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Evaluation of the InSightSeers and DART Boarders Mission Observers Programs

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Abstract

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1 Abstract

Encouraging diversity in planetary science requires making a particular effort to bring a broader range of people onto the mission teams that are the backbone of the field. Observer programs, which offer early-career researchers the chance to embed within a mission team during a science meeting are one way of doing this. Here, we present a quantitative analysis of the effectiveness of two observer programs: InSightSeers and DART Boarders, using a mixture of one-group pre-test/post-test and one-group post-test only evaluation methods (total participants, N = 59). We find substantial educational value added to participants from both programs, with particular strengths being the effectiveness of these programs at providing an introduction to mission teams and international collaborations. This work demonstrates that mission observer programs can be an effective way of exposing early-career researchers to planetary science missions.

2 Main

Despite some significant progress in recent decades, many demographic groups continue to be under-represented in the planetary sciences [1, 13, 14]. This is especially true in leadership roles and on mission teams [16, 17]. As well as being inequitable to individuals from under-represented groups and their communities, this imbalance has been shown to have a direct, negative impact on mission and research outcomes [10].

Recruiting and including more early-career researchers (ECRs) from more diverse backgrounds is clearly a necessary step toward making the field more equitable [4, 15]. Within the earth and planetary sciences, there are numerous proposed routes toward this, ranging from funder-mandated changes to grant and program administration [9], more equitable design of graduate recruitment pipelines [18], and grassroots programs focussed on making individual missions more inclusive [8].

One such grassroots initiative has been the establishment of 'mission observer' programs. These are designed to give ECRs an opportunity to experience planetary science mission dynamics and the ways teams work firsthand, normally through embedding them for a time-limited duration in said team during a science meeting, and providing mentorship during the program. Many of these programs have the specific aim of reaching under-represented populations (for example, graduate students and postdocs from institutions without a strong planetary science research presence) in a cost-effective and scalable way. By exposing these ECRs to mission teams, these programs are designed to benefit individuals through offering networking and horizon-broadening opportunities of use in their career development, and to benefit teams by bringing in a more diverse group of potential future mission participants.

Thus far, observer programs of this type have been restricted to NASA-funded missions. Based upon a concept developed by the Europa Clipper team, subsequent iterations have run on the InSight [6], DART [7], and Dragonfly

missions. NASA Headquarters has since instituted a program inspired by the Europa Clipper example, which includes funding for long-term partnerships between missions and minority-serving institutions (MSIs) ('Here to Observe (H2O)' [19]).

In this paper, we focus on two observer programs, InSight's *InSightSeers* and DART's *DART Boarders*. Places in both programs were competitively selected based upon an online application, and whilst the exact format of said application varied over time an exemplar copy is included in the Supplement to this paper. Eligibility varied from cohort to cohort, but in general participants were required to be either senior graduate students or postdoctoral researchers. Applications were greatly oversubscribed (by a factor of 2-3x in most rounds).

In both programs, cohorts of participants were invited to attend a mission Science Team Meeting (3-5 days), and given full access to team presentations, discussions, and networking activities for that week. Each participant was assigned a mentor from the science team to serve as a point of contact for the week. Later cohorts of the InSightSeers program were also invited to present their own research to the team during a poster session.

Both DART Boarders and InSightSeers began during the pandemic, and as such were originally designed for virtual participation. The former was online-only throughout its three iterations, which involved a total of 25 participants. The latter was virtual in its first four iterations and in-person for its final two, involving a total of 97 participants (66 virtual, 31 in-person).

For the last two iterations of the InSightSeers program, applicants were fully funded (i.e. travel, subsistence, and expenses paid) to attend the team meeting in person. As this funding was supplied from NASA and UK Space Agency programs, eligibility was restricted to those currently working or studying in the UK or USA. Although some nationality restrictions were legally unavoidable, the middle three cohorts of InSightSeers and all three cohorts of DART Boarders included numerous non-US/UK participants, who reported the experience as being especially beneficial when coming from countries without extensive planetary science programs.

Where participants have shared informal feedback on these programs, they have generally given strongly positive reviews and highlighted the value of taking part in them [5]. However, a formal and quantitative evaluation of such a program has not yet been published.

In this paper, we evaluate the implementation and outcomes of InSightSeers and DART Boarders. A joint evaluation of these two programs is natural given their similar setup and implementation, and given that both have now completed mission operations, with the DART project completed in November 2023 and Insight currently in Phase F (closeout). This paper evaluates specific value added from the program, lessons learned from an organiser perspective, and best practices for similar programs moving forward.

The methodology used to survey the program participants is described in the Methodology section.

3 Methodology

Because both InSightSeers and DART Boarders were run with limited funds available for organiser time, the ability of organisers to undertake contemporaneous monitoring and evaluation was limited. For the first five cohorts of InSightSeers and all three DART Boarders cohorts, evaluations were only carried out some time after participants had taken part in their respective programs (between 12 and 34 months later). Therefore, the strategy in these cases was to identify long-term value added by participation, for example by using questions designed to explore how individuals' career choices had been shaped (or not) by being a InSightSeer or a DART Boarder. These evaluations constitute a one-group post-test-only evaluation.

For the final cohort of InSightSeers, a small amount of funding was sourced which enabled us to undertake comprehensive pre- and post- program monitoring of both participants and their mentors. This constitutes a one-group pre-test/post-test evaluation. Participants were asked the same set of questions before and after participating, to identify how their responses changed as a result of the program, as were mentors. Such one-group pre-test/post-test evaluation is in common use in educational research [24], especially in settings such as these where we could not practicably generate a control group (e.g. [25–27]). Future studies might consider the creation of such a control group to further investigate program-specific improvements.

Participants were asked to evaluate their familiarity with various aspects of planetary science missions. This included asking them to judge how familiar they were with the mission proposal process, the operation of mission teams in practice, and the scientific side of investigations. Two career-focused questions were also asked, asking participants whether they intended to join a mission team or to pursue a career in planetary science. In these questions, participants were presented with the relevant statement and offered five options ranging from strongly agree to strongly disagree,and then asked to select one.

The pre-program questionnaire also included questions about worries or anxieties which the organisers took steps to address prior to the meeting, whilst the post-program questionnaire also offered space for more detailed qualitative feedback. A similar approach was taken for mentors, though their pre- and post-program questions focused on assessing their confidence in guiding and mentoring ECRs through the experience.

In all cases, surveys included questions on participant demographics. These questions were not compulsory, and were designed to gather information that would help us to assess whether the program had met its aim of encouraging greater diversity within planetary science.

Whilst some questions were multiple choice (e.g. 'What is your age?'), others offered options between multiple choice and free-form text to give participants the space to express themselves freely (e.g. 'What is your gender?'). The language used when describing personal characteristics (especially gender and race/ethnicity) was designed to be both flexible and sensitive, bearing

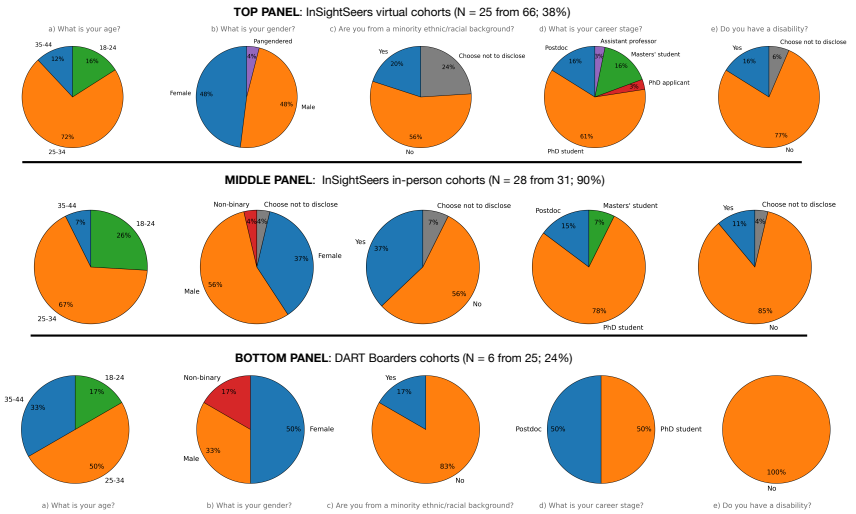

Fig. 1 [Make full size, sideways figure]. Top panel: demographic information for the first four (virtual) InSightSeers cohorts, 38% of participants responding. Middle panel: demographic information for the last two (in-person) InSightSeers cohorts, 90% of participants responding. Bottom panel: demographic information for the three (virtual) DART Boarders cohorts, 24% of participants responding. Across all three panels from left to right, responses are displayed for questions about: (a) participant age, (b) gender, (c) racial/ethnic background, (d) career stage, and (e) disability. Note that for the DART Boarders and InSightSeers cohorts 1-5, where surveys were sent out some time after individuals had completed the program, participants were explicilty asked for their age and career stage at the time of meeting to ensure that results are comparable. Colour-coding is consistent within each column; with the largest proportion overall in orange and the second-largest in blue.

in mind the wide variations in terminology used internationally and changes therein over time.

For the one-group pre-test/post-test evaluation (for the final cohort of InSightSeers), statistical changes were considered between the pre-test distribution and the post-test distribution. This data is treated as paired, and p-values are derived to test significance using a two-tailed test given that changes are seen in both directions. We assume that the null hypothesis, of no statistically significant difference between the pre- and post-test scores, can be rejected if $p < 0.05$.

4 Results/Discussion

We begin by considering the demographic makeup of the InSightSeers and DART Boarders. These data are presented in Fig. 1, split between virtual and in-person cohorts in the case of InSightSeers.

The demographics of all three groups are broadly comparable, though a sample size of 6 for DART Boarders naturally limits how diverse a population can be represented.

Participant demographics were not considered during selection, but nonetheless both missions appear to have attracted a diverse range of applicants, and in turn participants. Whilst there is no single benchmark against which to compare these results, data from a 2020 survey of the American planetary science workforce [17] suggest that the mission observers' cohorts are more diverse than the US planetary science community as a whole. Using these benchmarks, we highlight a few particular strengths , which are listed below. We note of course that these observer programs were open to international applicants whilst the community survey data are dominantly US-based, and that there are differences in terminology used by participants to self-describe their gender identity as compared to the language used in [17].

The greater diversity of the observers' cohorts is particularly true in terms of gender (varying between 37% and 50% identifying as female in our cohorts as compared to a workforce mean of 32% identifying as women), and also race/ethnicity (self-identified between 17% and 37% minority in our cohorts as compared to a workforce mean of 13%).

We also consider changes between InSightSeers cohorts 1-4 (virtual) and 5-6 (in-person), as this dataset gives us an opportunity to explore how participant demographics differed between the virtual and in-person groups.

Firstly, the proportion of younger (18-24) InSightSeers was much higher in-person, as was the proportion of male participants (moving from gender-balanced to 50% more male than female). Virtual cohorts also had higher representation of Masters' students (20% versus 7%), but almost identical representation of postdocs (15% versus 16%). The proportion of those identifying as not from a minority ethnic or racial backgrounds was also the same (56%), though the percentage choosing not to disclose was considerably higher for the virtual cohort (24% versus 7%). The virtual cohort also had a higher proportion reporting a disability (16% versus 11%).

Note however that as successive iterations of the program included changes to make meetings more accessible to ECRs, which may have influenced outcomes, we nonetheless make the following observations and hypotheses:

- The virtual meetings took place before (and earlier in the pandemic) than those in-person. This switch likely impacted the accessibility of the meeting, even though full funding was provided for UK and US participants in-person. Specifically, a week's worth of potentially international travel may not have been practicable for many people, and may have affected the gender and age balance of the meeting, as well as the fraction of those reporting a disability.
- The difference in student makeup (especially the lack of Masters' students in the in-person cohort) may be a reflection of meeting timing, with one falling in the middle of many university term-times (November) and the other in the run up to exams (March). This may be compared to the four virtual meetings, where two fell during summer breaks.

- The substantially higher fraction of respondents identifying as from a racial/ethnic minority background at the in-person meetings may be a product of only UK and US attendees being funded, given that the UK and US have a greater proportion of the population from an ethnic minority than most countries in Europe, where the majority of other participants were drawn from (e.g. see [20, 21]). A specific effort was also made to advertise the final round of InSightSeers to US Minority Serving Institutions (MSIs), which likely affected these results.
- The lower fraction of respondents choosing not to declare their ethnic/racial background in the in-person cohorts may also be attributable (at least in part) to nation-based restrictions. Statistical monitoring of ethnic and/or racial background is common in the UK and US, but rare or discouraged in France and several other European countries from which a substantial fraction of the virtual InSightSeers were drawn [22, 23].
- The lower survey turnout for the virtual cohorts (both InSightSeers and DART Boarders) is likely attributable to the increased length of time between the program and the evaluation being carried out.

Although not part of the survey, we also measured the number of US participants from MSIs by comparing their declared affiliation against NASA's 2023-24 MSI list (https://msiexchange.nasa.gov/msilist). After a specific effort to contact program coordinators and faculty at MSIs to advertise the final round of InSightSeers, the proportion of US participants in Cohort 6 from an MSI was 50%, up from 25% in Cohort 5 (in-person) and 33% in Cohort 4 (virtual). Note that of course not all individuals from an MSI will be from a minority group themselves.

Next, we consider the attitudes of the mission observers toward the programs as a whole. As outlined in the Methodology section, different surveys were used for the three different groups; as such we present the data slightly differently. Fig. 2 presents evaluation data from the final cohort of InSightSeers.

As per Fig. 2, substantive and statistically significant increases (p ¡ 0.05) in the fraction of positive responses are recorded in five of the eight categories. In particular, after the program, 100% of participants agreed that they had 'A good understanding of how planetary science missions work' and 'A good understanding of how techniques in my field developed for Mars might be applied to the Earth or other planets', compared to 25% and 62%, respectively, before participating. These data indicate significant value added to the individuals by participation in the program.

In the two final categories ('I am likely to apply to join a mission team in the future' and 'I hope to pursue a career in planetary science'), only small changes are observed. In the former case it is a small positive increase, in the second case a small decrease is noted. We do not necessarily consider this to be a 'bad' outcome - it may simply indicate some participants decided against working in a mission team environment or pursuing planetary science career. Such an awareness would be equally valuable for planning future education or career steps.

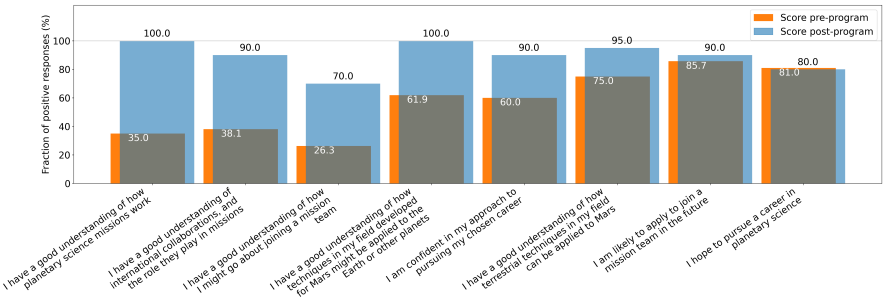

Fig. 2 InSightSeers' evaluations from the final cohort (N = 21 from 22, or 95%, filled out both surveys). The horizontal axis lists all of the questions asked in both the pre- and post-program evaluations, whilst the vertical axis shows the fraction of InSightSeers responding positively (either 'somewhat agree' or 'strongly agree') to each question. Orange bars and white text illustrate the fraction of positive responses pre-program, whilst blue bars and black text illustrate positive increases post-program. For all but the last three columns on the right, the null hypothesis (no significant change) can be rejected at the $p < 0.05$ level.

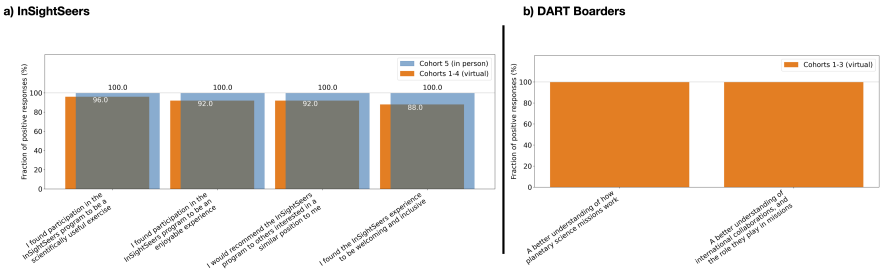

Fig. 3 Panel (a): data from the first five InSightSeers cohorts, split by cohorts 1-4 (virtual, orange bars, N = 25 from 65 in these cohorts) and cohort 5 (in person, blue bars, N = 6 from 9). In the latter case, the fraction of positive responses in every category was 100%. Panel (b): data from all three Boarder cohorts. The questions asked were slightly different, beginning with 'Because of the DART Boarders program, I have...'. Again, the fraction of positive responses was 100%.

Next, we evaluate the attitudes of the first five InSightSeers cohorts and the three DART Boarders cohorts toward their respective programs. Because no pre-program evaluation was carried out, this purely post-program evaluation aimed to judge long-term value added by participation in the programs. These data are presented in Fig. 3.

As per Fig. 3, the overwhelming majority of participants from both InSightSeers and DART Boarders found their participation in the program to be scientifically useful, enjoyable, and welcoming and inclusive. This is a clear indication that they found taking part in the programs worthwhile. Similarly,

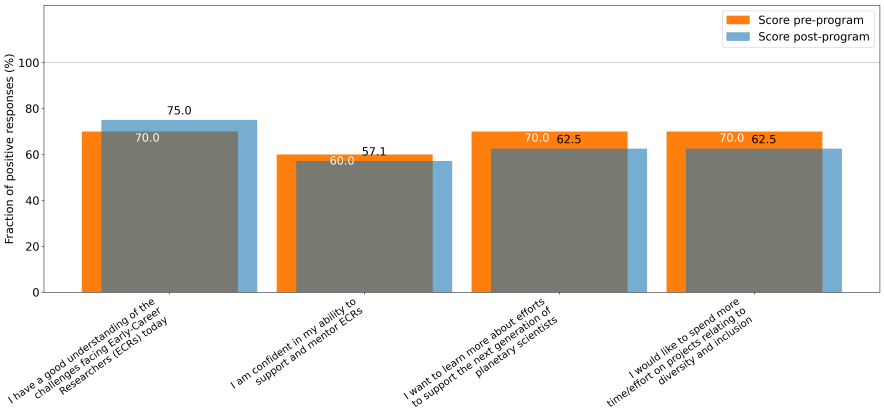

Fig. 4 Data from the InSightSeers' mentor evaluations, with the pre-program scores in orange/white text, and post-program scores in blue/black text. N = 8 from 11.

amongst the InSightSeers (DART Boarders were not asked this question), almost all would recommend a similar program to their peers.

We note that for the InSightSeers, the fraction of positive responses is higher across all categories for the in-person cohort. This is likely attributable to a greater scope for informal discussions, networking, asking questions, and intra-cohort bonding during the in-person meeting. Some improvements are also likely attributable to changes to the meeting program to better accommodate InSightSeers, for example reserving the two questions after each talk for an ECR.

Finally, we consider the attitudes of mentors toward the program. As noted previously, only the mentors from the final InSightSeers cohort were surveyed. These data are shown in Fig. 4.

Fig. 4 indicates no significant changes (at the p ¡ 0.05)in any category for the mentors from the final InSightSeers cohort; with a small positive changes in one category and small negative changes in three others.

The interpretation of these results is multi-faceted: this program was designed to be of most benefit to InSightSeers, not mentors, and hence substantial changes would not be expected. It may even be seen as a positive that there was no substantive decrease in attitudes toward the program, despite the mentors having undertaken a week-long service role with no direct compensation. Conversely, the lack of improvement may indicate that mentors did not gain a better understanding of the challenges facing ECRs today or how to effectively mentor them, and hence explicit opportunities for 'inverse mentoring' or mentor training could be implemented. This is particularly important given that the mentor cohort was more gender-balanced (50% female) than the community as a whole (32% identifying as women, [17]), and hence it is crucial

to ensure that this responsibility does not simply become an additional 'minority burden' or effective time-tax on individuals from already under-represented groups.

It may be that a differently phrased set of mentor evaluation questions would be able to better elucidate potential benefits; but nonetheless we are heartened by the large number of repeat mentors across all cohorts, which indicates that taking part was perceived as at least somewhat valuable or worthwhile.

For completeness, we also estimate the carbon emissions associated with our projects. This is part of a drive toward greater sustainability in scientific research. Emissions are associated with participant travel for InSightSeers cohorts 5 and 6, with other InSightSeers and DART Boarders cohorts being virtual and InSightSeers mentors attending the meeting anyway. Travel-related equivalent carbon emissions for these two cohorts were approximately 25-35 tCO_{2e}. This is made up almost entirely of transatlantic flights by Cohort 5 members from the US travelling to a team meeting in London, UK; and by Cohort 6 members from the UK travelling to a team meeting in Alabama, USA. This is based on an approximate value of 0.15 g/CO_2 emitted per person per kilometre flown. We recognise that this is only an estimate, given both the fundamental uncertainties in such calculations and the fact that we do not have an exact routing itinerary for each individual, only their listed start and end point (though we do account for the fact that all transatlantic flights to/from Alabama require at least one change. Environmental impacts could of course be minimised by matching observers to meetings locations closer to their home; but this was not possible here as funding was not secured more than one meeting in advance.

5 Conclusions

Our analysis of the InSightSeers and DART Boarders programs highlighted the particular value added to observers from learning about how planetary science missions and their international collaborations work. Our data also indicate that these programs have succeeded in exposing a group of individuals to mission teams who are more diverse than the workforce at large, especially in terms of gender, ethnicity, and institution type. From a team perspective, these data also suggest that observer programs are effective ways of getting exposure to new ideas and potential new collaborations.

Drawing upon this experience, and conversations with organisers of similar programs on other missions, we conclude by presenting our identified best practices for the design and execution of mission observer programs.

As recruitment was conducted by program organisers and not participants, suggestions the 'advertising' in this section are based off organiser observations across the multiple iterations of the program, in particular reflections on what 'worked'. Suggestions in the 'setting expectations' and 'meeting format'

sections are additionally include participant reflections shared through longer-format responses to the free-text survey questions; in particular, answers to the four questions 'What did you enjoy most/least about the Science Team Meeting?' and 'If you could change one thing about the program/meeting what would it be?'. The full set of responses to these questions are described in the Declarations section and are included in the Supplementary Information.

Advertising

- Under-represented groups require specific, concerted efforts to reach. They are less likely to be connected into the planetary science community through advisors or mentors, and hence targeted recruitment is beneficial. These efforts can include reaching out to program coordinators or faculty in relevant departments at MSIs, and advertising in minority-serving groups or professional societies. For example, in the final cohort of InSightSeers, 50% of US participants were at an MSI.
- Advertising well in advance is crucial to securing the most diverse group of applicants possible. An additional effect of not being as well-connected to the existing planetary science community is that the 'diffusion time' over which prospective applicants become aware of opportunities is considerably longer. Furthermore, if in-person travel is needed, applicants with more complex personal circumstances (especially with regard to immigrant or visa status) may require more time to prepare; and this would likely disproportionately affect under-represented groups.
- Providing sample application text can help newcomers to the field judge what a successful application will look like. For example, guidance could suggest that applicants not focus solely on demonstrating an existing knowledge of planetary science research topics, but also convey how learning more about a specific mission would align with their current and future research plans and career trajectories.

Setting Expectations

- A pre-meeting online briefing can be a valuable way of introducing observers to their mentors and the wider team, and of enabling the cohort to begin bonding.
- Setting guidelines for the expected frequency of mentor-mentee interactions (e.g. daily during the meeting and at least once after to de-brief/wrap-up) helps to make obligations clear and emphasise that this is a time-limited interaction with no expectation of further interaction or opportunities. This helps manage the mentor's time as well as the participant's expectations.
- Asking all participants to agree to the mission's guidelines/Code of Conduct emphasises that team meetings will be a welcoming and inclusive space, and sets guidelines for what can and cannot be shared with a wider audience (e.g. supervisors) beyond the meeting. It can also provide an opportunity to signpost additional points of contact for any observers who might experience difficulties.

Meeting Format

- As per the data above, it was clear that in-person iterations of the program were much preferred; this was backed up by numerous virtual participants who conveyed that they would have liked to attend in-person. Although virtual participation may improve accessibility and be cost-effective, its negative aspects (e.g. reduced networking and time zone challenges) should be fully considered. An implication may be that it would be potentially less desirable to have observers be virtual whilst the rest of the team is in-person; though this is not a format that we experimented with.
- For in-person meetings, the provision of full funding was clearly crucial to making the meeting accessible to more participants. Buy-in from funding sources (and the ability to leverage secured funding to gain buy-in from international partner agencies) is an important step toward achieving this.
- Where possible, adjusting meeting formats to maximise observer participation was appreciated by the observers. This could include specific opportunities for observers to interact with mission leadership, to present their own work to the team, and to encourage question-asking (for example, by reserving the first question(s) after a talk for a self-identified early-career researcher.

Program-level suggestions

We recognise that implementation of the extensive list of suggestions given above would come with significant overhead in terms of time and budget. Where possible, we suggest the following program-level developments which would support this:

- Compensating organisers for their time, especially if they themselves are early-career researchers, would make the running of mission observer programs more sustainable. This could be either in the form of logged 'service hours' in lieu of other mission work, or financial compensation (either accounted for as hours-per-week on a grant, or direct payment).
- Given the relatively low cost per participant of even the in-person iterations of InSightSeers (mean $\sim$ 000-1500 USD pp), scope likely exists to make inclusion of budgets for grassroots, mission observer programs a default for planetary missions. This could potentially expand their reach enormously at little cost.
- Until funding for mission observers programs becomes the default, the community should encourage and advertise opportunities to secure agency-level support, including NASA's Topical Workshops, Symposia, and Conferences grant call and the UK Space Agency's Space for All scheme. With enough planning, it may be possible to avoid applicants having to pay upfront and be reimbursed as a later date. For missions with regular meetings both in the US and abroad, funding from international partners could also be used to bring down the per capita cost of participation: for example US funded participants could be directed to US iterations of team meetings (reducing

travel expenses and carbon emissions), with European funded participants attending European meetings.

In this article, we believe that we have demonstrated the enormous value of mission observer programs to the ECR participants, based on quantitative analysis of survey data from the InSightSeers and DART Boarders programs.

We end by sharing some quotations from anonymous participants in these programs (with their explicit consent), which we believe highlights the value of the experience. These include:

- "The DART Boarders program has helped me feel supported in the community as an early-career scientist...I don't know if the other programs also had that kind of approachability from the high-ups in the mission, but that's something that has meant a lot to me..."
- "[DART Boarders] was a very significant part of my career so far. Without this program, I would not nearly be the scientist I am today. This gave me an opportunity to learn from the best in my field about the things I'm acutely interested in."
- "I just want to say thanks for looking out for early career people and making a program like [DART Boarders]. Sometimes it is very hard to get your foot in the door but you simply removed the hinges. :)"
- "Thank you so much for the opportunity! [InSightSeers] inspired me to be where I am today."
- "[InSightSeers] was an unforgettable experience and so much fun. Thanks to everyone who made this happen!"
- "Just want to say, THANK YOU! It's honestly been one [of] the best experience I got to participate so far during graduate school"
- "This whole experience was absolutely amazing. I learned so much and met some great people, both who have had successful careers and fellow Seers. This is a great program, and I believe it really provides great scaffolding for early career scientists."
- "Participating during InSight's 26th STM made me realize that I chose the correct career path in my life, and motivated me further to reach my goals."

Acknowledgments. The InSightSeers and DART Boarders program acknowledge the work of the Europa Clipper team in developing the original 'mission observers' model.

Declarations

5.1 Author contributions

BF, IJD, CN, and MP led the organisation of InSightSeers. NLC and ASR led the organisation of DART Boarders. All other authors assisted in the organisation of InSightSeers and the securing of funding.

The authors are grateful to editor Luca Maltagliati and an anomymous reviewer for their suggestions which helped to improve this manuscript.

5.2 Competing interests

The authors declare no competing interests.

5.3 Data Availability Statement

An exemplar application questionnaire, the various surveys used, and raw data are available in the supplement to this paper. Raw data have only been edited insofar as to remove personally identifiable information in a one location, or to clarify named references to InSightSeers organiser team members in one place. Where this has been done, it has been clearly marked as so.

A copy of the participant agreement to take part in the survey, including approval and consent to publish results from our surveys, is included in the supplementary material to this paper.

5.4 Funding

The InSightSeers program was funded in part by the Jet Propulsion Laboratory at the California Institute of Technology under the NASA InSight mission. JPL provided travel support for InSightSeers' travel and the organiser time needed to undertake this analysis. Additional organiser support, was provided by the UK Space Agency under the Space for All program. The DART Boarders program was run by the Johns Hopkins Applied Physics Laboratory under the NASA DART mission.

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