White Paper Topic 1-slide Lightning Talks

Human Resources // New Technologies and Mission Types

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11:32 AM	27	Mars Science Helicopter: Compelling Science Enabled by an Aerial Platform	Jonathan Bapst	02:32 PM
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11:56 AM	35	Pterodactyl: Non-propulsive Control System Designs for Future Planetary Missions	Sarah D'Souza	02:56 PM
11:58 AM	36	TPS and Entry System Technologies for Future Mars and Titan Exploration	Robin Beck	02:58 PM
12:00 PM	37	User-focused Data Catalogs Enhance the Value of Planetary Missions	Shoshanna Cole	03:00 PM
12:02 PM		Discussion - e.g., thoughts on these topics? what's missing?		03:02 PM

These slides and 1-pagers for each of these concepts can be found at: https://mepag.jpl.nasa.gov/meetings.cfm?expand=m38

Expanding Mars Science Return in the MSR Era: The Need for, Capabilities of, and Challenges Associated with Small Mars Science Missions

POC: James M. Kaufman (james.m.kaufman@aero.org, W: 626-873-7704 C: 626-660-6577)

The Problem

- Implementation of MSR will use a large fraction of the MEP budget
- Other important science investigations will likely be delayed
- Analogy: Impact of JWST on other astrophysics missions for over a decade
- Need a low-cost alternative program to maintain a diverse Mars investigation science portfolio during the "MSR Era"

Potential Architectural Solutions

- Numerous low-cost *in situ* and remote architectures have been recently studied
  - *Miniature entry systems with novel EDL techniques (parawings, deployable/inflatable drag devices, hard landers, etc.)*
  - *Small orbiters/flybys (CubeSats, SmallSats)*
  - *Mobility systems (balloons, hoppers, mini-rovers, helicopters, other airborne systems)*
  - *Modular designs*

Enabled Science

- Have identified 11 separate investigations spanning all four MEPAG Goals that could be conducted using low-cost architectures (with many more easily envisioned). Examples include:
  - *Determining if time-varying methane signatures are biogenic or non-biogenic in nature*
  - *Search for water at RSLs, candidate human landing sites for ISRU, and other locations*
  - *Climate variations via PLDs*
  - *Dust storm generation, saltation, & electrostatics*

Challenges

- Limited launch opportunities, especially for co-manifested or ride-along missions
  - *Mars via SIMPLEx is not generally possible*
- Acceptance of novel, small, low-cost architectures
- Lack of alternate launch means, e.g, Rocket Lab
- Lack of technology maturation opportunities

➢ SMEX- to MIDEX-class small Mars mission program (using various launch methods) augmented with ROSES-funded, non-instrument technology maturation program

See the White Paper summary here for more details and author list (others welcome!)

Moving forward….. Expand the summary with more details into a full White Paper

Planetary Science Decadal Survey Whitepaper

Mars Science Helicopter

Compelling Science Enabled by an Aerial Platform

Jonathan Bapst, T. J. Parker, J. Balaram, T. Tzanetos, L. H. Matthies, C. D. Edwards, et al.
Jet Propulsion Laboratory, California Institute of Technology

Revolutionizing Mars Exploration with Rotorcraft

- Mars Helicopter Technology Demo aboard Perseverance Rover will demonstrate flight at Mars next year
- Dragonfly at Titan in 2030s

↳ **Rotorcraft enable science impossible from orbit and inaccessible to landers and rovers**

Rotorcraft-Enabled Exploration

MSH Vehicle Capabilities:

- **Range (2–10 km/sol)**
- **Extreme terrain access and traversability (cliffs, skylights, sand dunes)**
- **Atmosphere (1 km+ altitude)**
- **Payload Capability (1–5 kg)**

*Exact capabilities depend on vehicle and tradeoffs

Compelling Mars Science

High-priority questions and investigation resources:

↳**Community**

- **Planetary Science Decadal Survey**
- **MEPAG Goals**
- **JPL A-Team Study**

Hyperlinks

Seeking Co-Signatories! (Google Doc)
MSH MEPAG 1-Pager (MEPAG Site)
jonathan.bapst@jpl.nasa.gov (Email)

Emerging Capabilities for Mars Exploration

C. D. Edwards, Jr.[1], J. Baker[1], N. Barba[1], J. Balaram[1], J. Day[1], M.R. Grover[1], S. Hubbard[2], D. Lavery[3], L. Mandrake[1], L. Matthies[1], G. Meirion-Griffith[1], M. Munk[4], I. Nesnas[1], M. Ono[1], V. Stamenković[1], S. Townes[1], K. Zacny[5] *(Contact: chad.edwards@jpl.nasa.gov)*

[1]Jet Propulsion Laboratory, California Institute of Technology, [2]Stanford University, [3]NASA HQ, [4]NASA LaRC, [5]Honeybee Robotics

The paper will survey developments in a number of capability areas, including:

- *Entry, Descent, and Landing*
- *Surface & Aerial Mobility*
- *Subsurface Access*
- *Autonomy*
- *Avionics*
- *Communications & Navigation*
- *Power*
- *Propulsion*
- *Small Satellite Technologies*

For each capability area, we will address the following questions:

- *What is the current State-of-the-Art for operational Mars orbiters, landers, and rovers?*
- *What new capabilities are under development and targeted for infusion into currently planned Mars missions?*
- *What capability gaps remain to enable the next generation of Mars exploration, and what technology investments are needed in the coming decade to close these gaps?*

High Science Value Return of Small Spacecraft at Mars

N. Barba[1], A. Austin[1], D. Banfield[2], A. Chmielewski[1], P. Clark[1], R. Conversano[1], V. Cormarkovic[1], S. Diniega[1], C. Edwards[1], R. French[3], J. Fuller[4], M. Gallagher[1], L. Giersch[1], T. Komarek[1], R. Lillis[5], C. Loghry[6], S. Matousek[1], L. Montabone[7], P. Niles[8], C. Norton[9], W. Coogan[10], M. Shihabi[1], V. Stamenkovic[1], C. Swann[11], F. Tan[9], S. Vijendran[12], R. Woolley[1].

[1]Jet Propulsion Laboratory, California Institute of Technology, [2]Cornell University, [3]RocketLab USA, [4]Virgin Orbit, [5]UC Berkeley, [6]Moog Inc., [7]Space Science Institute, [8]NASA JSC, [9]NASA HQ, [10]Firelfly Aerospace, [11]US Naval Research Laboratory, [12]European Space Agency

Image: NASA/JPL/Caltech

Precise and Repeatable Science Measurement Capability

Low-Cost Mission Architecture

High Value Science Return

Drivers for High Science Value Missions at Mars

Science
- New Measurements
- Simultaneous Measurements
- Continuity Measurements
- Small Spacecraft Instruments

Implementation
- Ways to get to Mars
- Propulsion Options

Technology
- Telecommunications
- Propulsion
- Rad Tolerant components
- Small Landers

Applications & Concepts
- Science
- Resources
- Infrastructure

Policy & Programmatic
- NASA Rideshare Policy
- Cost and Risk Models
- Other

Low Cost Mission Architectures

POC: Nathan Barba, nbarba@jpl.nasa.gov

For more information, please see our 1-pager at https://mepag.jpl.nasa.gov/meetings.cfm?expand=m38

Discovery-class missions for Mars surface exploration

- Twenty five years of flagship-class missions in the Mars Exploration Program have matured Mars science to the point where we can answer critical science questions with smaller, focused missions
- MEP investment in the development of landers and rovers that fit under the Discovery cost cap will generate mission opportunities in the next decade in a stable, existing flight program

Michelle Minitti, minitti@me.com

MER-Class Rover Investigations of Mars in the Coming Decades

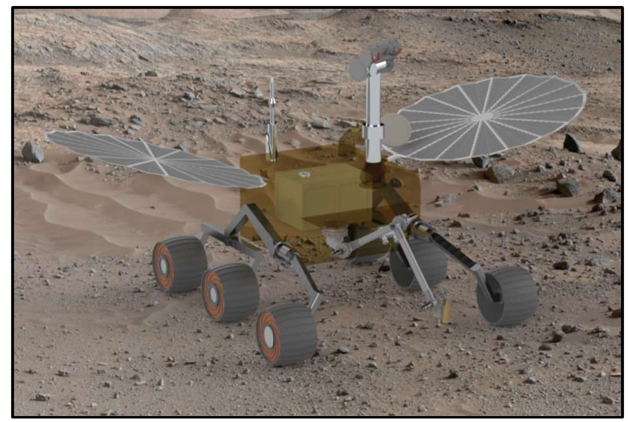
David Blake, Ames Research Center

- The landing sites for both MSL and Mars 2020 are ancient crater lakes.
- Dozens of geologically diverse & scientifically compelling landing sites were characterized during site selection workshops.
- In order to understand the geology of Mars, its early habitability and its potential to support ISRU and eventual human habitation, full and comprehensive science investigations are needed at many diverse sites.

20 years of instrument development & miniaturization now allow for Flagship-class instruments to be packaged in MER payloads

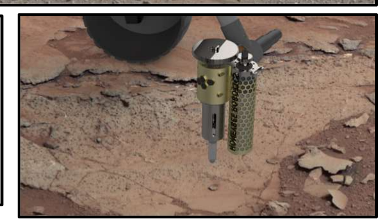
Example MER-class payload

- Mastcam, MAHLI, etc. for context
- Robotic arm with RAT, powdering drill and imaging X-ray spectrometer.
- XRD/XRF in the body of the rover to provide quantitative mineralogical analysis



Together, these instruments could fully capture the science capabilities of the MSL rover, with the exception of the SAM instrument.

A cookie-cutter approach to the development of a MER-class architecture suitable for multiple mission opportunities would reduce cost and risk. Only by accessing and fully characterizing multiple sites representing the full diversity of geologic and morphologic features on Mars will we be able to fully elucidate its early history and habitability potential.



Revolutionizing Access to the Martian Surface

Point of Contact: Paul Niles (paul.b.niles@nasa.gov); Abigail Fraeman (Abigail.a.fraeman@jpl.nasa.gov, 626-616-5071)

- Many of Mars' most pressing scientific questions can only be addressed on the surface
- This white paper will explore new cost-efficient approaches that could enable the cadence of multiple landed missions at Mars demanded by science
- Costs might be lowered by employing multiple craft builds which could also be beneficial to mitigating programmatic risk, allowing budgetary flexibility, reducing cost risks related to spacecraft operations, and shifting technology development efforts to scientific instrumentation.
- Innovations driven by the commercial sector may provide a mechanism for reducing per/mission cost of surface Mars missions.
- Working draft here

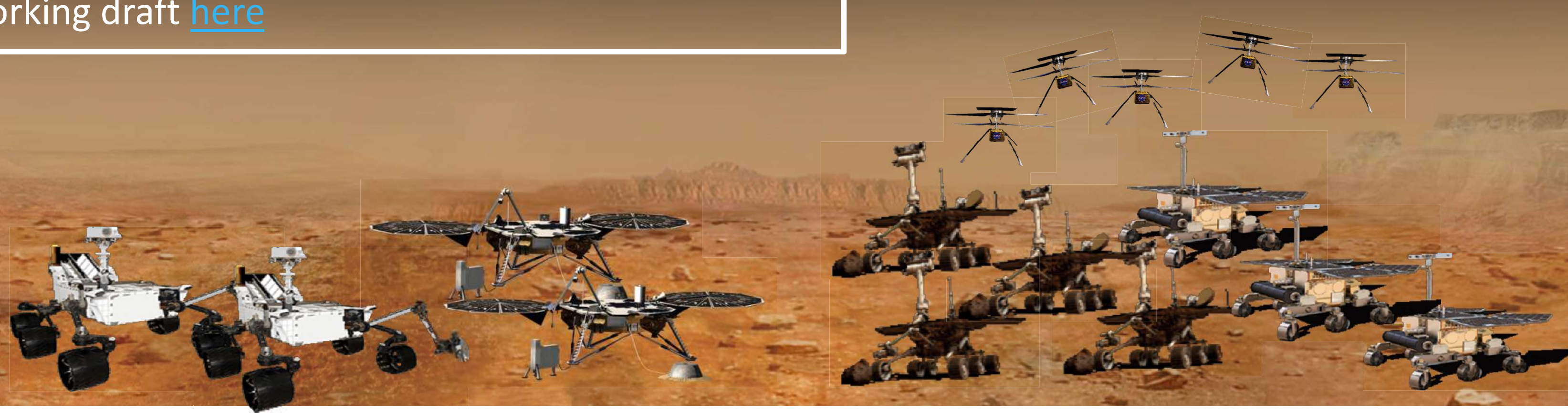
Upcoming Keck Institute for Space Studies workshop (delayed to Oct) with goals:

(1) ID important questions that require distributed measurements at the Martian surface, and what instruments/platforms/mobility are required to achieve them

(2) Conceive mission architecture to access surface and conduct efficient operations of multiple Mars assets

(3) Identify how/if emerging commercial lunar capabilities can be leveraged to break the mass-cost dependency for Mars surface missions.

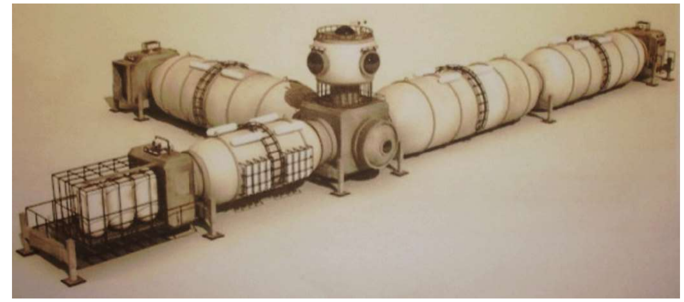
Workshop website here



https://mepag.jpl.nasa.gov/meeting/2020-04/whitetopics/WhitePaper_32_Fraeman.AccessSurface.pdf

Resources for Settlement

Survey for Resources to Build a Permanent Mars Settlement



Bruce Mackenzie, K. Lutz, M. Felch, N. Brackley
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Dialog between current scientific exploration & proponents for human exploration & settlement

Proposed white paper to identify:

Suggested **<u>in-situ construction materials</u>**
likely: polymers, cast basalt, basalt fiber, cement, concrete, sintered bricks, cements, plant nutrients, chemicals,

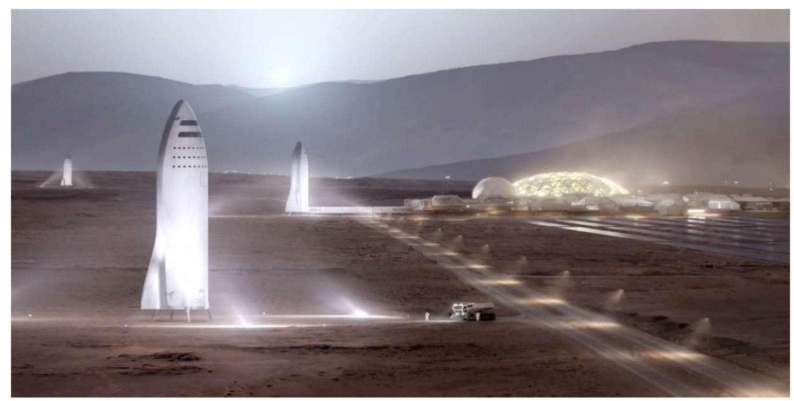
Likely technologies to **<u>excavate</u>** & separate:
regolith, dust, rock, minerals

Properties important for **<u>refine</u>** & **<u>manufacture equipment</u>**
ie: melting points, solubility, strength of cast basalt, etc.

Affects architectural designs

<u>Water</u> extraction, large scale, impurities, perchlorates, salts...

How to **<u>identify sites</u>** with wide range of resources from orbit.



Additional co-authors and specialty experts are welcome

(credits: Bryan Versteeg, Phil Smith, SpaceX)

Non-Propulsive Control Systems for Future Planetary Missions

POCs: Dr. Sarah D'Souza (sarah.n.dsouza@nasa.gov) & Antonella Alunni (antonella.i.alunni@nasa.gov), NASA ARC

Imagine returning preserved core samples from Mars' polar regions or delivering instruments that were once too expensive to protect against design entry loads

Advantages of Non-Propulsive Control System Designs

1. Maintain entry deceleration & thermal loads low enough for sensitive payload handling
2. Provide feasible integrated SW & HW solutions to achieve precision targeting
3. Yield propellant mass savings from use of non-propulsive control systems

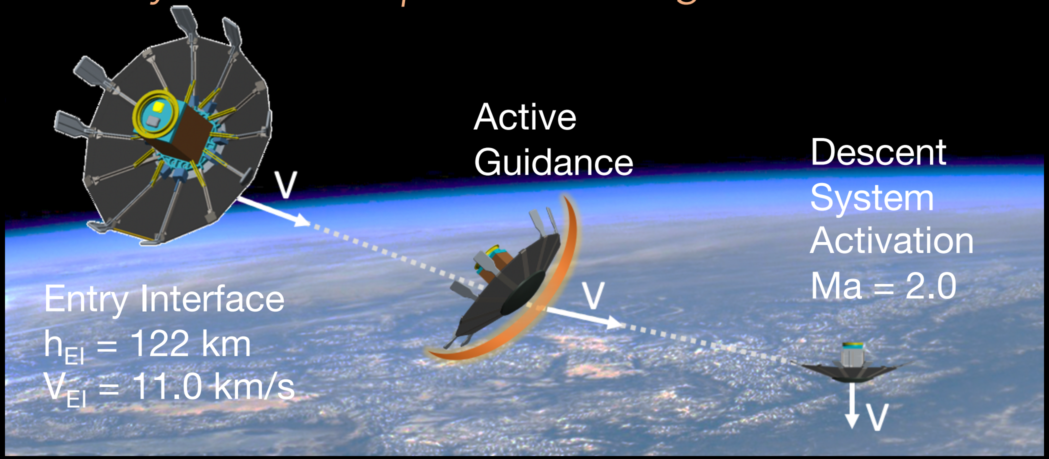
Pterodactyl's lunar sample return design reference mission:

Deployed Entry Vehicle

Diameter: 1.0 m

(fits ABC of Atlas V when stowed)

Payload: 2U, 1 kg



Peak g-load: 6.2 g

Peak heat rate: 211 W/cm²

Miss distance: 0.64 km

Continued investments in non-propulsive control systems can advance EDL technologies that are expected for future planetary science missions

Please refer to our MEPAG 1-pager for more information, see our form for co-signer support, and contact POCs for co-author support

Entry Systems and Technology Division

TPS and Entry System Technologies for Future Mars and Titan Exploration

National Aeronautics and Space Administration
Ames Research Center

- **POC**: Robin Beck robin.a.beck@nasa.gov and Milad Mahzari, milad.mahzari@nasa.gov
- **Current author list**: Robin Beck, Milad Mahzari, Helen Hwang, Mairead Stackpoole, Ethiraj Venkatapathy, Alan Cassell, Cooper Snapp
- **Overall message**: NASA has overcome past failures for nearly 20 years delivering science oriented payloads to the surface of Mars. We have demonstrated the capability of landing nearly a metric ton and have the TPS and entry technology to continue. The same or similar technology is expected to be successful for Mars2020 and at Titan for Dragonfly. We will, however, need to develop better, more easily processed TPS for the larger payloads that will be required for human exploration.
- **Collaboration desired**: requesting status on the development and current TRL of improved (higher strain-to-failure, scalable to larger sizes, easier process and manufacturing, etc) TPS. In addition, we are looking for additional reviewers and cosigners for the final paper

User-focused Data Catalogs to Enhance the Long-term Results of Planetary Missions

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shoshe@astro.cornell.edu

Interested in being a co-author or signatory? Please fill out this form:
https://forms.gle/1fghgyC6YQwjVgDN9

A user-focused data catalog:

- Makes data easily accessible to people who aren't involved in the mission
- Preserves the team's corporate knowledge
- Enables contemporary and future non-team researchers to analyze mission data

We propose that this should be a standard product for planetary missions.

For more information, please see
https://mepag.jpl.nasa.gov/meeting/2020-04/whitetopics/WhitePaper_37_Cole.UserFocusedData.pdf

LPSC abstract and poster:
Identifying Community Needs for a MER Data Catalog
https://www.hou.usra.edu/meetings/lpsc2020/pdf/1709.pdf
https://www.hou.usra.edu/meetings/lpsc2020/eposter/1709.pdf

MER Data Catalog user survey: http://www.merdatacatalog.com/survey

The survey should take approximately 5-10 minutes to complete. No identifying information is collected, and all data will be presented in aggregate. Conducting a survey constitutes experimenting on humans; this survey has received approval from the Cornell University Institutional Review Board (IRB) Office.