Science Initiative: Leading Planetary Exploration and Spacecraft Missions

The EAPS planetary group already has a significant research program in planetary exploration that includes the evolution of planetary and satellite systems, the mineralogic, climatic, and tectonic evolution of planetary surfaces with an eye to past and future habitability, the physics of impact cratering, and involvement in a number of spacecraft missions including remote sensing, rover missions, and sample return. With a significant investment in new planetary science faculty, EAPS is now positioned to take on greater leadership roles in the design, proposal, and execution of new spacecraft missions, target selection and technology design for human exploration, development of new missions and facilities for returned sample analysis, as well as new exoplanet observations from missions and ground-based telescopes. Expansion of EAPS roles in planetary missions will provide new research funding streams, present new research opportunities for faculty and students, increase collaborative opportunities within and outside the department, and elevate the department's international recognition. The EAPS planetary group is uniquely positioned to lead and synthesize space exploration research efforts across campus at Purdue.

Spacecraft Mission Opportunities:

1. **Robotic exploration of the Solar System**

   Initiative: EAPS is now well-positioned to lead robotic spacecraft mission proposals in Solar System exploration. We will increase participation in and leadership of robotic spacecraft missions for planetary science and train the next generation of planetary science mission leaders.

   Rationale: EAPS and the College of Science have invested significantly in new planetary science faculty with the expressed goal of proposing and leading spacecraft missions. The planetary group is already participating in mission and instrument proposals, leading mission concept studies, working on spacecraft and rover teams, and analyzing returned samples. Along with the recent addition of junior faculty who also have significant experience in spacecraft missions, EAPS is now well-positioned to lead mission proposals across many disciplines. This initiative would ensure the development of a long-lasting bridge between the top-ranked AAE program and the emerging leadership of the Planetary Sciences group, as the small satellite capabilities currently under development by AAE could facilitate the development and operation of EAPS-led missions in house at Purdue. These capabilities would position Purdue in a rarefied group of universities around the world and would allow us to develop internationally recognized undergraduate and graduate programs in planetary science and spacecraft missions.

   Key Implementation Tasks:

   A. Make a senior faculty hire with expertise in spacecraft mission or instrument design to provide leadership in mission planning, proposals, and administration.
   B. Conduct interdisciplinary research that cross-cuts themes in planetary science (surfaces, atmospheres, interiors, materials, dynamics) to be responsive as a department and institution to exploration directions and priorities set by NASA and private industry.
   C. Sustain involvement in the science and operations of large-scale NASA planetary exploration missions (Discovery, New Frontiers, and Flagship class mission) through selected proposals to NASA's data analysis programs and direct involvement with mission teams.
   D. Develop undergraduate and graduate programs in spacecraft mission design in collaboration with Purdue's engineering departments through classes and seminars.

E. Lead and participate in concept studies for NASA missions.

F. Increase participation in NASA's Earth-focused spacecraft missions through collaborations between planetary science and the non-planetary disciplines in EAPS and/or a faculty hire at any level with expertise in Earth-focused NASA missions.

2. Sample return missions and analysis (Michelle)

Initiative: Existing expertise positions EAPS to lead and participate in sample return missions and the analysis of those samples. We will continue to build on our analytical laboratory capabilities to capitalize on recent investment from NASA for sample return missions and to ensure our emergence as a community leader in returned and planetary sample analysis.

Rationale: Recent cross-disciplinary hires in EAPS have built a core group of individuals with expertise in the analysis of returned and other planetary samples. The associated development of cutting-edge laboratory facilities has provided the department with strong analytical tools which are capable of investigating a dynamic range of questions related to planetary samples. This initiative would build on this momentum and work to develop a Center for Returned Sample Analysis, making EAPS a compelling and competitive environment for leadership in sample analysis and returned sample missions. A focus on sample return and related missions would leverage NASA's recent investment in these missions and prepare us for the planned return of samples from Mars and the Moon through robotic and human exploration, respectively.

Key Implementation Tasks:

A. Make a faculty hire in the area of planetary petrology to support sample analysis in EAPS, an existing gap in the Planetary group which would offer cross-cutting opportunities with Geology and Geophysics.

B. Sustain involvement in the sample return analysis and mission through selected proposals to NASA's participating scientist programs and direct involvement with mission teams.

C. Increase the analytical capabilities of the department, bringing in bulk chemical analytical tools (e.g., electron microprobe, or ICP-MS) which offers cross-cutting opportunities with Geology and Geophysics.

D. Develop the Center for Returned Sample Analysis on campus to further establish EAPS as an emerging leader in the analysis of planetary samples.

3. Remote Characterization of Exoplanets

Initiative: The interdisciplinary nature of the exoplanet field lines up well with the scientific interests of our department, and recent hires linking G&G and atmospheric with planetary have positioned EAPS to participate in understanding and classification of exoplanets. To establish ourselves in this field we will increase participation in exoplanet observations, build modeling and laboratory capabilities to enable interpretation of those observations, and train the next generation of exoplaneteers. In order to become a leader in the field growth is needed in the areas of remote observations of exoplanets (Astronomy) and planetary interiors (EAPS).

Rationale: Exoplanets lend invaluable insight into the formation of planetary systems and the uniqueness of (or lack thereof) our own solar system. They also have the opportunity to inform some of the biggest scientific questions – Where did we come from and are we alone? Since the boon of exoplanets discovered by Kepler, NASA has been putting money

into learning more about the frequency, type, and characteristics of exoplanets and their planetary systems. These pursuits have brought together astronomers, geochemists and geophysicists, atmospheric scientists, and planetary scientists. With the impending launch of the James Webb Space Telescope (JWST), and several other space and ground-based observatories planned or under consideration, the disciplinary breadth of our EAPS faculty uniquely positions us to capitalize on our current expertise, grow into areas of further interdisciplinary studies, and make our mark in a relatively new, rapidly evolving and impactful field.

Key Implementation Tasks:

A. Establish cross-campus connections between Physics (Astronomy) and EAPS (Planetary, G&G, and Atmospheric) for the holistic study of exoplanet atmospheres, biospheres, surfaces, and interiors via remote observation.
B. Write proposals and develop collaborations to leverage data from current space telescopes (e.g., Hubble), large ground-based observatories, and upcoming exoplanet observation missions (JWST, Nancy Grace Roman Space Telescope (formerly WFIRST)) and proposed mission concepts such as LUVOIR or HabEx.
C. Make a joint hire with Physics focused on remote characterization of terrestrial exoplanets and their atmospheres.
D. Make an (exo)planetary interiors hire within EAPS to complement existing expertise in planetary atmospheres and surface environments, all of which must be considered in evaluations of planetary habitability and even inhabitation status.
E. Develop exoplanet classes for undergraduate and graduate students in EAPS and Physics.

4. Human exploration of the Solar System

Initiative: Make EAPS the leader of campus-wide efforts to develop technologies and strategies for human exploration of the Moon, Mars, and beyond. The rare combination of highly ranked engineering programs (AAE, CE, ME, IE, ABE, and Agriculture) and a diverse planetary science program uniquely positions Purdue to become a world-leader in human spaceflight development, leveraging Purdue's reputation as the Cradle of Astronauts.

Rationale: Ongoing efforts to inform NASA's mission architectures and technology for returning humans to the Moon would benefit greatly from practical knowledge about conditions and materials on the lunar surface, and further analysis and modeling of remote sensing data and returned samples is needed to support these efforts. However, there is currently limited collaboration between human exploration-relevant groups on campus. Collaboration in this area will leverage the existing capabilities on campus, synthesizing our efforts to establish Purdue as a leader in human space exploration. In addition, EAPS lacks expertise and instrumentation in key areas of interest for human exploration, including bulk sample analysis and petrology relevant for landing site selection, planetary origins, and igneous processes.

Key Implementation Tasks:

A. Establish a cross-campus consortium in space exploration to foster collaboration in science, exploration, and engineering efforts across departments and schools. Possible activities could include introductory mixers, internal seminars, and proposal brainstorming sessions. This effort could eventually mature into an official research center.
B. Make a faculty hire in the area of planetary petrology (e.g., igneous petrology) *(joint task with Returned Sample initiative)*

C. Write proposals to be a member of the Solar System Exploration Research Virtual Institute (SSERVI), a NASA block grant program that fosters collaborations among selected teams to advance basic and applied research fundamental to lunar and planetary science, and advance human exploration of the solar system through scientific discovery.
D. Maintain involvement in NASA-funded human exploration initiatives for Mars and the Moon.
E. Further integrate human exploration priorities into our existing curricula (e.g., Mission Design Capstone course).

Key Goals and Metrics:

1. Successful establishment of the Center for Returned Sample Analysis
2. Successful establishment of new avenues for collaboration in space exploration across Purdue including holding at least one campus-wide conference.
3. Make a successful tenure-track hire that contributes to this Strategic Plan (senior hire in missions, planetary petrology, or exoplanet characterization)