NASA Planetary Science Vision 2050

Steve Mackwell, Doris Daou, Jim Green
and the PSV 2050 Team

EPSC – Sept. 20, 2017

Charge to the Committee

This Planetary Science Vision (PSV) 2050 Workshop will:

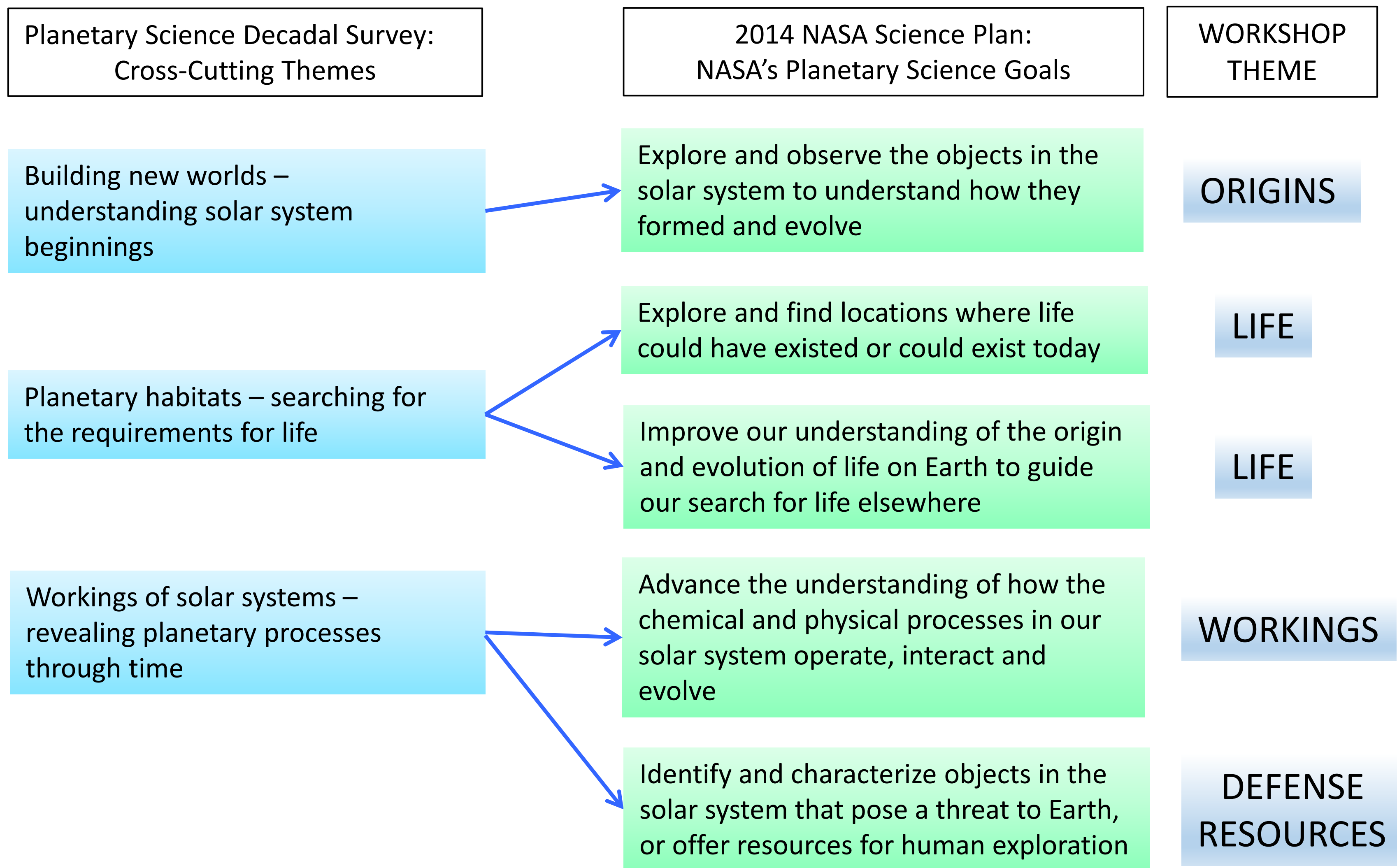
- present a compelling, 34-year science vision within the frame work of the future decades (2020s, 2030s, and 2040s);
- build from the Planetary Science decadal survey (Vision and Voyages 2013-2022);
- be science based, with notional technologies and missions;
- take into account community input through the workshop (papers, posters, presentations);
- prepare a Vision 2050 Report summarizing the workshop results;
- deliver report to NASA's Planetary Science Division Director.

The PSV 2050 report should:

- have a compelling, over-arching planetary science theme for each decade as the next phase in Solar System Exploration;
- contain one or multiple paths forward (science areas and technologies needed) towards a long-range vision;
- consider cross-cutting opportunities with other disciplines as well as the larger context of international planetary science and human exploration;
- be built on science investigations goals, leading to notional missions that achieve the science as appropriate;
- consider the technology needed to achieve specific goals;
- identify challenges (e.g. measurement challenges, technology challenges….) that will need early investment to become viable.

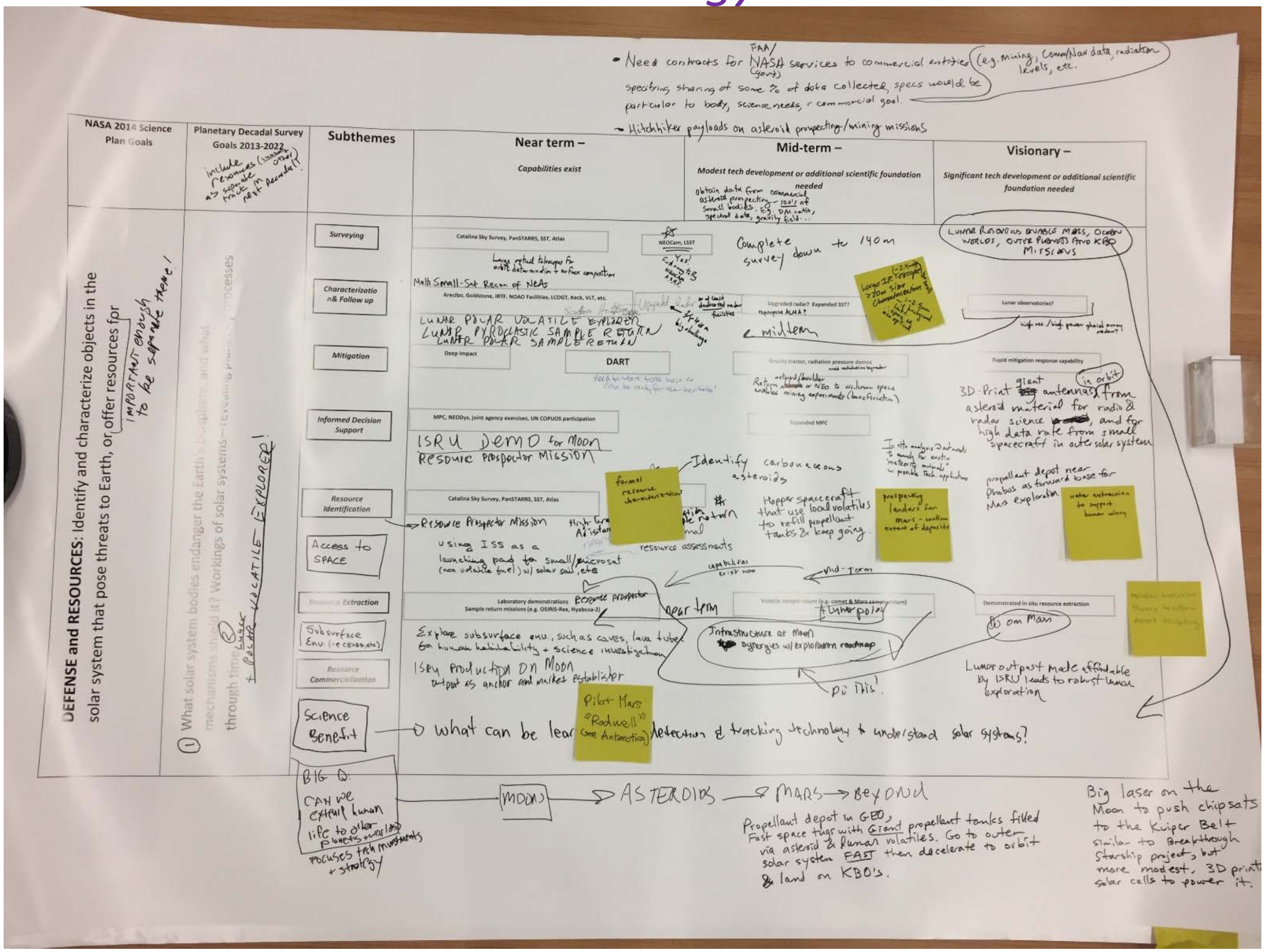
Workshop Themes

- **ORIGINS** — understanding formation and evolution of solar systems (including exoplanetary systems)
- **WORKINGS** — understanding how the processes in our solar system operate, interact, and evolve
- **LIFE** — improve our understanding of the origin & evolution of life, including Earth analogs, to guide our search for life elsewhere
- **DEFENSE AND RESOURCES** — identify and characterize objects that pose threats to Earth or offer resources for human exploration
- **POLICIES, PATHWAYS, TECHNIQUES and CAPABILITIES** — other thoughts about where we might be in three decades that are not captured above (e.g., terraforming)


Planetary Science Decadal Survey: Cross-Cutting Themes
2014 NASA Science Plan: NASA's Planetary Science Goals
WORKSHOP THEME
Building new worlds – understanding solar system beginnings
Explore and observe the objects in the solar system to understand how they formed and evolve
ORIGINS
Explore and find locations where life could have existed or could exist today
LIFE
Planetary habitats – searching for the requirements for life
Improve our understanding of the origin and evolution of life on Earth to guide our search for life elsewhere
LIFE
Workings of solar systems – revealing planetary processes through time
Advance the understanding of how the chemical and physical processes in our solar system operate, interact and evolve
WORKINGS
Identify and characterize objects in the solar system that pose a threat to Earth, or offer resources for human exploration
DEFENSE
RESOURCES

Thematic Posters

for Origins, Life, Workings, Defense and Resources, Policies, Pathways, Techniques and Capabilities, and Overarching Technology



Report- What We Heard

The following fundamental questions seem to have come up again and again:

- Where do we come from? (Life, Origins)
- Are we alone? (Life, Origins)
- Are we unusual? (Life, Origins, Workings)
- Where are we going? (Defense & Resources, Workings)

Also we identified 2 cross-cutting themes:

- Life
- Planetary Systems (exoplanets)

And synergistic relationships (will NASA's current divisions and directorates even make sense in 2050?):

- NASA Science Mission Directorate Divisions
  - Astrophysics (exoplanets)
  - Heliophysics (stellar influences)
  - Earth Science (is also a planet)
- NASA Directorates
  - HEOMD (human exploration)
  - STMD (enabling technologies)
- Commercial sector involvement (public-private-partnerships)
- International – working together, both in planning and implementation (Horizon 2061)

Realizing the future - capability needs:

- Technology
  - Mission requirements, including long-lead development
  - Earth and Space-based observatories
  - Laboratory requirements (e.g., sample return)
- Workforce
  - Diversity (gender, ethnic, career focus, etc.)
  - Sustainability (maintenance of critical capability)
- Engagement and Outreach

Where is the report now?

Currently defining science threads (goals) and their implementation over the coming decades that address the questions:

- Where do we come from?
- Are we special? *(Are we alone? / are we unusual?)*
- Where are we going?

Once we have a sensible science plan, we will hold a smaller technology workshop to look at overarching technology needs and onramps.

Material will be posted on the website as it is developed.

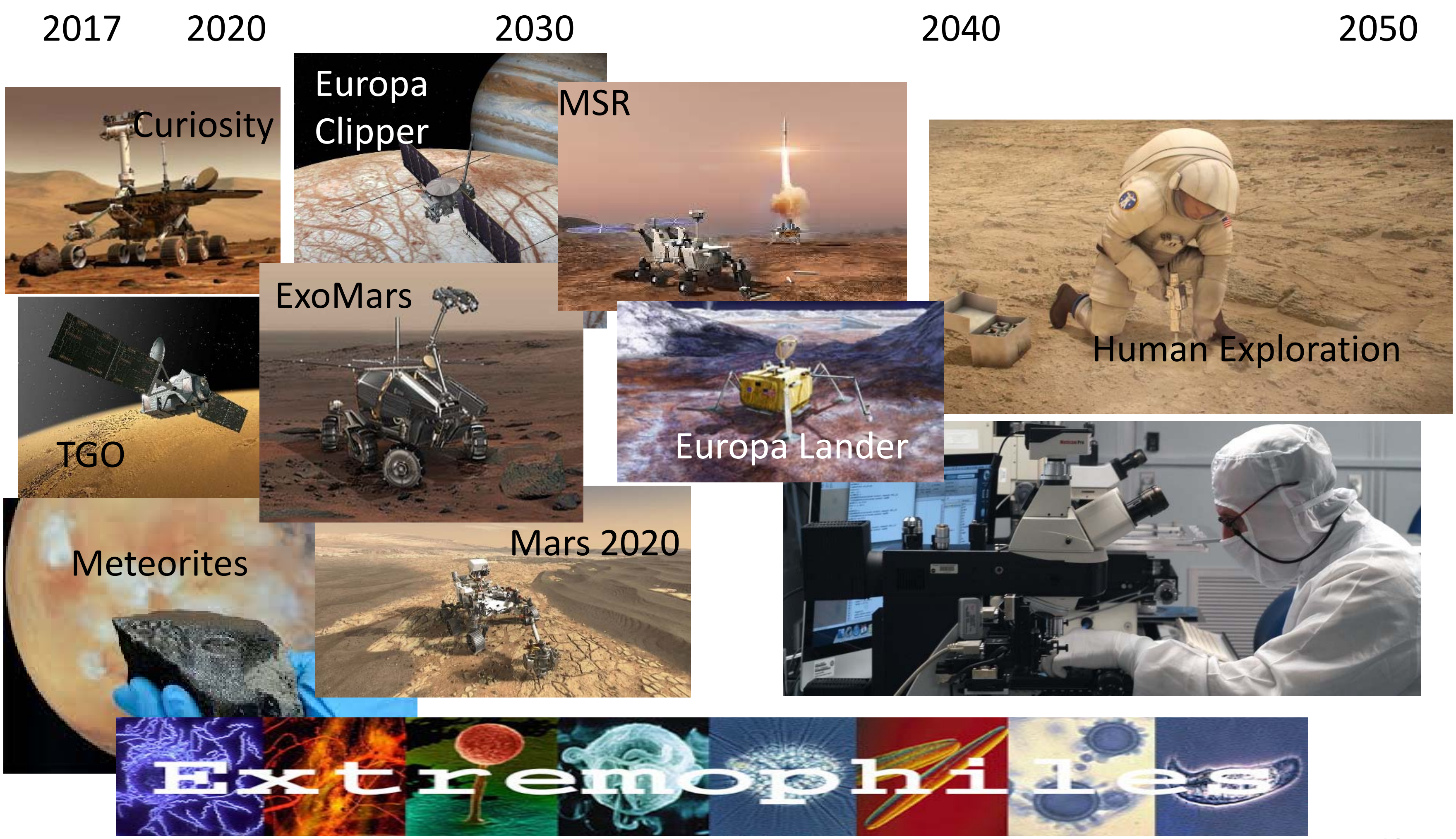
Where do we come from?

This question addresses the early history of the solar system, including the formation and early evolution of the planets, and the development of habitable environments and living organisms. The following science threads for the decades to 2050 address this question:

- Converge on a model that represents the history of the formation of our solar system from its beginnings to the present day, validated by observations;
- Understand the accretion of the giant planets and their migration to new orbital positions;
- Determine the origin, distribution, and timing of delivery for volatile compounds (e.g., water) and organics throughout the solar system, including the roles of bombardment by large projectiles;
- Determine the variation in geochemical behavior of elements in the protoplanetary disk, planetary embryos, and planets and assess its effects on the internal structure of planetary bodies and their thermochemical evolution;
- Assess whether the origins story for our own solar system is applicable to exoplanetary systems;
- Determine whether life ever developed and evolved elsewhere in the solar system, and whether it migrated to (or from) Earth; and
- Find evidence of habitable environments and possibly life beyond our solar system.

Where do we come from?

Determine whether life ever developed and evolved elsewhere in the solar system, and whether it migrated to (or from) Earth



Are we special?

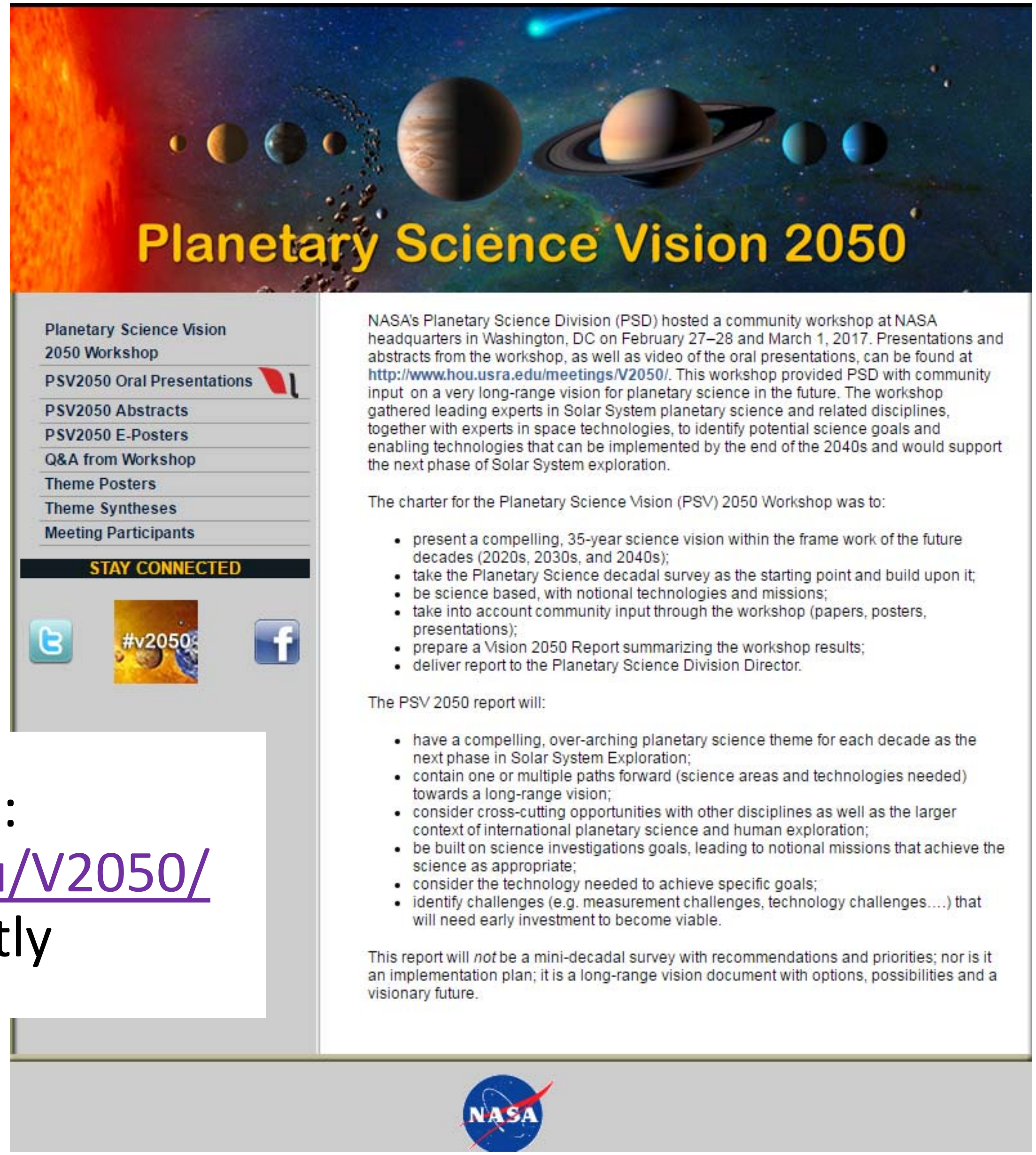
This question speaks to the uniqueness of our solar system and whether we are alone in the cosmos. It addresses solar system dynamics and architecture relative to distant planetary systems, and the evolutionary fates of planets and their atmospheres.

- Characterize how the myriad chemical and physical processes (e.g., tectonism, volcanism, interior dynamics, impacts) that shaped the solar system have operated, interacted, and evolved over time through remote observation, *in situ* exploration and return of samples to terrestrial laboratories;
- Characterize the diversity of planetary bodies in the solar system, including asteroids, comets, and bodies in the Kuiper Belt and Oort Cloud;
- Understand the conditions that lead to stable planetary atmospheres and investigate the roles of physics, chemistry, geology, and dynamics in driving planetary atmospheres and climates to obtain a better understanding of long-term climate change on Earth, Venus and Mars;
- Understand planets in our solar system as a key to understanding exoplanets (e.g., Venus versus Earth, Mars versus Earth, Ice Giants versus mini Neptunes);
- Study the evolution and stability of habitability through time, including the complex interactions of solar, geological, and atmospheric processes by detailed investigations of the geological record;
- Develop an operational (versus complete) definition of life and technologies to search for it, applicable across different targets/environments and responsive to discovery and planetary protection requirements;
- Search for extant life both in our solar system and in exoplanetary systems.

Where are we going?

This question addresses the future of our solar system, including threats to Earth and human civilization, as well as resources enabling expansion of human presence beyond Earth.

- Improve understanding of the composition and evolution of the Solar System through identification and characterization of potential resources and hazards;
- Work to complete an inventory of potentially dangerous objects and determine the diversity of potential hazards to Earth;
- Determine needed resources and how we identify and develop safe areas in the Solar System for long-term human habitation beyond LEO (e.g., 100+ people, 1+ year);
- Develop technologies for use of *in situ* resources to address more complex science objectives and enable sustained human presence off-Earth;
- Develop space and planetary infrastructures that will enable future sustainable human habitation off-Earth.



Planetary Science Vision 2050

- Planetary Science Vision 2050 Workshop
- PSV2050 Oral Presentations
- PSV2050 Abstracts
- PSV2050 E-Posters
- Q&A from Workshop
- Theme Posters
- Theme Syntheses
- Meeting Participants

STAY CONNECTED

#v2050

NASA's Planetary Science Division (PSD) hosted a community workshop at NASA headquarters in Washington, DC on February 27–28 and March 1, 2017. Presentations and abstracts from the workshop, as well as video of the oral presentations, can be found at http://www.hou.usra.edu/meetings/V2050/. This workshop provided PSD with community input on a very long-range vision for planetary science in the future. The workshop gathered leading experts in Solar System planetary science and related disciplines, together with experts in space technologies, to identify potential science goals and enabling technologies that can be implemented by the end of the 2040s and would support the next phase of Solar System exploration.

The charter for the Planetary Science Vision (PSV) 2050 Workshop was to:

- present a compelling, 35-year science vision within the frame work of the future decades (2020s, 2030s, and 2040s);
- take the Planetary Science decadal survey as the starting point and build upon it;
- be science based, with notional technologies and missions;
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This report will *not* be a mini-decadal survey with recommendations and priorities; nor is it an implementation plan; it is a long-range vision document with options, possibilities and a visionary future.

NASA

Visit our web site:
www.lpi.usra.edu/V2050/
updated frequently

Workshop Planning and Report Writing Team

Steve Mackwell (Chair)	USRA	Deborah Amato	NASA Goddard
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Anthony Freeman	NASA JPL		
Shawn Domogal-Goldman	NASA Goddard		
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Gregory Schmidt	NASA Ames		
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*Len Dudzinski **	*NASA HQ SMD*		
*Michael Seablom **	*NASA HQ SMD-HEOMD*		

** ex officio*

Workshop Format

- We received 250 abstracts, many more than we anticipated
- Participation ~170 scientists and technologist (40% Female, 60% Male)
- 6 non-overlapping oral sessions (~70 speakers – 15 or 3 min talks) and panel discussions were live-streamed and archived for later viewing
- We used a web tool to collect questions from remote participants
- Two poster sessions, one each on Monday and Tuesday evening
- All Abstracts, Posters & Presentations are posted on workshop website and are being used in the development of the workshop report

http://www.lpi.usra.edu/V2050/ #V2050

Planetary Science Vision 2050 Workshop
NASA Headquarters
February 27-28 and March 1, 2017

Monday, February 27, 2017

8:30 a.m. Welcome
9:00 a.m. Life Oral Session
11:15 a.m. Life: Panel Discussion
1:30 p.m. Origins
3:45 p.m. Origins: Panel Discussion
5:30 p.m. Posters – Life; Origins; Workings

Tuesday, February 28, 2017

8:30 a.m. Workings Oral Session
10:45 a.m. Workings: Panel Discussion
1:00 p.m. Defense and Resources
3:15 p.m. Defense and Resources: Panel Discussion
5:00 p.m. Posters - Defense and Resources; Policy, Pathways, Techniques, and Capabilities

Wednesday, March 1, 2017

8:30 a.m. Policy, Pathways, Techniques, and Capabilities Oral Session
10:45 a.m. Policy, Pathways, Techniques, and Capabilities: Panel Discussion
1:00 p.m. Future Technologies: Panel Discussion
2:30 p.m. Overarching Issues Oral Session

-IMPORTANT-

This workshop (and report) is not a mini-decadal survey with recommendations and priorities; nor is it an implementation plan; it is a long-range vision document with options, possibilities and a visionary future.