THE NASA PLANETARY SCIENCE SUMMER SCHOOL: INSTRUCTIONAL PRINCIPLES, REMOTE/IN-PERSON FORMAT, AND ALUMNI CAREER PATHS AND DEMOGRAPHIC DATA. J. E. C. Scully[1], T. L. Hudson[1], L. L. Lowes[1], K. L. Mitchell[1], A. E. Nash[1], and B. Rodriguez[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91101, USA.

Introduction: The NASA Planetary Science Summer School (PSSS) prepares the next generation of engineers and scientists to participate in future solar system exploration missions. PSSS provides a bridge from participants' knowledge gained in graduate, postdoc and junior faculty positions to facilitate a jumpstart into the world of planetary science missions.

PSSS strongly encourages a diverse group of eligible students/early career professionals to apply, so that the next generation of scientists and engineers are equitably provided with opportunities to become involved in planetary exploration, and so that future solar system exploration missions can benefit from a diverse range of viewpoints.

Ten years after its inception in 1989 in a lecture format, JPL evolved the PSSS experience to focus on the process of developing a robotic planetary exploration mission concept into reality through concurrent engineering, mentored by members of JPL's advance project design team (Team-X) and by JPL scientists. The participants, guided by the mentor team, progressively refine their mission concept to greater levels of detail following the framework of Concept Maturity Levels. This model of PSSS provides breakthrough learning of concrete skills directly applicable to future careers in planetary exploration.

Overview of the PSSS Experience: PSSS is an 11-week long career development experience: a series of 10 weekly preparatory remote webinars and assignments culminates in an intensive one-week (usually) in-person exercise at NASA Jet Propulsion Laboratory's Project Design Center. During PSSS, participants act as a mission science team (assuming principal investigator and science team roles) and select their mission and science goals from options defined as high priority by the scientific community. Guided by mentors, they begin the development of an early mission concept study in response to a recent NASA Science Mission Directorate Announcement of Opportunity (AO), including mission-science hypotheses, science traceability, instrumentation suites and data sufficiency requirements. Participants also assume engineering roles, such as project manager and systems and subsystem engineers, and work alongside mentors from JPL's advance project design team, Team-X.

The full-time culminating week is typically hosted onsite at NASA's Jet Propulsion Laboratory, where participants undertake a series of Team-X project design sessions. Their mentors aid them in finalizing the design of their mission and instrument suite, and in making the necessary tradeoffs to stay within the cost cap. Once the mission concept design is finalized, the participants present it to a review board of NASA Headquarters and NASA center experts, who give feedback about the strengths and weaknesses of their proposal presentation.

Principles of Instruction: Course design of this immersive experience intentionally includes effective instructional design principles, authentic learning experiences, and design thinking. PSSS is based on the principles of instruction that most promote learning [1]:

- *Learners are engaged in solving real-world problems*: PSSS participants choose to develop a mission concept aligned with planetary science community priorities and their specific interests.
- *Knowledge is activated as a foundation for new knowledge*: by stimulating mental models of experiences in graduate school and beyond to be applied in the mission concept design.
- *New knowledge is demonstrated to the learner*: PSSS mentors guide participants to sources of relevant background information, and provide specific examples from their vast repertoire of actual mission development experiences.
- *New knowledge is applied by the learner*: as participants advance in the understanding of the chosen mission and their roles within it, they increasingly take ownership, while mentors shift from a teaching to a guiding role.
- *New knowledge is integrated into the learner's world:* participants publicly demonstrate their knowledge to the review board of experts, as well as in subsequent conference presentations and professional publications.

An Authentic Learning Experience: A key element of effective instructional design, authentic learning is an instructional approach characterized by real world projects that are relevant to the learner [2]:

- By its nature, PSSS is an authentic activity as conceiving and designing a mission concept in response to a NASA Announcement of Opportunity (AO) mirrors the core reality of doing mission-based science. Moreover, the Team-X tools utilized are the same tools that are used for actual missions.
- By developing a mission in response to a recent NASA AO, PSSS provides an authentic context that reflects the way participants' knowledge will be used in real life.

- PSSS is infused with science and engineering professionals serving as mentors, providing access to expertise and modelling of processes. Mentors guide participants both inside and outside of their areas of expertise, sharing technical knowledge, experience, and valuable narratives.
- Participants assume multiple roles and learn other perspectives from the mentors, who represent different technical areas.
- Concurrent engineering design is by definition collaborative: PSSS utilizes participants' backgrounds and specialized technical roles to collaboratively construct their mission design.
- In addition to Team-X sessions, participants further refine the mission concept design and prepare their final presentation, promoting reflection and articulation, which enables abstractions to be formed and tacit knowledge to be made explicit.
- Given the fast-track nature of mission concept development during PSSS, coaching is provided at critical times to guide participants away from road blocks and enable the participants to stay on track towards the closure of the mission design.
- The preparation and presentation of the participants' mission concept, with feedback from the review board of NASA Headquarters and NASA center experts, serves as an integrated authentic assessment of learning.

Shifting PSSS to an Entirely Remote Environment during the COVID-19 Pandemic: For most PSSS sessions, the culminating week took place at the NASA Jet Propulsion Laboratory's Project Design Center. However, in 2020–2022, the entirety of the culminating weeks took place in a remote environment. This change was made because of safety concerns and restrictions on in-person work arising from the COVID-19 pandemic. The 2020–2022 participants all expressed disappointment at the lack of an in-person experience at JPL, but still rated the sessions highly and on par with previous years that did contain an in-person culminating week. We plan to return to an in-person culminating week at JPL in 2023. The following are approaches and lessons learned from an entirely virtual experience:

The use of technology and collaborative tools

- *For structured interactions:* The mentors set up WebEx meetings for the preparatory webinars and the Team-X sessions. WebEx was suitable to use in these instances because the focus was on the structured relay of information.
- *For free-form interactions:* The participants set up tools that allowed for more free-form interactions, including Slack, Gathertown and Discord. Gathertown and Discord enabled communication between many sub-groups in parallel. Slack and Discord enabled asynchronous communications between the team, which was especially important because of the multiple time zones in which participants and mentors were located. Moreover, taking ownership of these tools at the beginning of PSSS enabled team dynamics to develop early.

The importance of structure

- *Briefings/debriefings:* It is more difficult to ensure that all the mentors and participants are on the same page in an entirely virtual format. Therefore, there were structured briefings and debriefings at the beginning and end of each day, which also provided an opportunity for the mentor team to receive feedback from the participants. Tweaks to the structure and content of the culminating week were often made in real time as a result of this feedback.

Adaptation of networking opportunities

- *Networking with peers:* The Slack, Gathertown and Discord tools were utilized by the participants not only to develop their mission concept, but also for informal networking. There was also at least one participant-led video call per week to work on the assignments. The participant teams built impressively strong team dynamics despite most of the participants never having met in person.
- *Networking with mentors and experts:* Opportunities were provided for informal interactions between the participants and the mentors and experts, but these were generally not as effective nor as frequent than during the in-person culminating weeks. We are looking forward to re-implementing in-person networking opportunities when we return to in-person culminating weeks for the 2023 PSSS sessions.

Updated Employment and Demographic Information for Alumni: PSSS collects demographic data, to track the percentage of women participants and participants from underrepresented groups, compared to the overall community. We also track the career paths of alumni, to evaluate the impact of PSSS on the planetary science community. In our presentation, we will show this latest data and discuss trends throughout the history of PSSS.

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References: [1] Merrill et al. (2002) *Educ. Technol. Res. Dev.* 50, 43-59. [2] Herrington, J. et al. (2014) *Handbook of Res. on Edu. Comm. & Tech.*, 401-412.