human-scale payload masses on the Martian surface is daunting. Many of the configurations being considered offer key trade-offs in terms of reducing risk, mass, cost and schedule. The key to achieving human scale EDL is making early architecture decisions to narrow the trade space and proceeding down the path of design solutions and testing to verify these solutions.

DEVELOPMENT PLAN ON FOLLOWING PAGE

Getting Humans on Mars by the mid 2030's (Fast Track)



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