

## The Value of Participating Scientist Programs to NASA's Planetary Science Division

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## 1 Executive Summary

This white paper is presented in response to perceived inconsistencies about the value of Participating Scientist (PS) programs to the NASA Planetary Science Division, mission leadership, and program participants. It is coauthored by representatives of the NASA Analysis/Assessment groups. Data was collected and analyzed from two surveys: one of the planetary science community, and one of the leadership of current and past planetary missions. We asked these groups to share their experiences and opinions about PS programs, discussing what worked well, what could be improved, and what the perceived value was to them personally.

We find overwhelming support for PS programs both from the planetary science community, and from mission leadership. As expected, 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.

On the basis of our survey results, we conclude that greater consistency in timing and approach could make PS programs even more effective and useful to NASA. Current and former PSs noted difficulties regarding their integration onto some project teams, a lack of transparency regarding the duration and timing of funding, and a desire to get more involved in mission operations. Mission leaders noted the benefits in bringing PSs onto the project earlier in the mission timeline, and the need for open communication with NASA in order to preclude overlap with existing team research.

As a result of this study, we offer these recommendations for future Participating Science programs:

1. Participating Scientist programs should be included on every planetary mission, whether competed or directed.
2. Expectations for the timing, duration, and scope of a Participating Scientist program should be agreed between NASA HQ and mission leadership as early as possible within the mission timeline, ideally during Phase A. The results of these discussions should be publicized to the planetary community through, e.g., NSPIRES, the Planetary Science Advisory Committee, relevant assessment and analysis groups, and community newsletters.
3. The planetary community should be given as much time as possible to prepare for a Participating Scientist call and sufficient information regarding mission payload and operations activities (e.g., through a Proposal Information Package), and existing team scientific capabilities and goals.
4. Sources of funding for Participating Scientist programs should be identified early, and ideally included in the release of a competitive mission AO or in the announcement of a directed mission.
5. Once allocated, Participating Scientist funds should be held as inviolable, unless significant changes occur to the mission that would warrant a reduction in the program (e.g., failure of a portion of the mission or instrument), or an increase (e.g.,

groundbreaking findings that may require additional members with specific expertise). Participating Scientist programs should be included in extended mission phases.

6. The amount of funding for a Participating Scientist program and expectations for its duration should be clearly communicated to Participating Scientists when they are selected.
7. Participating Scientists should be brought onto a mission as early as feasible, bearing in mind the trade between cost and integration issues. For most missions, the Participating Scientists should be brought onto a project at least one year before operations at the relevant major target. If possible (and appropriate), Participating Scientists should be given the opportunity to participate in mission operations.
8. Full integration of Participating Scientists onto a project should be given high emphasis by mission leadership and the mission team. Expectations for the Participating Scientists' scope of work should be made clear when they join the team (e.g., operations, data analysis only, etc.) and they should be treated as equivalent to any other Co-Investigator on the team. This is especially important for Participating Scientists who are selected later in a mission (e.g., missions with a long cruise phase).

## **2 Background**

### **2.1 Motivation for the study**

This study was instigated at the Outer Planets Assessment Group meeting held February 1-2, 2016, at the Southwest Research Institute in San Antonio, TX. During the meeting a discussion ensued about the role of Participating Scientists (PSs) on NASA planetary missions. It became apparent that there were different views among meeting attendees and the NASA participants regarding the role of such PSs. At NASA's request, the OPAG community agreed to write a White Paper that examined the role of PSs on missions, and their value to NASA, and it was decided that this would include participation by other Assessment/Analysis Groups (AGs). A meeting finding was formulated to show OPAG's commitment to PS programs and to capture the action to write the white paper.

Several OPAG participants (shown on the title page) volunteered to help author the white paper. Subsequently, other AG leaders were approached to see if they wished to participate. There was enthusiastic endorsement from all the AG Chairs; each one committed to either participating directly in the white paper, or delegated this responsibility to others on their steering committees or within their communities. Consequently, this white paper is coauthored by representatives from all six of the NASA Assessment/Analysis groups (OPAG, MEPAG, LEAG, VEXAG, SBAG and CAPTEM), including three Chairs and several Steering Committee members. This demonstrates the broad community support for this effort.

In addition, our team includes social scientists that are experts in analysis of sociological data: Janet Vertesi, David Schwartz, and Meghan Wheeler from Princeton University. Dr. Vertesi has carried out extensive research on spacecraft teams [e.g., 1], and two of her students assisted in the qualitative and statistical analysis of the data that was collected.

Interim results from the study were presented at meetings of OPAG, SBAG, VEXAG, MEPAG, the NASA Planetary Science Subcommittee, and the annual AAS Division of Planetary Sciences conference [2], and received uniformly positive feedback.

## 2.2 Charge

The discussion at the original OPAG meeting outlined the following objectives for the study:

- (1) Assess the value that PS programs add to NASA missions
- (2) Understand similarities and differences among existing and past programs, and gather lessons learned
- (3) Investigate how to maximize the usefulness of the programs for future missions.

## 2.3 Expected outcome

It was agreed that the white paper containing results and recommendations would be delivered to the leadership of the six Assessment/Analysis groups, and made available to the wider planetary community. It is anticipated that the study's conclusions will be communicated from the AG leaders to the Planetary Science Advisory Committee (PAC), who will in turn pass any recommendations onto NASA as they see fit.

## 2.4 Caveats

We wish to emphasize that the goal of this study is to give useful feedback to NASA on its PS programs. It is NOT intended to highlight or compare how such programs worked on different missions, and whether any mission was more or less successful than others in incorporating PSs. We have therefore tried to remove any identifying information in our results and discussion and are primarily looking to highlight general themes that emerge from the data. We note that this is not a particularly scientific study; we gathered a substantial amount of data from the planetary community, but should stress that those data are qualitative. The study is informal and unfunded, and the results should be interpreted in this light. Nevertheless, we are surprised by the consistency of much of the feedback we have received, and have done our best to represent this feedback as openly and fairly as possible.

## 3 Approach

We solicited feedback from the planetary community in two phases: Phase 1 was for those who have served or are currently serving as PSs on planetary missions, as well as anyone who has an interest in, or opinion about these programs; Phase 2 was for leaders of planetary missions, either Principal Investigators and/or their deputies for competed missions, or Project Scientists and/or their deputies for directed missions<sup>1</sup>.

For clarification, we assumed that the term "PS" included both of the following categories:

**Participating Scientist:** A scientist who is brought onto a mission after selection, through a NASA Announcement of Opportunity (AO) call. PSs are generally funded directly by NASA, independently from the project they serve.

**Guest Investigator:** As with PSs, Guest Investigators (GIs) are brought onto missions through a NASA AO, and are funded directly by NASA. The purpose of GIs is generally to carry

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<sup>1</sup> **Competed mission:** Mission that is openly competed and is led by a Principal Investigator, e.g., Discovery, New Frontiers, and Mars Scout missions. **Directed mission:** Mission that is directed by NASA to one of its centers. These are usually larger and/or strategic missions, including the Mars Science Laboratory (JPL), Lunar Reconnaissance Orbiter (GSFC), Cassini (JPL), etc.

out data analysis; they are not expected to participate in mission planning or operations, although this varies with the project.

We do not consider someone a PS if they are funded directly by the Project. Therefore, Co-Investigators, Collaborators, Postdocs, students, or Team Affiliates are not PSs according to our definition. We also did not include scientists on non-NASA missions unless they received NASA funding as a GI. Even if a respondent did not meet our official criteria for inclusion as a PS, we still incorporated their comments and suggestions on the value of the program.

### **3.1 Phase 1: Current/former Participating Scientists and entire planetary community**

A survey was formulated containing questions for existing/past PSs and/or anyone who has an interest in, or opinion about, these programs (Appendix A). The survey was divided into three parts:

- a) Questions for past or current PSs (or GIs) about their experiences while participating in NASA planetary missions.
- b) Questions for the entire community about their opinions on planetary missions and the perceived value of these programs to NASA.
- c) A request to all respondents to a) and b) for limited demographic information, including age range and current career level.

An effort was made to collect as much input as possible, while keeping the survey to a reasonable length. We also ensured that the survey was conducted anonymously, so that respondents felt comfortable speaking freely. The survey was conducted using Google forms, a freely available user-friendly tool which allows the results to be returned in .csv format. Respondents who had served as PSs in more than one planetary mission were requested to identify themselves in such a way that we could tell that they had answered section (a) more than one time, but had only included answers to sections (b) and (c) once.

In order to ensure the widest possible participation, the survey was advertised to the community via the Lunar and Planetary Institute newsletter, the Planetary Exploration Newsletter, the regular DPS mailing, and the six AG mailing lists. The community was given about six weeks to respond.

### **3.2 Phase 2: Current/former planetary mission leadership**

Experiences of the authors of this white paper led us to expect that mission leadership might have a different view of PS programs than the broader planetary community, given that they are managing large, complex projects and have spent a lot of time putting their core science teams together. We wanted to gather opinions from mission leaders to see whether they viewed the PS programs as a useful addition to their projects, and to investigate the challenges in incorporating them. We therefore formulated a separate (much shorter) survey (Appendix B) focusing on management challenges and lessons learned. Input for this survey was solicited in person or via email. Although the leadership survey responses were not anonymous, we have taken care to look for generalities in the responses and to try to remove information that identified specific missions.

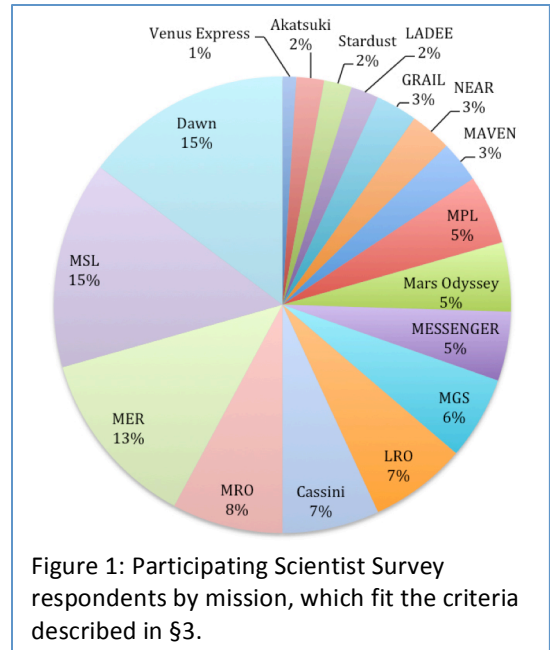
## **4 Methodology**

Some of the questions in the community survey (Phase 1) asked for a simple yes/no answer, or for a number. These were plotted and are shown in the Results section (§5). We also

asked for comments on respondents’ experiences, and their opinions on the implementation and value of PS programs. These responses were imported into the software package nVivo [3-4], a standard package for qualitative data analysis used by social science researchers that handles tabular entry and allows for flexible cross-correlation between types of responses. A full description of the methodology used in analyzing the data from both phases of the survey is given in Appendix C.

## 5 Results: Community survey

We received a total of 211 responses to the community survey, of which 122 were self-identified current or former PSs or Guest Investigators (hereafter collectively referred to as PSs). Of these, 101 met the criteria outlined in §3. Some of the responses were for missions that were ultimately unsuccessful, but were included if the PS had been part of the mission for a reasonable amount of time and had useful feedback<sup>2</sup>. We also received input from a number of people who had served on non-NASA missions; these were not included unless the respondent had received NASA funding, although we did review any comments they made on the overall value of their program. In the results that follow, it should be noted that not all respondents answered all questions, so we use percentages rather than numbers.

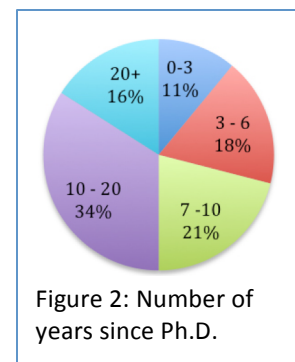


### 5.1 Responses by mission

As expected, the highest numbers of respondents (Fig. 1) are from currently or recently active missions (e.g., Dawn, MSL). High numbers of respondents also came from missions that have been active for a long time (e.g., MRO, MER). In general, responses appear consistent with the size and longevity of the mission, and the number of PSs that were funded by NASA.

### 5.2 Participating Scientists by seniority

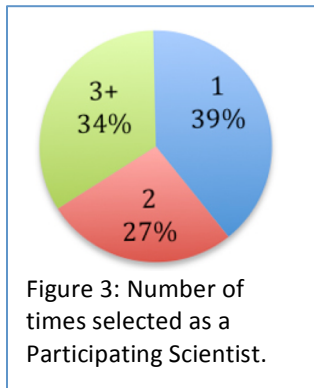
We asked the community to tell us how many years it had been since they received their Ph.D.s when selected as a PS, in order to determine whether there was any bias in seniority in these selections. Results showed that PS programs draw from all career levels (Fig. 2). Almost one-third of PSs are within 7 years of their Ph.D. (NASA considers these scientists to be “early-career” researchers), and half were within 10 years of their Ph.D. All but two of the 0-3 year PSs were on directed missions; about half of those in the 10-20-year range served on competed missions, and the majority of the remainder served on directed missions (with Mars dominating the longer-term missions).



<sup>2</sup> For example, a respondent may have been a PS for some time during mission development and cruise phases, but the spacecraft failed to deploy (e.g., Mars Polar Lander).

### 5.3 Number of times selected as a Participating Scientist

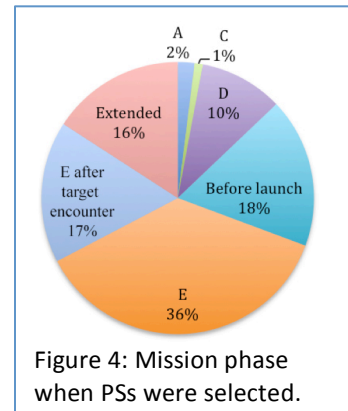
We wished to investigate whether some in the planetary community had served as a PS multiple times. Of the 101 respondents, almost two-thirds had been selected as a PS more than once (Fig. 3). The breakdown showed that 39% respondents are “first-time” PS’s, 27% have been selected twice, and 34% have been selected three times or more. Of the 39% of respondents who have served as a PS on one mission, about half were on non-Mars missions.



Of the “repeat” PSs, about two-thirds had served on one or more Mars missions. This is perhaps not surprising given the funding profile within the Planetary Science Division over the last two decades; Mars missions have been more numerous and several have been active for many years, so it follows that some in the community would gain mission experience from one mission that would make them potentially more valuable as team members for future missions.

### 5.4 Timing of Participating Scientist additions

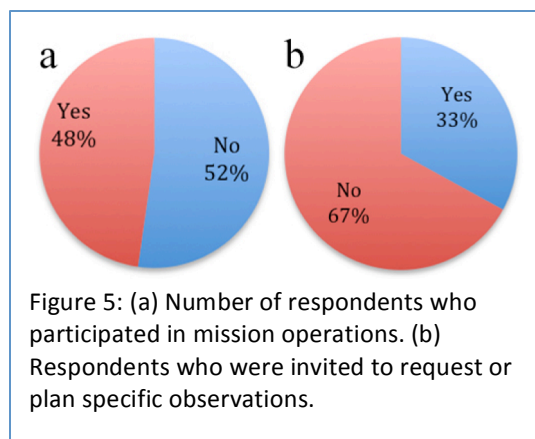
One issue we wished to investigate was how much the timing of the addition of PSs to a mission affected their participation as team members and their effectiveness in carrying out scientific research. Many of the respondents did not know at which stage of the pre-launch Project lifecycle they were selected, but 31% were selected at some point within phases A-D (Fig. 4; Phases A-D and “Before Launch” are the same). Over half (53%) were selected during cruise (E in Fig. 4) or after the encounter with the primary target, and 16% were selected during extended mission phases. Many of the respondents felt strongly that timing was a key component to their effectiveness; this is discussed further in §5.6 and §5.8.



### 5.5 Participating Scientist activities

Part of the motivation for this study (§2.1) was a lack of clarity about the specific role of PSs on missions, and whether they should be carrying out mission operations, doing data analysis, or both. To investigate this, we asked whether the PSs had been involved in mission operations, or had only carried out data analysis. Just under half of the respondents had been involved in mission operations in some form (Fig. 5a).

We also asked whether PSs were invited to request or plan specific observations related to their PS proposals, or whether they had to use data from existing observations that were planned without PS input. Some people did both (with hindsight, this question was not worded sufficiently well to elucidate that). Some respondents noted the value of being able to request specific observations:





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“...the ability to make decisions affecting the types of observations was really valuable to me as it enabled the science that I wanted to do.”

Nevertheless, we learned that over two-thirds of respondents were not invited to request specific observations from the mission-planning team (Fig. 5b). This is not necessarily negative; some PSs were eager to use mission data and this was quite adequate for their needs; similarly, GIs for several missions are generally only expected to conduct data analysis. However, in some cases PSs noted that they were not able to schedule observations tied to their PS proposals, making it challenging for them to meet their science objectives. Others noted a reluctance on the part of the mission team to accept suggestions for science observations from PSs (see §5.8).

### 5.6 Funding for Participating Scientists

Selection for the program, including timing and re-proposals, was one topic frequently addressed by participants. Although they would have liked more funding, respondents acknowledged the realities of limited mission budgets, and 84% stated that their funding was adequate over a range of timescales (Fig. 6). However, they did request that funding decisions become more predictable with respect to transparency and timing. In several cases, participants were forced to scale back team involvement or abandon projects while executing their science plan

“PS's were in the position of little certainty about how long our position would continue. This was especially true of US contribution to [NASA-directed mission], where the role of a number of us pure science PS's (as opposed to those involved with mission ops) was soon de-funded, so that I had to abandon participation [in] team meetings, etc.”

One-third of the respondents were required to repropose as a PS during the mission (Fig. 7). Individuals highlighted the time constraints and stress associated with reproposing for on-going projects, as well as the inconvenient timing of selection.

“Not having to re-propose once part of the team is very valuable. In particular, it allows one to be more integrated within the team, rather than a "second-class" team member.”

However, we note that requiring PSs to repropose can be beneficial because it gives additional scientists an opportunity to join a mission team and carry out new science investigations. This also allows the missions to be flexible and bring on additional expertise in response to new discoveries.

In addition, as the quote below makes clear, uncertainty regarding funding can contribute to conflict between the original team and PSs. Alongside calls for more long-term funding, these responses suggest improving the communication and planning of funding decisions.

“If the PI knows they will be expected to incorporate PS's into their program, and knows when this will happen, and how these additional [science-team members] will be funded, I think it will reduce [the] conflict that can happen when PS's are added to a team, and can only add to the overall science return.”

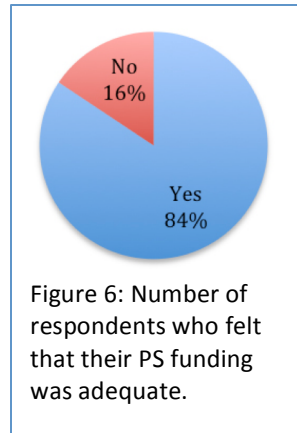


Figure 6: Number of respondents who felt that their PS funding was adequate.

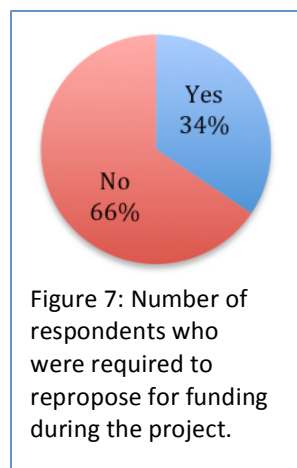


Figure 7: Number of respondents who were required to repropose for funding during the project.

### 5.7 Duration of team membership as a Participating Scientist

We were interested to know how long most respondents served as a PS on a mission team, and how likely it was that they would be asked to remain on a project after their PS term expired. We therefore asked the length of time for which respondents served as a PS on a particular mission (Fig. 8). This varied widely depending on the mission, but the average length of time served as a dedicated first-term PS was between 3-4 years. Those who have served for 10 or more years are all associated with Mars missions. Several additional respondents reported that they were still active on a particular mission but did not say how long they had been associated with the mission.

After their original term as a PS, many respondents continued to be involved in a mission through a subsequent round of PS selections, or as a funded Co-I or unfunded Collaborator. Almost one-quarter of the respondents continued to be associated with a mission after their original period of performance ended; nearly 10% transitioned into a funded Co-Investigator role (which demonstrates their value to the mission), and 14% continued to be associated with the mission as unfunded Collaborators. Some of the latter were graduate students who

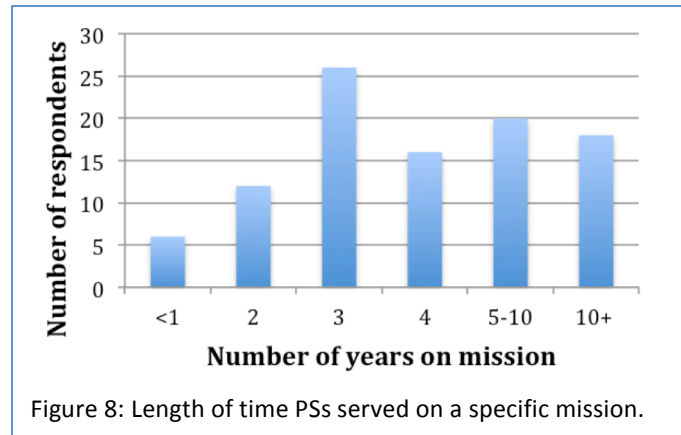


Figure 8: Length of time PSs served on a specific mission.

continued to be associated with a team Co-Investigator after they finished their Ph.D.s. It should be noted that responses to this question were less clear-cut than some others, primarily due to inconsistencies in how PSs were treated on different missions once their period of performance ended, but also because some respondents received no-cost extensions to their awards.

### 5.8 Integration into teams

We expected that full team integration would lead to better collaborative science, and therefore asked the PSs whether they felt they were integrated into the mission team after a reasonable period of time. The vast majority of respondents did eventually feel fully integrated into their mission project (Fig. 9) and many noted that when they were integrated early and well it made the experience a positive one:

“This mission was very good about treating all PS’s as full team members. We were explicitly treated as equals by the PI, and [their] example was followed by all of the original team members. Because we were treated as full team members, we were never asked to re-propose to retain our PS status (i.e., the same arrangement as any of the original Co-Is).”

“The PI was very good about integrating PS’s onto the team. It seems that this is a key aspect of whether or not a PS has a good experience.”

However, some participants identified integration into existing teams and missions as one area of the program that could be improved:

“Feeling more integrated into the team could have improved my experience. I was invited to one science team meeting, which I did not attend because [reason]. However, I have not been invited to mission telecons [sic], am not on the mission’s email list, etc., so while I can place

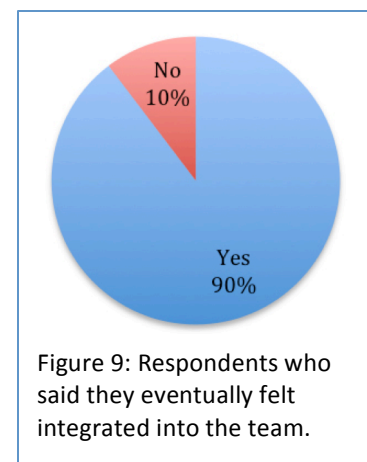


Figure 9: Respondents who said they eventually felt integrated into the team.

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on my CV that I am an associate for the [mission], I really feel disconnected. I'm very excited about the science that [the mission] has done. However, it's difficult to keep that excitement going when I feel so isolated.”

The issues related to integration pointed out by participants include PI leadership, on-boarding issues, the re-proposal process, and involvement in planning processes. There may be a tendency on the part of PIs to overlook PS science plans in favor of data analysis, a dynamic to which early-career scientists are most susceptible.

“However, I learned my fresh-off-the-PhD-boat scientist lesson to broadcast even more broadly than mere sufficiency my analysis plans. But I also think there could be a process improvement with more Project-side buy in to the PS and their roles, including, possibly, a larger role in selection and/or later championing of PS science.”

Significantly, the requirement to repropose for funding can be linked to integration (see §5.6), where the process of reproposal could disconnect a PS from existing team members and detract from time spent on research. In general, improvement suggestions focus on the relationship between selection, integration, and funding.

In order to help identify the optimum outcomes of different aspects of PS programs, we sought to identify those factors that produced higher degrees of PS integration (Table 1). Of particular interest was whether the perceived level of integration varied with the time at which a PS was brought onto the project, and whether or not they participated in mission operations. The methodology behind these results is in Appendix D.

TIME BROUGHT ON	ACCESS TO OPERATIONS	LEVEL OF INTEGRATION		
		LOW	MEDIUM	HIGH
<b>EARLY</b>  (20)	<b>YES</b> (14) <b>70%</b>	<b>LOW</b> (0) 0%	<b>MEDIUM</b> (2) 14%	<b>HIGH</b> (12) <b>86%</b>
	<b>NO</b> (6) <b>30%</b>	<b>LOW</b> (1) 16%	<b>MEDIUM</b> (4) <b>66%</b>	<b>HIGH</b> (1) 16%
<b>LAUNCH</b>  (11)	<b>YES</b> (10) <b>90%</b>	<b>LOW</b> (0) 0%	<b>MEDIUM</b> (4) 40%	<b>HIGH</b> (6) <b>60%</b>
	<b>NO</b> (1) <b>10%</b>	<b>LOW</b> (1) <b>100%</b>	<b>MEDIUM</b> (0) 0%	<b>HIGH</b> (0) 0%
<b>LATE<sup>3</sup></b>  (67)	<b>YES</b> (27) <b>40%</b>	<b>LOW</b> (2) 7%	<b>MEDIUM</b> (5) 19%	<b>HIGH</b> (20) <b>74%</b>
	<b>NO</b> (39) <b>57%</b>	<b>LOW</b> (9) 23%	<b>MEDIUM</b> (26) <b>66%</b>	<b>HIGH</b> (4) 10%

TABLE 1: Temporal and operational factors affecting integration (Chisq = 61.95, df = 12, p-value = 9.922e-09 [see Appendix D for methodology]).

<sup>3</sup> One respondent did not indicate if they had access to operations.

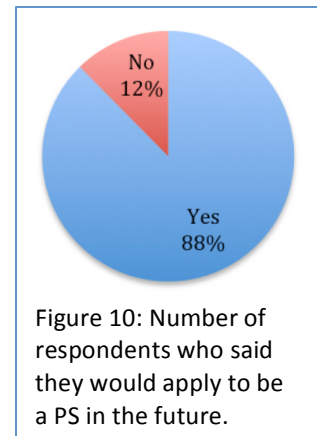
Although many PSs indicated that being brought onto the project earlier was beneficial, PSs brought on before launch did not regularly report more integration with the mission than those brought on in phase E. We further disaggregated responses based on whether or not the respondent had access to operations experience. Across the board, those with access to operations experience reported higher degrees of integration than those who were not allowed access to operations, regardless of time brought on board. We therefore conclude that access to operations experience is a stronger predictor of team integration than the time at which team members are added.

We also investigated whether there was a correlation between the level of integration on a team and a PS’s overall satisfaction with a project, and found that this is indeed the case (Appendix D). Finally we investigated whether there was a correlation between the type of mission, i.e., directed or competed, and a PS’s satisfaction, and found that the level of satisfaction was somewhat higher on PI-led missions than on directed missions (Appendix D).

**5.9 Future interest in Participating Scientist programs**

We asked whether the community would be likely to apply to a PS program in the future. This question was asked of all respondents, regardless of whether they had already served as a PS on a mission. The overwhelming response was positive (Fig. 10), reinforcing the community’s desire for mission involvement.

Of the 12% of the community who said that they would not apply, one commented that there was insufficient focus or attention paid to mid-career folk and that too much emphasis was being paid to early-career researchers (although our data does not support that assumption for PS programs). Others were close to the end of their careers and said that it would not be realistic for them to apply in the future. One respondent noted that the proposal process can be rather daunting, with insufficient information given to proposers about science being carried out by the existing team. They went on to suggest that it is a lot easier to become a PS if you have already been associated with the mission in some capacity, e.g., as a graduate student, and so have “inside knowledge”.



**5.10 Perceived personal value of Participating Scientist programs**

Participants were asked to comment on the personal value of the program, with the bulk of responses touching on collaboration, data access, and the unique experience of mission team involvement itself. Collaboration and data access are often talked about together, as is shown in the following two quotes. Further, PSs talk about their membership in a team as a value in and of itself. They are happy for the opportunity to contribute their expertise to an active data retrieval mission.

“Becoming involved in a mission, opportunity to work with exciting new data, opportunity to get to know both famous established researchers and younger scientists (grad students, post-docs).”

“I was a fully integrated [mission instrument] science team member, with data access and the chance to collaborate with colleagues from around the country. It has shaped my research career.”

The program also provides the value of personal career development for scientists, and workforce development of future NASA scientists and mission leaders. Participants noted the

opportunities that the program provides for younger researchers and scientists who are able to utilize their mission experience to further their own research and career trajectories, and to develop the skills and knowledge necessary to take on leadership roles on future missions.

“PS programs are a way to provide early career scientists with an avenue for entry into active NASA missions. This provides critical experience that is, for all practical purposes, required for someone to be invited to join or lead a proposal effort for future mission opportunities.”

### 5.11 Participating Scientist programs and diversity

Many studies have shown that intellectual cross-fertilization is an important source of good ideas [5, 6], fosters better solutions to problems [7 – 10], and combats “group-think” [11]. Therefore increasing diversity on a mission team can lead to enhanced scientific productivity. There is a widely shared, and oft-stated perception among participants that mission leadership can be an “old-boys club<sup>4</sup>.” This term was used by more than one participant to describe their experience and perception of distribution of opportunities when faced with a closed network of generally senior researchers (although not necessarily white men). When referenced, participants commonly connected this phrase with the traditional inability for younger scientists and scientists from underrepresented groups to break into missions and leadership positions. It should be noted that although the following quote contains a reference to competed missions, we find that participants have diversity-related concerns about directed missions as well.

“Again, the old-boys network is very strong in the competed missions. One doesn't get the phone call unless you are on the inside. Requiring a PS program helps to break that inside track....”

Given this perception, many participants emphasize the value to science that pulling in a diverse cross-section of the community provides. Participants note the intellectual insularity that develops with a lack of diversity in mission environments, and point to both intellectual and demographic diversity as a way to foster innovative ideas and push research further. Participants noted the ability of the PS program to provide a pathway of entry into a scientific research environment for outside or younger scientists, underrepresented groups, and the international community.

“I view PS programs as one avenue that would provide opportunities to not only early career researchers, but also to people from underrepresented groups in planetary science to gain mission experience.”

“The PS program is vital to maintaining and improving the community's access to missions. Without it, NASA's mission aspect becomes (or remains in some instances) a “good-old-boys” program.”

## 6 Results: Leadership survey

For our Leadership survey (Phase 2; Appendix B), we received input from the leaders of twelve recent and current missions, six of which were competed, and two of which did not have PS programs. Several of these had more than one PS call. Most were dedicated PS program calls although in one case, PSs were associated with a Data Analysis R&A call.

Based on interview responses from mission leadership, the PS program is seen to contribute great value to NASA missions with respect to science return and allowing for an increase in

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<sup>4</sup> For more on “old boys’ clubs” and the effects of closed social networks see [12-15].

qualified and experienced experts working with mission operations and mission data. While there was a clear consensus that the program is valuable for NASA missions, there were somewhat varied opinions on the timing in which PSs should be brought on to missions. There emerged some commonality among responses that indicated that the earlier PSs could be brought on, the better, both for the mission and the PSs, and multiple comments indicated that one year prior to science operations was an ideal time to bring on PSs. The importance of timing and team integration seemed to be based on what the leadership thought the role of the PSs was within their mission: if they were primarily interested in filling in “gaps in expertise and experience,” then timing and team integration were only relevant in order for PSs to be able to understand the mission operations and to have access to necessary data, whereas if leadership was looking for the PSs to become influential and involved team members, there was great attention paid to the integration process and it was generally commented that PSs should be brought on as early as possible. Other themes that were mentioned in the comments had to do with funding issues and the PS selection process.

### 6.1 Adding value

While leaders generally commented that the PS program added value to their missions, especially with respect to science returns and publications, the specific value of the program differed based on mission specifics and the perceived role of PSs. PSs added value to missions either by being fully involved team members, leading to an increase in qualified and engaged mission team members, or allowing missions to have a resource to fill in “gaps in expertise and experience.” As such, some comments on the value of PSs focused on the full participation and integration of PSs into existing teams in order for them to have the most impact, and reflected the idea that PSs were fundamental to the operations and science of the mission:

“[PSs] fundamentally enabled the mission.”

“Key to success seems to be the selection of scientists who could indeed “participate” in the mission and instrument teams, as opposed to simply analyze data... when PS’s can add value by targeting or creating new data products their value is recognized and quickly become full-fledged team members.”

Other comments were more focused on the “void” in expertise within an already established mission team that the PS program could help fill, and reflected less on the importance of team integration:

“The [highest] value of a PS program comes when the selected PSs can fill a void in the existing team and add depth in expertise in the areas that the mission is most strongly addressing.”

“After the various instrument teams were integrated and the mission matured during development, it became clear where the gaps in expertise and experience were. These were filled by PS as much as possible. Also, the PS program allowed [the mission] to add additional senior scientists with broad expertise that could fill team leadership roles.....without being beholden to any instrument team or PI.”

“The [name of] mission made great use of PSs during the many extended mission phases we’ve had over a decade. So much was discovered by [mission name]...it was truly a godsend that we had the ability to bring in new energetic blood of unheard-of [at the time the mission was selected] specialists to figure it all out.”

Despite the slight differences in the ways in which most thought the addition of PSs contributes to a mission, it was clear from the responses that mission leadership felt that overall

the PS program added greatly to the science impact and science returns of the missions in which it was employed. Especially with respect to releasing peer-reviewed publications and papers, many respondents indicated that a PS program can “increase the impact of the mission [by] having more scientists able to analyze the data and interpret it in various ways.” Additionally, there was a recognition among mission leadership that PSs brought “new breadth, expertise, [and] perspectives,” which served to stimulate and engage the existing team and advance the overall mission science:

“The [mission] PSs made important contributions; the team couldn't have done the work without them. They definitely increased the science return from the mission.”

“The added experts brought fresh perspectives to the [small bodies] mission from the Mars and icy satellite community, which was stimulating for the rest of the mission team.”

One of our mission PI respondents chose not to include a PS program on their mission, because they wanted to focus on the prime mission objectives. This mission was very short in duration, and therefore there was thought to be insufficient time to bring on a PS team to help plan the science, which was determined well before launch. In addition, there were no cruise targets for which PSs could have contributed additional expertise. This particular PI thinks that PS programs are better suited for orbital missions or missions with a long cruise phase. However, they said that with hindsight and strictly from a “counting publications” point of view, a PS program would have definitely increased the impact of the mission by having more scientists able to analyze the data and interpret it in various ways, since “there are still many analysis papers that have not been written that could be”.

## 6.2 Timing

Generally, the responses from mission leadership indicated that bringing on PSs earlier on in mission operations and planning was viewed as preferable. It was commented that PSs needed time to familiarize themselves with mission operations and technicalities and to socially integrate themselves into the existing team in order to do their best work and transition into a new mission smoothly:

“...it takes time and practice for anyone to become proficient at [operations], and I wanted our new team members to have that time and practice before we landed.”

“...it takes time for new arrivals to blend into an existing team.”

“The timing of adding a PS program is also critical and the PSs must be selected and brought on early if they have any chance of informing the planning process.”

Bringing on PSs relatively late into a mission was said to have limited the impact that they had on the mission in terms of decision-making and planning:

“...the PS were joining instrument teams and a joint science team that had already been together for 7 years, so they could not participate in a lot of decisions, learning, and team-building during that time.”

“...the long-term planning for [mission target] was very finely tuned by the time the PSs were incorporated because the mission was under a tight cost cap, so the PSs did not participate in any operations or scientific planning.”

“...[the best time] to select PSs would encompass the time when the community becomes very interested in the designated targets (new observations, modeling, etc.) for a mission.”

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Opinions on more specific timing of when to bring on PSs differed based on the type of mission (flyby vs. orbital) and the perceived role and value that PSs were going to contribute, where involving PSs later into mission planning and operations allowed for missions to fill in holes in expertise emerging later in the mission:

“An advantage with having later timing is that [the mission] and its instruments could pick up ‘competing team’ members – i.e., after the instrument and mission selection. This alleviates issues with competition, dividing expertise.”

However, most mission leaders agreed that the potential sweet spot for timing of PSs, was one year prior to science operations because it gives enough time for the PSs to get up to speed on the instruments and operations while not being too much of a funding burden:

“[I] would bring them onboard earlier for more involvement with PSP science planning, but not too much earlier as don’t want to just do a team augmentation.”

“...the PSs should join a year or so before arrival at the main target, to give them enough time to become familiar with the mission, instruments, etc. and to integrate into the team.”

“That year was necessary for them to be ready to actively participate...”

### 6.3 Team integration

Views varied on how the integration process went for the PS group, and the importance of an overall “gelling” of the PS group and the existing mission scientists. It seemed that if mission leadership valued the inclusion of PSs into the mission operations, planning, and decision-making, they stressed the importance of full integration of PSs. One respondent commented that they banned the use of the term “PS” within the team, and had established at the outset that “the new team members have the same rights and responsibilities as the original team members.” On some of these missions, the lines between a PS and regular mission team members were blurred, with generally positive results:

“The key for us was to make them full members of the team, with equal rights to data and analysis and equal participation in science to any other team member.”

“On [the instrument] they became de facto members of the [the instrument] team, which worked well. [I] considered them equivalent to Co-Is.”

Even when a high level of involvement and mission operation engagement was desired, however, this level of PS involvement could be challenging to achieve:

“For our mission, identifying an operational role was difficult, both for them when they proposed and for us after we had them on board. In practice, most did primarily data analysis or modeling, with little true operational role.”

The integration process was described by mission leaders as ensuring that PSs are socially integrated into an existing team, training the PSs in terms of operations and mission information, and guaranteeing that the PSs have the same access to all the data and resources as other team members. Some comments indicated that this process was “challenging” and “difficult,” while other responses indicated that the process went very smoothly:

“It is challenging for the project science office to incorporate a large group of new investigators and their support staff into the project all at once. The challenge includes not only training on the mission science and science operations, but also physical and electronic access, credentials, export compliance, software licenses, contracts, etc. The second addition later in the mission required considerable effort to prepare updated operations training information.”



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“It was not a challenge – the addition of PSs into the [mission] team went smoothly and was very successful.”

### 6.4 Funding

Funding was mentioned throughout the comments made by mission leadership, referenced in relation to the timing of bringing on PSs and generally in the need for more funding in order to further develop and strengthen the PS program. One comment indicated that cost was a factor in deciding when to bring PSs onto the mission:

“It was an appropriate time when balancing the cost against the desire to allow time for the PS to get integrated into the larger science team and participate in operational readiness tests.”

Additionally, funding cuts and issues limited the ability of missions to take full advantage of the PS program:

“Although it was easy to identify the funds to support them initially... by the time those funds ran out and we had the opportunity to provide additional funding to extend their participation, no funds were available. All of the under-run had been returned to NASA, and we were getting squeezed on our budget. Funding them would have required taking larger cuts to the core science team, and this would not have been appropriate.”

“Prepare to keep them on during extended mission, or at least have a continuing program and open it up to new people. We continue to suffer on [the mission] because the funding dried up. I think this would not have been as fast if they were Co-Is, but as PSs they are no longer supported.”

The specific operations behind funding was commented on, with one respondent indicating a funding situation that worked relatively well and another identifying the competition for program funding:

“A higher level of support would be good... The [mission’s] PS program was run and funded separately from the [mission team] (by NASA Headquarters) and its selection (and cost cap); this arrangement likely led to its success in magnifying the [mission’s] science results.”

“cost of a PS program is expensive, so NASA doesn't like them. The choice for the community is between a PS program and more money in R&A, because that is where the funding for the PS program comes from.”

### 6.5 Participating Scientist selection

The missions differed in regard to the process by which and timing of when PSs were selected, and the extent to which mission leadership was involved in the selection process. It was mentioned that giving instrument PI’s the choice of whether or not to have PSs in the case of directed missions could potentially be beneficial, as well as ensuring that those responsible for selection fully understand the areas of expertise that are needed:

“...having the PIs of each instrument either opt to have PSs (or not) may have been a better approach. PIs can be very protective of their teams, adding new members to a team, without PI consent can be disruptive to a team.”

“an overabundance of PSs were selected with that [same] expertise, making it more difficult for each PS to find their own niche on the mission, which created some complaints from a minority of the PSs.”

“The key to a successful PS program is very open communication between the PI (mission leadership) and the NASA executives responsible for the mission and the PS program, from

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the time of writing the AO, through selection, and beyond to the execution such that everyone's expectations are understood and addressed.”

From these comments we conclude that frank and open communication must exist between mission leadership and NASA regarding the needs of the mission and the expected scope of the PS program, to ensure that selected PSs will be valuable additions to the project. It is also desirable that the planetary community be offered as much time to prepare for a call as possible, and ample information about the science goals and scope of existing research within the team, so that they can ensure they propose new and complementary science.

### 7 Discussion and recommendations

In general, comments from mission leadership and PSs reflected a consensus in regard to the overall value of the PS program for NASA (intellectual diversity allowing for an increase in science return and filling in gaps in expertise), the timing specifics of the program (bringing PSs on earlier can be beneficial), and funding (consistency in funding is desirable). We found no appreciable difference in the value of a PS program to NASA on competed vs. directed projects. From a personal perspective, many PSs commented about the value created by the program in advancing their career through networking and the opportunity to collaborate with other scientists and industry professionals, and by gaining mission experience in terms of data analysis and especially hands-on operational experience. This is significant, since career satisfaction is critical to retaining good people in any field.

Our data show that PSs are selected from a full range of career levels, thereby providing a significant opportunity for early-career researchers who may be at smaller institutions, or may not have associates on mission or proposal teams. Work by Rathbun et al. [16, 17] demonstrates that PS programs bring increased demographic diversity to planetary-mission science teams. They determined the percentage of women on science teams of robotic spacecraft missions and found that, for the past 15 years, the average percentage of women has remained flat at ~15.8%. They also determined the gender of scientists added to 9 science teams through PS and GI programs, finding that average percentage of women selected in these programs is 24.2%. However, due to the small number of total selections in these programs, each individual call does not substantially increase the percentage of woman on the team. Only for those missions with multiple PS calls was the percentage of women in the overall team increased substantially (13.5% - 25% after two PS calls for MSL, for example).

Because of the benefits of PS programs, unless a mission is of such short duration that no clear value may be added by the addition of such a program, we recommend that:

**Participating Scientist programs should be included on every planetary mission, whether competed or directed.**

#### 7.1 Planning of Participating Scientist programs

The anticipated duration and scope of a PS program should be discussed between NASA HQ and the mission leadership in order to establish the needs of the program early on and to ensure that the program meets the needs of the mission as well as the planetary science community. This will help to ensure buy-in from mission leadership and will help them better prepare for integration of PSs onto their teams. We encourage mission leadership and NASA to discuss the scope of the PS programs (including whether a Participating Scientist or Guest Investigator program is most appropriate) with relevant community groups such as the Planetary Advisory

Committee (PAC) and the Analysis and Assessment Groups. Given the strong support of the planetary community for PS programs, the results of these discussions should be disseminated as widely as possible among the planetary community. We recommend that:

**Expectations for the timing, duration, and scope of a Participating Scientist program should be agreed between NASA HQ and mission leadership as early as possible within the mission timeline, ideally during Phase A. The results of these discussions should be publicized to the planetary community through, e.g., NSPIRES, the Planetary Science Advisory Committee, relevant assessment and analysis groups, and community newsletters.**

The sooner the planetary community learns of a PS program call – even if years in advance – the better prepared they can be to respond. If the community knows that such a call will occur, they are likely to pay more attention to results from the mission, and the quality of proposals responding to that call may improve accordingly. Furthermore, mission leadership should engage in clear communication with NASA about any expertise or capabilities that may be missing from their teams in order that the most valuable PSs can be selected for the team. We recommend that:

**The planetary community should be given as much time as possible to prepare for a Participating Scientist call and sufficient information regarding mission payload and operations activities (e.g., through a Proposal Information Package), and existing team scientific capabilities and goals.**

## 7.2 Funding decisions

With respect to funding, mission leadership generally noted the need for more funding in order to further develop and strengthen the PS program, indicating that cost was a factor in deciding when to bring PSs onto a mission and that funding cuts and issues limited the impact of the PS program. PSs generally accepted the necessary limitations of funding but noted a lack of consistency and transparency regarding funding scope, duration, and the requirement to repropose. Both groups made the overall point that funding issues and cuts negatively impacted the influence and impact of the PS program, and more funding could make the program even more valuable.

Given the widespread benefits of PSs programs to NASA and the planetary community, it is recommended that funding for these programs is identified as early as possible. If PS programs are included in all planetary missions, this could be at the AO phase for competed missions, and when directed missions are first put into the NASA budget.

**Sources of funding for Participating Scientist programs should be identified early, and ideally included in the release of a competitive mission AO or in the announcement of a directed mission.**

While every attempt is made to hold to mission funding profiles, there are inevitably setbacks, and science funding is commonly a casualty of tightening mission budgets. Historically PIs may have been forced to choose between a PS program and some other significant need for their mission. Once the scope of a PS program is agreed between mission leadership and NASA HQ, the funds should be held as separate from other science-team funds unless there are significant developments in the mission that may warrant changes. Although funding is usually reduced in extended mission phases, this is an area where PSs can really contribute, and is an

excellent time to train early-career scientists for mission work at a time when more senior scientists may be moving onto other projects. We therefore recommend that:

**Once allocated, Participating Scientist funds should be held as inviolable, unless significant changes occur to the mission that would warrant a reduction in the program (e.g., failure of a portion of the mission or instrument), or an increase (e.g., groundbreaking findings that may require additional members with specific expertise). Participating Scientist programs should be included in extended mission phases.**

Many of the respondents noted a lack of clarity regarding the timing and duration of their tenure as PSs. It is hoped that this issue will be partially mitigated if a clear PS program plan is put in place early in a mission timeline and is followed, but new PSs should still be made aware of the expectations of their funding, and whether/when they may need to repropose for another phase of the mission. We recommend that:

**The amount of funding for a Participating Scientist program and expectations for its duration should be clearly communicated to Participating Scientists when they are selected.**

### **7.3 Timing of Participating Scientist additions**

Generally, the responses from mission leadership indicated that bringing on PSs earlier in a mission timeline was viewed as better, for the reason that PSs need time to familiarize themselves with mission operations and technicalities and to socially integrate themselves into the existing team. PS comments reflect a similar timing recommendation, namely that being included earlier on in the mission timeline would improve their experience as a PS for reasons of increased integration and easier team participation. However, there is no “one-size fits all” approach given that there is a wide disparity among mission classes and durations. For example, an outer Solar System mission might have a cruise time of many years, while a lunar mission might be completed in a matter of months. Thus careful consideration is needed on a case-by-case basis to determine when is the best time to bring PSs onboard for maximum benefit.

Adding PSs for extended missions can have the benefit of expanding the mission team far beyond its original constituents, and can bring in earlier-career researchers who may not have even been in the field when the mission was selected. These PSs can also bring in new and occasionally crucial ideas, especially if science results regarding a mission target have continued to be published after a mission was designed. Although PSs added during the later stages of a mission may have fewer opportunities to get involved in mission design or operations, they can still bring tremendous value to the mission science return, and can still benefit from being part of a mission team.

PSs noted the benefits of getting involved in mission operations, and our data show that those involved in such activities felt generally more integrated into the team. Many respondents who were not able to participate in these activities stated that they would have liked to have done so (Guest Investigators are generally expected to do data analysis only). This is another area where the timing of addition to the mission can have an effect; for example, when PSs are added during major mission operations, there may be no time to integrate them into these activities. Some PSs

also noted that they had hoped to contribute to mission planning, but that by the time they joined the team, these activities had already been determined<sup>5</sup>. We recommend that:

**Participating Scientists should be brought onto a mission as early as feasible, bearing in mind the trade between cost and integration issues. For most missions, the Participating Scientists should be brought onto a project at least one year before operations at the relevant major target. If possible (and appropriate), Participating Scientists should be given the opportunity to participate in mission operations.**

#### 7.4 Team integration

Whereas for PSs, the idea of team integration was mentioned numerous times and had a strong impact on their perception of the outcome of their PS program experience, the majority of mission leadership comments did not focus as strongly on the importance of integration, instead more on the logistics behind it. This indicates that mission leadership may not fully appreciate the influential impact of the integration experience for PSs and the effect it has on the productivity of the program itself. For PSs, it was clear that a positive team integration experience influenced their ability to work and have a meaningful contribution to the team, and more strikingly, that a bad team integration experience negatively impacted PSs and their experiences.

Comments from mission leadership reflected that the integration process was influenced by their perceived importance and value of the process overall; if it was seen as highly important, leadership made a conscious effort to make it a positive experience and to fully integrate PSs. Some of the differences in leadership perception of the importance of integration can be seen in the varied responses to the integration process itself, where some indicated that this process was “challenging” and “difficult,” and others indicated that the process went smoothly.

Once selected, PSs should be considered part of the science team, with the same status and access to data. Ensuring clear expectations for the timing and scope of PS programs early on in a mission’s lifetime should help to facilitate this. There should be clear understanding between the mission leadership and the PSs as to the projects proposed by the PSs and what can reasonably be accomplished. Efforts should be made to help get the PSs up to speed as quickly as possible, e.g., by assigning a mentor, putting together an onboarding package of useful material, etc. This would enable the PSs to fully participate in science discussions and data analysis, thereby enhancing the science return from the mission. We recommend that:

**Full integration of Participating Scientists onto a project should be given high emphasis by mission leadership and the mission team. Expectations for the Participating Scientists’ scope of work should be made clear when they join the team (e.g., operations, data analysis only, etc.) and they should be treated as equivalent to any other Co-Investigator on the team. This is especially important for Participating Scientists who are selected later in a mission (e.g., missions with a long cruise phase).**

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<sup>5</sup> This is an area that should be carefully noted when reviewing PS proposals; occasionally a PS experiment was proposed that required specific mission planning, but this was not possible within the bounds of the existing mission profile.

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## **APPENDIX A: Community Questionnaire**

### **Questionnaire about Participating Scientist (PS) experiences with NASA planetary missions and perceptions about PS programs.**

*Please note:*

- 1. For the purposes of this survey, we include Guest Investigators and Interdisciplinary Scientists as a type of PS. It is your choice to specify whether you held one of these positions.*
- 2. All answers will be treated in strict confidence.*

#### **Part 1: EXPERIENCES OF CURRENT OR FORMER PARTICIPATING SCIENTISTS ON NASA PLANETARY MISSIONS**

- Are you now, or have you ever been, a Participating Scientist (PS) on a NASA planetary mission (if not, please skip to Part 2)? If so, which mission(s)?
- At which point in the mission were you appointed as a PS?
  - (a) before launch (if you know the mission phase i.e., A-D, please state it)
  - (b) during cruise (Phase E)
  - (c) during the primary mission but after arrival at the primary target
  - (d) during the extended mission
- How long did you remain on the project as a PS? (Please describe how long your funding/PS position lasted, also whether you were kept on the team as an unfunded PS after this time period.)
- Did you have an opportunity to participate in mission operations?
- Were you invited to request/plan specific observations/observing conditions in order to address your scientific focus or did you have to pull your science from observations that the core team planned without PS interaction?
- After an initial time period, did you feel integrated into the team? For example, did you actively participate in science telecons and team meetings?
- Did you transition from a PS to a Co-Investigator on the team? If so, please describe at which phase of the mission this occurred.
- Were you required to re-propose to stay on the team as a PS after the original performance period ended?
- What was most valuable to you about your PS experience (can be different for different projects)?
- What do you think could have improved your PS experience?



**Part 2: PERCEPTIONS ABOUT PS PROGRAMS**

- Is it likely you would apply to be a PS on future mission projects? (Please answer regardless of whether you have been a PS already.)
- What do you think is the value of a PS program for NASA?
- Do you think that a PS program should be included in all directed SMD missions (that is, non-competed; directed to a NASA center), or should this be decided on a case-by-case basis? Please give a reason for your answer.
- Do you think that a PS program should be part of competed, PI-led missions such as Discovery and New Frontiers? Please give a reason for your answer.

**PART 3: OTHER INFORMATION**

- At what stage of career are you?
  - Pre-PhD
  - Early (<10 years from PhD)
  - Mid (10-20 years from PhD)
  - Senior (20+ years from PhD)
  - Other (please specify, e.g., no PhD but active in the planetary field)
- Please tell us about your current professional role. Do you consider yourself to be primarily:
  - A faculty professor at a University or college
  - A soft-money researcher at a University or college
  - A researcher working at an institution that is primarily a mission or instrument provider, (e.g., JPL, GSFC, APL, etc.)
  - A researcher working elsewhere – non-profit (e.g., PSI, SETI, etc.)
  - A researcher working elsewhere – for-profit company
  - A postdoc
  - A graduate student
  - Other (please specify)
- Is there anything else that you would like to tell us that is relevant to this study??

## **APPENDIX B: Leadership Questionnaire**

### **Did you have PSs on your mission(s)?**

If yes:

- At what stage in the mission was it decided that there would be a PS program (e.g., at the proposal stage, after selection, etc.)? How much input did you have into this decision?
- When were the PS's brought on board?
- With hindsight, do you feel that was the right time? ? If not, when would have been a better time?
- Do you feel it was challenging to incorporate the PSs into your mission team? If so, why? (And if, with hindsight, you have any suggestions on what could have been done better – by you, by the mission team, by NASA HQ, etc. – please share.)
- Do you feel the PSs brought additional value to your mission? Please give some examples to support your answer.
- If you were PI of a new mission now, what might you do differently with respect to a PS program?

If no:

- What was the main reason for this (e.g., lack of appropriate finances, mission was too short to warrant them, just didn't see the need)?
- With hindsight, do you wish you had included PSs onto your mission?

Is there anything else you would like to tell us?

## **APPENDIX C: Coding methodology**

Comments on respondents' experiences and their opinions on the value and implementation of PS programs were imported into the software package nVivo [3-4]. This is a standard package for qualitative data analysis used by social scientists, which handles tabular entry and allows for flexible cross-correlation between types of responses.

Responses from the survey were coded by trained sociologists with expertise in survey data analysis and interview analysis. The coding schema included A) a series of pre-determined codes to inquire into specific responses and topics of interest to the research team, and B) a round of open coding, wherein researchers looked for relevant themes that occurred natively across answers and deployed the "nodes" feature in nVivo to capture and cross-compare these themes. The sociologists also deployed C) "grounded theory" [18-19] to retain actors' phrasing and native understandings to allow the data to speak outside of predetermined themes. Codes were cross-compared between the two researchers for validity with good inter-coder reliability. Responses were clustered by program participation to garner understandings of the experience of specific mission programs; they were also coded overall for topics and themes common to all PS programs.

The key themes as expressed by PSs and coded independently by two of the coauthors (Schwartz and Wheeler) included: data access, integration, intellectual diversity, underrepresented groups, expertise, science return, selection, open and competed, workforce development, operational involvement, collaboration, mission experience, and funding. Themes were grouped together as they related to three broad categories: the value of the program (for PSs and NASA missions), suggested improvements to the program, and diversity. Across these three categories, participants were most vocal about team integration, the training of future generations of NASA scientists, the science return afforded by the program, and diversity gains (both in terms of intellectual diversity and the incorporation of traditionally underrepresented groups).

A similar method of analysis to the first part of the survey was used for Phase 2: PI and project scientist comments. All of the comments were qualitatively coded by themes (such as Integration, Funding, Value-Added, Leadership, Timing). Again, key quotes and comments were identified in the responses and these were used to help develop an overall analysis of the survey. There were fewer responses in Phase 2 than in Phase 1, so the analysis was more qualitatively focused. For instance, observing common themes in responses that were associated with particular questions allowed us to search for generalizable patterns or sources of consensus in the survey responses.

## APPENDIX D: Program Features and Outcomes

The vast majority of PS participants were positive about their experience and would choose to be a PS again given the opportunity, but this did not give us a sense of which aspects of the PS programs made a true difference. Because each mission's PS program is unique, we tracked core features that varied across all missions: time of onboarding, level of integration, and whether or not they are involved in operations (see §5.8). We also investigated correlations tied to whether or not the mission was directed or competed (single PI) to determine any structural characteristics that affected PS satisfaction.

### Methods

Data was obtained from a survey issued to participants in the Participating Scientists (PS) program, which asked respondents about the experiences and value of the PS program. From this initial dataset, key themes were drawn out in order to assess the value of and potential areas for improvement within the PS program. These areas were the level of integration, when PS participants were brought on to the mission within the mission timeline, and whether PSs had opportunities to participate in mission operations. Responses from the initial dataset that had no mission entered were not included in the analysis, making for a total of 98 responses for this analysis.

For the question of when PSs were brought onto the mission, answers were taken directly from question 1. C) (At which point in the mission were you appointed as a Participating Scientist?), where any time before Phase D was marked as "Early", Phase D was marked as "Launch", and Phase E and later were marked as "Late." Access to operations was taken from responses to question 1. E) (Activities as PS: [Did you have an opportunity to participate in mission operations?]) where the yes/no responses were recoded as they were in the initial dataset.

Since there was no direct question on the initial survey assessing the level of integration that the participating scientist felt overall, responses were qualitatively selected and marked as either "Low" "Medium" or "High" using a combination of:

(A) answers from question 1. E) (Activities as PS: [After an initial time period, did you feel integrated into the science team? For example, did you actively participate in science telecons and team meetings?])

(B) the open response questions such as 1. G) (What was most valuable to you about your PS experience?) and 1. H) (What do you think could have improved your PS experience?).

When a respondent mentioned integration in a positive light or attribute of their experience in these open-response questions, *in addition to responding "yes" to question 1. E*, they were marked as "High." If they did not mention anything about integration or feeling a part of the team in the later questions but also marked "yes" to question 1. E they were marked as "Medium" or "Neutral," and if they responded "no" to question 1. E they were marked as "Low."

Other variables that were included in this analysis included PS levels of satisfaction, where respondents were marked as having a "High" level of overall satisfaction if their open-response survey answers were relatively very positive about their experience, marked as "Low" if they had relatively negative comments, and were marked as "Neutral" if they had

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no strong opinions either way as indicated in their responses. The respondent’s mission alignments were also taken from the initial dataset, and were categorized into single- or multi-PI led missions.

With the new dataset compiled, analysis consisted of comparing the various categories and counting the responses in each in order to identify potential correlations between the three major themes of level of integration, when PSs were brought on, and access to operations. Further comparisons were made between these variables, as well as the PS’s overall level of satisfaction with their experience and mission characteristics (single- vs. multi-PI) in order to identify the specifics strengths and weaknesses of the PS program.

**Results**

We conducted statistical analysis to ensure our findings are meaningful and not due to random chance or dependencies. Using chi-square, the table in §5.8 and those below all showed high degrees of significance with p values less than 0.01. Thus the chances of a random distribution matching these results is less than 1%, and the correlations we observe in the data are trustworthy.

OVERALL SATISFACTION	LEVEL OF INTEGRATION		
<b>HIGH</b> (19)	<b>LOW</b> (0) 0%	<b>MEDIUM</b> (4) 21%	<b>HIGH</b> (15) 79%
<b>NEUTRAL</b> (76)	<b>LOW</b> (12) 16%	<b>MEDIUM</b> (37) 49%	<b>HIGH</b> (27) 36%
<b>LOW</b> (3)	<b>LOW</b> (1) 33%	<b>MEDIUM</b> (1) 33%	<b>HIGH</b> (1) 33%

TABLE D1: Integration vs. Satisfaction (Chisq = 12.179, df = 4 p-value = 0.01043)

To explore whether team integration made a difference for PS program satisfaction, we assembled Table D1. Those who were most highly satisfied were also highly integrated, with comments that spoke to PS’s sense of belonging, of productivity, and of possibility in the field. Those who ranked their satisfaction well but not most highly were on the whole generally well-integrated, with a little over a third of participants reporting the highest level of integration. This indicates to us that **higher levels of PS program satisfaction display higher levels of integration on the mission team.**

However, higher levels of integration are not necessarily a predictor of satisfaction, and the p-value for this table was high compared to the other analyses. This indicated that there may be an additional variable affecting results. Tests on whether or not mission participants already had mission experience, whether on the same mission or another, were inconclusive. In Table D2, then, we report on disaggregating the data between directed and competed missions to see if there was a link between the single- versus multi-PI experience, levels of

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integration, and satisfaction. To do so we eliminated mission reports with only one respondent and focused on those for which we had many replies.

Levels of integration on both directed and competed missions were equally split between low, medium, and high. However, participants on single-PI missions were much more likely to be more enthusiastic about their satisfaction in the program. Well over a third of competed mission participants described their experience in the most enthusiastic terms, while 86% of directed mission participants had satisfactory experiences but only 10% ranked their experience most highly. The p-values for this test support its statistical significance; such distribution cannot be due to chance.

SINGLE PI <sup>6</sup>	LEVEL OF INTEGRATION			OVERALL SATISFACTION		
<b>YES (Competed)</b> (37)	<b>LOW</b> (5) 14%	<b>MEDIUM</b> (16) 43%	<b>HIGH</b> (16) 43%	<b>LOW</b> (1) 3%	<b>NEUTRAL</b> (23) 62%	<b>HIGH</b> (13) 35%
<b>NO (Directed)</b> (51)	<b>LOW</b> (6) 12%	<b>MEDIUM</b> (22) 43%	<b>HIGH</b> (23) 45%	<b>LOW</b> (2) 4%	<b>NEUTRAL</b> (44) 86%	<b>HIGH</b> (5) 10%

TABLE D2: Directed versus Competed mission integration and satisfaction (Chisq = 34.71, df = 12, p-value = 0.00052)

Tempering our results from Table 1, then, integration and satisfaction are clearly correlated, but outcome of that correlation may depend on the PI. On directed missions, the PI's have a more direct opportunity to "make or break" the PS experience either through warm welcome or through benign neglect, producing a stronger effect on levels of satisfaction. On multi-PI missions a welcoming PI clearly makes a difference, but there is much more variation among instrument teams on the same mission. Further, PS's placed on an instrument team with less emphasis on PS integration, or those building bridges between teams, may not be as enthusiastic about their experience as a PS welcomed into the fold. The data therefore suggest that **the instrument or mission PI's effect on the PSs in combination with level of team integration makes a difference for PS satisfaction with the mission experience.**

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<sup>6</sup> International missions or missions with only one response not included.