COVER PAGE

Re-Imagining NASA Planetary Mission Science Opportunities for the next two decades

Anthony Freeman, Michael Mischna, Christina Richey, Joseph Lazio, Carol
Raymond and Morgan Cable

Jet Propulsion Laboratory, California Institute of Technology

Primary Author: Anthony Freeman

Tel: (818) 726 6281

Jet Propulsion Laboratory, California Institute of Technology

email: anthony.freeman@jpl.nasa.gov

COVER PAGE

Re-Imagining NASA Planetary Mission Science Opportunities for the next two decades

Anthony Freeman, Michael Mischna, Christina Richey, Joseph Lazio, Carol Raymond and
Morgan Cable

Jet Propulsion Laboratory, California Institute of Technology

Abstract

NASA's Planetary Science Division (PSD) offers a wide spectrum of opportunities for planetary scientists to get involved in science missions, through ROSES calls for Data Analysis, Participating Scientist and Guest Investigator calls; announcements of opportunity for SIMPLEX, Discovery, and New Frontiers, and calls for Flagship mission science definition teams and science teams. While these opportunities have served the community well up to the present epoch, they may be overly restrictive, projecting forward over the next couple of decades. With a few relatively minor tweaks, NASA PSD could open up the range of mission science opportunities to energize its science community, riding a global tide of interest in deep space missions, and a wave of innovation using SmallSat technology.

Executive Summary

Goal: To provide a broader and less constrained set of mission science opportunities that leverages the imagination and entrepreneurial skills of a growing and diverse population of planetary scientists and astrobiologists.

In pursuit of this goal, we have suggested five areas where NASA PSD could expand the mission science opportunities open to planetary scientists and astrobiologists:

- 1 *US Participating Scientists Program for non-NASA missions*
- 2 *Enhancing the value of Missions of Opportunity (MoO) calls*
- 3 *Re-examining Discovery, New Frontiers Incentives*
- 4 *Relieving Regulatory Burdens/Providing Necessary Services*
- 5 *Adopting a more Strategic approach to Technology Infusion*

In each area the changes proposed are fairly modest and fit easily within the existing PSD framework, but could have a big impact on future planetary and astrobiology missions. We are confident that other, similar, ideas are out there that the community would embrace.

Future PSD Program Enhancements

1. *US Participating Scientists Program for non-NASA missions*

A 2017 community-led study [1] concluded: “PS programs provide significant value in increasing intellectual diversity among a project science team, and hence enhance the mission’s science return for NASA. Less obvious is that these programs also enhance demographic diversity among teams, and are seen as a valuable opportunity for many in the community who may not

otherwise have access to mission participation. PS programs also provide useful career experience, training, and networking opportunities for participants, especially those in the early stages of their careers. We speculate that PS programs provide more value than has previously been appreciated, and we recommend that they should be included on every mission."

Currently, participating scientist calls under ROSES are restricted to very specific calls tied to particular missions to given targets in the solar system. This leaves planetary scientists dependent on whether PSD make the decision to devote the necessary time/resources to set up such a call. For NASA missions this has clearly been a priority for PSD, and our only suggestion would be to provide more opportunities to participate, for example in extended missions by prioritizing allocation of funding for Participating Scientists later in the mission lifecycle. Discoveries occurring during the primary mission often open new scientific vistas which may be best addressed by a new 'crop' of Participating Scientists with different skills and different expertise.

For non-NASA missions, there have been missed opportunities (e.g. JUICE, ExoMars and the ISRO Venus mission) where US scientists have been invited to join science teams that have then been selected by ESA for flight, or to form an instrument team in the case of the ISRO mission, but for which no mechanism existed under ROSES for them to obtain funding from NASA. In a re-imagined participating scientist program for non-NASA deep space mission science teams, investigators find their own mission science team (or science teams) to join and make the case for NASA PSD to fund that involvement. With the proliferation of planetary science CubeSats and SmallSats, exemplified by Artemis-1 and -2, but also the CubeSats manifested with ESA's Hera mission and NASA's DART mission, opportunities are opening up for science investigations utilizing non-NASA platforms – a trend expected to increase over the next two decades [2]. This includes traditional players such as ESA, JAXA, DLR, ASI, and CNES, and also newer entrants to the great venture of deep space exploration such as ISRO, the UK, Spain, S. Korea, UAE, Israel, and commercial entities such as Bradford Space [3] and Rocketlabs [4].

An advantage for NASA in soliciting such proposals, is to spread its knowledge of how to plan and conduct a successful Deep Space missions in pursuit of specific science objectives, with the aim of obtaining some great science results in return. Mid-career or late-career Participating Scientists could bring this expertise to the table based on their experience; early career scientists might be expected to identify someone with such experience who would mentor them through the process. Investigators could be asked to say how they might tap into NASA assets to help the mission succeed, e.g. the DSN, AMMOS, GFE equipment (spare transponders, etc.), PDS, data analysis tools, SPICE, and open-source software such as F-PRIME. Investigators would also be expected to articulate the value (and uniqueness) to NASA of the data returned. A standing call of this nature would relieve NASA program scientists of the burden (and currently the necessity) of setting up bilateral science team agreements and coordinating calls for each and every CubeSat and SmallSat mission. The aim would be to fund only a small number of investigators using this mechanism – say one or, at most, two per non-NASA mission.

For scientists proposing to such a call, key benefits are that they can tap into opportunities to join science investigations that are relatively frequent – instead of spaced decades apart; and to

build out their resume of science team membership. Experience gained by scientists in this fashion adds value to NASA mission science teams.

2. Enhancing the value of Missions of Opportunity (MoO) calls

PSD offers fewer Mission of Opportunity (MoO) calls than its sister divisions in SMD. Over the past decade, there have been only three formal competitions: Jupiter Icy Moons Explorer Instruments in 2012; the Korean Pathfinder Lunar Orbiter in 2016; and the Martian Moons eXploration (MMX) in 2016. A less formal MoO call in 2018 invited three centers (GSFC, JPL, and APL) to propose a radar instrument and telecom system as NASA contributions to the proposed ESA M-5 mission candidate, EnVision. In the early days of Discovery, a more open MoO call was attached to Discovery and Mars Scout announcements of opportunity, but this practice fell off in the mid-2000s. Through its Senior Review process, PSD has informally encouraged what might be considered “missions-of-opportunity” — imaginative re-purposing (and re-naming) of Discovery missions Stardust and Deep Impact to fly by comets Hartley 2 and Tempel-1, as Stardust-Next and EPOXI.

A distinguishing feature of the handful of formal Planetary Science MoOs released over the last decade has been their tightly constrained nature: investigations are again solicited only for one particular mission at a time to one target in the solar system. In contrast, MoOs in Heliophysics, Astrophysics and Earth Science allow their science community much more latitude: proposers are relatively unconstrained as to what mission they are adding to, so long as they can demonstrate the value of their investigation to NASA’s science goals in that division. Picking non-NASA missions to offer MoOs for makes sense when there are relatively few non-NASA Deep Space missions. As argued above, this landscape is already changing with the advent of SmallSat Deep Space missions, and the entry of new players onto the stage of planetary exploration. As this future evolves over the next two decades, NASA PSD should take advantage of it and issue broader, more open and more frequent MoOs. In doing so, they would place their trust in the planetary science community to come up with entrepreneurial and innovative ways to achieve PSD science goals.

A class of MoO that is uniquely suited to planetary science missions is the ride-along CubeSat or SmallSat, carried to its destination by a host spacecraft and deployed only on arrival at its destination. This enabling mission architecture will be first demonstrated by NASA/JHUAPL’s DART mission, which will carry the Italian Space Agency’s LiciaCube. LiciaCube will be deployed on arrival at Didymos and observe the impact of the DART spacecraft when it drives into the lesser of this asteroid binary. A couple of years later, ESA will deploy two CubeSats from its Hera spacecraft, when it arrives at the same destination. As more nations venture out into deep space, offering such ride-along opportunities is a natural thing for NASA PSD to continue to take the lead on.

A formal way to encourage ride-along CubeSat or SmallSat missions would be to solicit accommodation for them under the Discovery and New Frontiers calls, or under competed payload calls for Flagship missions. For Discovery and New Frontiers, NASA PSD could do this by

providing an incentive for the primary proposing teams to define accommodation of a to-be-specified ride-along MoO, then, immediately following selection for Step II, issuing a MoO call for investigations that utilize the opportunity within the resources identified by each Step II team. It would have to be clear to the primary Step II team that the ride-along MoO will not be evaluated as a risk factor applied to their proposed project. But that the MoO would be evaluated in the risk it posed to that project.

[Note that we differentiate here between ride-alongs and secondary launches, where the MoO launches on the same launch vehicle as the primary spacecraft, but is not dependent on it for any resources during flight (e.g. MarCO). PSD has already offered secondary launches through the SIMPLEx-2 call.]

Ride-along MoO calls need not be limited to US teams: encouraging non-US teams from other national space agencies would be a way for NASA to continue its global leadership role in planetary science. US involvement could be ensured by requiring that each MoO science team have at least one investigator from a US institution. Especially for Outer Planets missions, this would be a way for NASA PSD to encourage new players to enter into the enterprise of exploring the outer solar system. The present situation, in which only NASA and ESA have the wherewithal to execute an Outer Planets mission, limits opportunities to one or two missions in a career as a planetary scientist. New players can increase the cadence of missions, by bringing in new funding, new ideas, and technological innovations, as we have seen recently for the inner solar system in lunar exploration [6], at Mars [7], and in small body missions such as Hayabusa-2 [8], for example.

3. Re-examining Discovery, New Frontiers Incentives

PSD mission AOs under the Discovery and New Frontiers programs already offer a variety of incentives to proposers: to infuse new technologies; incorporate Radioisotope Power Sources; eliminate Phase E costs in evaluation; to use lower capability launch vehicles. These incentives are designed to lessen the risk of taking on new technologies, encourage longer ranging missions, e.g. to the outer planets; and lower the cost, or cost risk to NASA. Why not, then, have incentives for proposers to take on higher-risk, higher impact science?

Jim Green, in his tenure as PSD Division manager, famously outlined a logical sequence of solar system science missions for a given target in the solar system: Flyby, Orbit, Land, Rove, and Return Samples (e.g. [4]). Clearly these mission architectures are each, in turn, more complex and take on more risk than their predecessor, and arguably offer a richer science return. For any given body in the solar system, the cost of each type of mission in this logical sequence is ever-increasing, so sample return missions will tend to cost significantly more than flybys. But, there is a well-known tendency for NASA review panels to award high marks to the lowest-risk option in Step II of any mission competition. And lowest risk tends to strongly overlap with lower cost (and, therefore, earlier in the mission-type sequence). To encourage more ambitious, higher risk, and higher impact missions under Discovery and New Frontiers, NASA PSD could incentivize them, by lowering or increasing the PI-managed Mission Cost Cap (PIMMC) accordingly. The amounts for such incentives might vary depending on the size of the call, but one could imagine

values of (-10%, -5%, 0%, +5%, and +10%) applied to each class of architecture (Flyby, Orbit, Land, Rove, and Return Samples) would be appropriate and relatively affordable.

Larger launch vehicles are going to become available for planetary missions, e.g. Space-X's Falcon-Heavy or Starship, Blue Origin's New Glenn and ULA's Vulcan Centaur, and as this future is realized it is worth re-examining the launch vehicle/Phase E costs incentive structure for Discovery and New Frontiers. In most mission design trade studies, a larger launch vehicle usually means shorter cruise times, and fewer gravity assists (GAs) for Outer Planets missions, and, of course, more launch mass margin. For a given mission, heading out to Jupiter and beyond, a typical trade might look like this: using a standard launch vehicle, multiple GAs including Venus, and a 12-15-year mission duration versus using a larger launch vehicle, no Venus GA, and a shorter 6-8-year mission duration. The cumulative net cost of each mission to NASA PSD may be about the same, but allowing the latter option could, over the long run, have a marked effect on the cadence of Outer Planet missions, therefore increasing the overall science return in a given period. This effect could be compounded as flight system and operations costs for future deep space missions drop significantly by infusing new technologies at a faster pace (see discussion below)

4. Relieving Regulatory Burdens/Providing Necessary Services

Regulatory burdens and the daunting range of tasks necessary to produce flight-qualified hardware/software for deep space missions currently pose as a disincentive to non-traditional proposing teams on calls such as SIMPLEX. Given the expansion of and interest in CubeSat and SmallSat activities in aerospace engineering departments all across the US, and assuming that NASA PSD wants to expand participation in planetary exploration, NASA could do more to take some of the regulatory/bureaucratic burden off teams, and task its centers to provide necessary services where they already have the expertise (as is done for the DSN for example):

- NEPA compliance, especially for RHUS, compact RTGs (when realized)
- Planetary Protection
- Frequency Allocation
- Parts screening
- Software QA

This would help lower the barrier to entry for Universities and Colleges in the US to field successful proposals under calls like SIMPLEX.

5. Adopting a more Strategic approach to Technology Infusion

The last two Discovery calls have offered Technology Demonstration Options (TDOs) and Psyche will fly one of those – the Deep Space Optical Communication (DSOC) demonstration. DSOC has been developed through STMD. In this latest round of Discovery, proposing teams have been offered STMD-funded TDOs including a Deep Space Atomic Clock, a low-light intensity solar array, and a long-lived Venus Lander demonstration. With clear feed-forward to future mission needs, these are all great examples of strategic technology infusion.

New technologies being developed under the “NewSpace” umbrella are being rolled out at a pace that has the potential to disrupt planetary science exploration over the next few decades. Rates of infusion for new technologies have dropped from decades, in some cases, to just a few short years [9]. Examples include: advanced manufacturing, even 3-D printing in space; compact, science-grade instruments [10]; onboard computing power and corresponding software functionality; multi-function structures and advanced thermal/power management systems; imaginative new mobility systems for surface/subsurface exploration. These advances in technology will enable new science missions, and have the potential to reduce flight system and operations costs, as we have seen already for Earth-orbiting spacecraft. The question is: does the current structure of mission opportunities in PSD — Flagship, New Frontiers, Discovery, Missions of Opportunity, SIMPLEx — encourage planetary scientists to adopt these new technologies? We would argue that it does not, and that it pushes the community away from innovation and towards conservatism. This could easily be altered by being consistent in incentivizing technology infusion in future mission opportunities and including it in the evaluation criteria. Proposers (or Flagship project teams) would still have to balance technology development risk against achieving their primary objectives.

We recommend, therefore, the following actions for a more strategic approach to technology infusion:

1. Incentivize technology infusion in competed mission calls in a consistent manner. Settle the rules down so technology developers know what they are aiming for.
2. Identify where the particular technology lies on a roadmap. Ask proposers to be specific about the feed-forward opportunities – the next mission or missions in PSD’s pipeline that will take advantage of the particular technology
3. Task flagship missions with flying at least one new flight system technology – could be science-enhancing, but does not have to be science-enabling for that mission.

References

- [1] Prockter, L., et al, The Value of Participating Scientist Programs to NASA’s Planetary Science Division, White Paper submitted to the PSADS, 2020
- [2] Freeman, A., Deep Space Nanosats – Positioned for Exponential Growth, ESA 4S Symposium, Valletta, Malta, May 2016.
- [3] <https://www.bradford-space.com/products-xplorer.php>
- [4] <https://www.space.com/rocket-lab-private-venus-mission-2023.html>
- [5] Green, J., Planetary Science Division Overview to the OPAG, Oct 2011.
- [6] <https://nssdc.gsfc.nasa.gov/planetary/lunar/lunartimeline.html>
- [7] https://en.wikipedia.org/wiki/List_of_missions_to_Mars
- [8] <https://en.wikipedia.org/wiki/Hayabusa2>
- [9] Freeman, A., Small is Beautiful — Technology Trends in the Satellite Industry and Their Implications for Planetary Science Missions, Planetary Science Vision 2050 Workshop, DOI: 10.13140/RG.2.2.16329.75364, 2017

[10] Stephens, G., Freeman, A., et al, The Emerging Technological Revolution in Earth Observations, Bull. Am. Meteorol. Soc., Vol. 101, No. 3, E274-E285, March 2020, DOI: 10.1175/BAMS-D-19-0146.1

Acknowledgements

Some of the work described here was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.