"Big Questions" in Planetary Science
MEPAG submitted to NASA PSD
August 15, 2019

Included here: **(1)** Request from MEPAG Chair Aileen Yingst, including PSD Director Lori Glaze's original request, **(2)** Cover letter for submitted MEPAG response, **(3)** the submitted MEPAG response. This document is posted at https://mepag.jpl.nasa.gov/meetings.cfm?expand=m37.

1)
Email sent to MEPAG list, Wednesday, July 31, 2019
Subject: *Action items from MEPAG 37: "Big questions" and initial comments on MEPAG Goals document*

MEPAG community,

This is a reminder about 2 requests for input, from the recent MEPAG Meeting 37.

(1) **Suggestions for "big questions" are due to** MEPAGMeetingQs@jpl.nasa.gov **at the end of this week (August 2).** This is in response to the original request to the Analysis/Assessment Groups (AGs) from Dr. Lori Glaze from July 16, 2019 (appended below). Once we have all responses the Executive Committee will summarize the ideas to a tractable number (3 to 5, similar to the number of panels on past Decadal Surveys).

Note that Dr. Glaze responded to our question regarding whether she was interested in "big picture" questions from the other AGs, or questions specific to each AG. The answer is: Questions are desired that *encompass* the top issues in the other AGs' Goals documents (and MEPAG's). This covers the other question that came up as well, i.e., how specific should each "Big Question" be? Thus, as Wendy Calvin pointed out during the meeting, HQ is most interested in questions on the level of "How do you create a habitable planet?" or "How do atmospheres work?" rather than "How does variable X feed into habitability?"

[Second input request was related to a request for Goals comments]

Original request from Lori, regarding item #1, above:

As we heard yesterday there is movement within the community to consider an alternative approach to the decadal panel structure. The idea posed yesterday by Ellen Stofan et al., is to organize the survey around ~6 or so "big science questions". It was also suggested that engaging the AGs is a way to see if the science questions Ellen et al. came up with encompass those thought to be of high priority by the community.

I would like to engage the community to give them a chance to comment.

To this end, I am asking each AG's executive secretary to send a note to their analysis group to request:

1) what are highest priority questions for your community (hopefully this is an easy one!! But ask them to think big), and

2) what do they perceive as the highest priority questions for each of the other AGs (CAPTEM, LEAG, MAPSIT, MEPAG, [Mercury?], OPAG, SBAG, and VEXAG)?

The second question should be seen as a "fun" exercise to see how well we do at understanding the needs of the broader planetary science community!

Please let your community know that we are using this informational response in assessing how we would like to configure our decadal survey statement of task.
Thank you.

Dr. Lori S. Glaze
Director, Planetary Science Division
NASA
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2)
Email sent from MEPAG Chair R.A. Yingst to PSD Director L. Glaze, Thursday, August 15, 2019
Subject: *Response to overarching "Big Questions"*

DATE: 15 August 2019
TO: Dr. Lori Glaze, *Director, Planetary Sciences Division (PSD)*
FROM: Dr. R. Aileen Yingst, *Chair, Mars Exploration Program Analysis Group (MEPAG)*
SUBJECT: BIG QUESTIONS

Please find below a list of the "Big Questions" that you requested the AGs help frame, with the idea that such questions might drive the planetary community's science over the next ten years and which therefore might serve to guide the organization and structure of the upcoming Planetary Decadal Survey.

The Mars community naturally looked to its prior studies and its goals document as starting points. However, MEPAG was also able to take advantage of recent discussions at the 9th International Conference on Mars and the following 37th MEPAG Face-to-Face meeting (thank you for your participation!) to get a fresh look at this. Essentially all the questions submitted during and after the MEPAG meeting were combined, summarized or reworked by the MEPAG Executive Committee to get them down to a high-level, manageable set.

Five overarching "Big Questions" emerged:

- **What are the pathways that lead to habitable environments across the Solar System and the origin and evolution of life?**
- **How do climates and atmospheres change through time?**
- **How do planetary surfaces, crusts and interiors form and evolve?**
- **What is needed for humans to explore on the Moon and Mars?**
- **How is the solar system representative of planetary systems in general?**

While the above "Big Questions" are phrased as Solar System questions, we believe that they are also essentially the "Big Questions" for Mars:

- **Did Mars ever support life?**
- **What are the processes and history of climate on Mars?**

- **What was the origin and evolution of Mars as a geological system?**
- **How do we prepare for human exploration on Mars?**
- **What does Mars have to tell us about the origins of planetary systems and might Mars-like bodies occur in the habitable zones around other stars?**

The first four Big Questions reflect the prime goals of Mars Exploration (Life, Climate, Geology/Geophysics, Preparation for Humans), as articulated in the *MEPAG Science Goals, Objectives, Investigations, and Priorities* document. The fifth overarching question has come to the fore in Mars studies, as for other planets, as observations of exoplanets have challenged our understanding of planetary system origins and early evolution. Answering all these questions for Mars will go a long way to helping answer the overarching questions for the Solar System.

We organized the rest of the questions that we received as sub-bullets under the five overarching Big Questions above and these are included in the attachment. We included this more specific material to give you a feel for the wealth and range of planetary science yet to be done. Finally, in considering what the other AGs might suggest as Big Questions, the answers seemed to be narrower forms of the bigger questions, and are reflected in the sub-bullets.

Let us know if you have questions about these "Big Questions".

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Dr. R. Aileen Yingst
Senior Scientist
Planetary Science Institute

3)
Document attached to the above email (2):

Potential overarching science questions related to solar system exploration ("Big Questions")

Input as requested by Dr. Lori Glaze for the next Decadal Survey

*Overarching questions are in **bold**. Sub-bullets provide specific examples of supporting questions; italics indicate possible rephrasing of (part of) the overarching question.*

• What are the pathways that lead to habitable environments across the Solar System and the origin and evolution of life?

- Does extraterrestrial life exist or has it existed in the Solar System?
- If life has developed elsewhere, where is it and why, what are its characteristics, and how do we detect and confirm its presence?
- If life is not found elsewhere: Why not? (Specifically, are there features of the environment or chemical evolution of that Solar System body that limited biological potential, or is the lack of detection due to our limits to detect it?)
- How have water and the availability of habitable/inhabited environments on and within planets changed with time?

- What are the environments and environmental gradients (pH, water activity, energy, nutrients, key elements) relevant to habitability and how do they vary across the solar system and link to the evolution of the molecular building blocks of life?
- What is the liquid water inventory of the interiors of solar system planetary objects?
- How do asteroids and comets play into habitability?

• How do climates and atmospheres change through time?

- *How do atmospheres develop and what drives their composition and dynamics?*
- How do magnetic fields influence the surface, the atmosphere and the near-space of planetary bodies?
- How do solar system objects interact with their space environment (and what are the consequences)?
- What is the evidence and what are the drivers for geologically recent climate change?
- What are the causes, effects, and roles in atmospheric evolution of planetary-scale extreme weather events, such as Martian dust storms, Saturn's Great White Spots, Titan's polar cloud bursts, and similar phenomena occasionally observed on Uranus?

How do planetary surfaces, crusts and interiors form and evolve?

- *What was the timing of early solar system processes, including accretion, impacts, and dynamical evolution?*
- What are the limits of planetary body size and other factors necessary for forming and preserving anorthositic crust from an early magma ocean, as definitely occurred on the Moon and controversially occurred on Mercury, Mars, and elsewhere?
- How do planets lose their heat?
- How old are planetary surfaces? Where in the Solar System is the early geological record preserved and what are the process that have led to that record?
- How do ocean worlds form and evolve: Not just icy moons, but what was the early inventory of water on Earth, Mars (with a possible ancient ocean), and Venus?
- What are the fundamental physical processes and rates of surface-atmosphere exchange (of material and volatiles) on planetary bodies?

• What is needed for humans to explore on the Moon and Mars?

- What knowledge of the Moon or Mars is needed to design and implement human missions to their vicinity or surface with acceptable cost, risk, and performance?
- What knowledge of the Moon or Mars is needed to design and implement *sustained* human presence on these bodies with acceptable cost, risk, and performance?
- Is a dynamic atmosphere predictable?
- How do humans change planetary environments over time?

How is the solar system representative of planetary systems in general?

- How can our solar system help us understand exoplanetary systems (Gas & Ice Giants, Terrestrial Planets, satellites, and small bodies?)
- How can the search for life in the Solar System inform the search for habitability and evidence of life elsewhere in the universe?
- What are the implications of other planetary system geometries for the origin and evolution of our own Solar System?