**Space Research Network Funded APR Intern**

**Name of Company:** NASA Jet Propulsion Laboratory, California Institute of Technology

**Website URL:** [**https://www.jpl.nasa.gov/**](https://www.jpl.nasa.gov/)

**Student “Space Pitch” Project: Choose one area.**

Example projects to which the successful candidate can be matched:

**Science Projects**

1. What Planetary Chemical Conditions Support the Emergence of Life?
2. Elemental and habitability gradients in hydrothermal vents relevant to ocean worlds
3. Cryominerals Across the Solar System
4. Exploring Atmospheres of the Outer Solar System by Remote Sensing
5. Environmental controls on the formation of “spiders” on Mars

**Robotics Projects**

1. Endurance – autonomy software development and testing for a long-range lunar rover
2. LINC (Learning Introspective Control) – applying machine learning methods to adapt control and planning algorithms to disturbances
3. NeBula Autonomous Search and Rescue – developing robotic search algorithms and testing on ground and/or aerial robots.
4. Long-Range Navigation (LORNA) for a Future Mars Helicopter – aerial vision navigation

**Extended Detailed Project Description & Scope (including tasks, responsibilities and required technical and professional skills):**

**Science Projects**

Scientists at JPL investigate a broad range of phenomena, with a particular focus on understanding the geology and atmospheres of the planets and moons in the solar system. Often these studies are driving research into the search for life, to identify conditions and phenomena that create environments conducive to life as we know it.

**S1. What Planetary Chemical Conditions Support the Emergence of Life?**

This project is part of a research effort to identify potential chemical conditions on exoplanets that would support the emergence of life, and spectral observables to search for such conditions using space-borne observatories. We build and utilize numerical models to predict atmospheric, ocean, and mineral compositions as functions of astrophysical parameters (e.g. stellar spectral type, planet mass, orbital separation) and identify conditions that yield key prebiotic chemicals, redox, and pH conditions. We first simulate modern and Archean Earth as integrated atmosphere-ocean-rock geochemical systems to validate and benchmark our models. We then investigate how varying astrophysical parameters drive prebiotic conditions. In addition to working with the primary mentor, the intern will collaborate with other team members that investigate prebiotic chemistry and exoplanet spectroscopy.

The intern will participate in the development of a computer software suite that incorporates solid and aqueous equilibrium chemistry, atmospheric chemistry, and atmospheric escape to simulate atmospheric compositions and observable spectra. In particular, the intern will investigate the impact of mineral (solid equilibrium) chemistry on atmospheric composition. The investigation will involve setting up appropriate scientific scenarios and conducting computer simulation runs. It will involve some amount of code development/revision as well.

**S2. Elemental and habitability gradients in hydrothermal vents relevant to ocean worlds**

High-temperature black smoker hydrothermal chimneys (up to 400 °C) are inferred to be present in other planetary bodies like Europa. These chimneys form from metal-rich supercritical fluids, which precipitate out as minerals they mix with cooler seawater. These nutrient rich systems are associated with Early life on Earth and are often studied due to their possible relationship with the emergence of life. In the past, we have grown simulations of these vents in the laboratory to study their reactivity based on their overall chemical composition. The next step would be to analyse a transect of a chimney sampled from the deep ocean to understand the elemental composition changes over the growth of the chimney.

Work on this project would consist of; descriptions of the morphology of the chimney, sub-sampling, and running elemental analyses. Skills that would be helpful for this project include; oceanography/geology/or inorganic chemistry, experience with spectroscopy, work with field samples, experience in a wet laboratory.

**S3. Cryominerals Across the Solar System**

Want to recreate an outer planets moon in the lab? The JPL Laboratory Studies Group specializes in the discovery of new and exotic materials relevant to the surfaces of icy bodies in the solar system such as Titan, Europa, Enceladus and Ceres. These materials form in the unique chemical and physical environments of these frigid worlds. Our group utilizes a range of experimental techniques – including Raman and IR spectroscopy, cryogenic X-ray and neutron diffraction, calorimetry, and microscopy – to characterize these materials and their interactions. This work has direct applications to current and future missions, such as Europa Clipper, Dragonfly, and concepts under development to explore Enceladus and the Uranian system. Possible projects include investigation of Uranian moon ice chemistry, Titan cryomineralogy, Europa and Enceladus salt hydrate chemistry, as well as photo- and radiation- chemistries of icy materials.

Useful skills may include: organic chemistry, diffraction experiments, vibrational spectroscopy, experience with vacuum and cryogenic hardware. All interested applicants are invited to apply regardless of experience level.

**S4. Exploring Atmospheres of the Outer Solar System by Remote Sensing**

This project has multiple components that merge data from various sources to explore and understand the processes affecting temperature, composition and cloud properties in the atmospheres of the outer solar system. Components of this exploration merge observations from: the Juno mission currently orbiting Jupiter James Webb Space Telescope, the Hubble Space Telescope, and ground-based observatories. The latter focus on infrared imaging and spectroscopy. Among these observatories are: NASA’s 3-m Infrared Telescope Facility, the Palomar 5-m (200-inch) Telescope, the Keck-II 10-m Telescope, and ESO’s 8-m Very Large Telescope. Individual research programs can combine observations from multiple sources, such as the Juno mission and contemporaneous supporting ground-based observations.

The program includes possible opportunities to engage in astronomical observations with the NASA IRTF or the Palomar Telescope. Tasks include efficient, accurate reduction of the data and the retrieval of atmospheric conditions using an atmospheric retrieval code. At least some programming experience is essential. Useful, but not required, skills/experience include familiarity with the Earth’s or other planetary atmospheres, experience with astronomical observations, or knowledge of retrieval algorithms.

**S5. Environmental controls on the formation of “spiders” on Mars**

Araneiforms, colloquially known as spiders, are distinctive radial-collections of shallow troughs, carved into the Martian surface. These landforms are thought to form due to high-pressure gas flow, due to basal sublimation of the CO2 ice layer that forms each Mars winter. Past students have mapped out the location of these features around the south pole, through a range of terrains. The next step in this work is to categorize the different morphologies of these features, so as to interpret specific morphological aspects as records of local surface and frost conditions.

Work on the project would focus first on the discrimination and mapping/characterization of different araneiform categories. Following this data collection, the work would focus on analysis of the features’ distribution relative to specific frost and surface characteristics so as to improve our understanding of the martian climate and its record. The specifics of the analysis may be tailorable to the student’s interest and expertise. Useful skills/experience include: planetary studies, especially those focused on study of landforms/geomorphology; mapping and interpretation of visible, spectral, and/or thermal aerial/orbital datasets – including comparison and correlation between information types; GIS-platforms for mapping and analysis.

**Robotics Projects**

Future exploration targets for NASA focus on targets in locations that are inaccessible to state-of-the-art rovers, and hence require new types of robot systems. Additionally, future missions require higher levels of autonomy to complete their mission, due to time constraints, communication delays and the challenges of the environment. Each of the projects will involve the development of software and/or hardware for novel robotic systems, including testing on real robots, or collected data.

**R1. Endurance – Long-Range Lunar Rover**

There is a substantial increase in lunar exploration, including the momentum for human spaceflight with the Artemis program. One science target of interest is the South Pole Aitken Basin – an ancient crater over which a rich geological history of the moon can be accessed on the surface. To maximize the science value from this region, however, a system needs to travel over 2000km in four years of operation (in lunar day and night). The Endurance rover is a concept in development for this mission (<https://science.nasa.gov/wp-content/uploads/2023/11/endurance-spa-traverse-and-sample-return.pdf>), with autonomy capabilities being developed for the concept at JPL.

The project will be focused on developing, testing and evaluating different autonomy capabilities for a prototype Endurance rover, including estimation, perception, mapping, planning, autonomy, operations and manipulation for sampling. The requirements on all these elements exceed what has previously been demonstrated in space, hence the team on this project is pursuing research and development to prove what is possible. Development will leverage simulations, building up to demonstration on an existing, scaled-down prototype rover.

Useful skills/experience include: autonomy algorithm development in any of the fields mentioned above, ROS (Robot Operating System), robotic simulations, software integration and field testing of robots.

**R2. LINC – Machine Learning Adaptive Control**

Robots operating in the field and in space are constantly encountering phenomena that are not previously known or modelled. These factors can include disturbances such as wind, complex terrain interactions, degradation in mobility performance, change in mass distributions or new types of terrain. The unmodelled phenomena impact the performance of the robot, degrading performance and increasing risk of damage to the system. The aim of the LINC project is to leverage advances in Machine Learning (ML) to adapt control and planning algorithms on-line to mitigate the effects of unmodelled disturbances. The project is sponsored by DARPA who is also interested in the technology to make human-driven vehicles safer: <https://www.darpa.mil/news-events/2024-3-7>.

Work on this project will focus on control and planning algorithm development and testing, with a focus on learning-based methods. There will be regular cycles of integrating the updated algorithms into the autonomy stack, and testing on hardware systems (tracked vehicles, robotic cranes or robotic boats). Simulation will be leveraged for initial testing and software integration, before testing on hardware.

Useful skills/experience include: control and planning algorithm development, machine learning for robotics, autonomy software stacks, ROS (Robot Operating System), robotic simulations, software integration.

**R3. NeBula – Autonomous Search and Rescue**

NeBula is an autonomy framework that has been developed over several years for autonomous exploration of unknown environments over extreme terrains. This capability is of interest to JPL and NASA fur surface and subsurface exploration of distant worlds. The current project applies NeBula to urban search and rescue, leveraging multiple robots as the mobility component including drones, wheeled robots and legged robots.

Tasks on the project will focus on development of autonomy algorithms to optimize exploration and search of previously unknown environments, including the perception to understand what is explored, and focus on objects of interest. Algorithms will be regularly tested in simulation and on the robots in representative urban environments.

Useful skills/experience include: ROS (Robot Operating System), testing robotic systems, Machine Learning based perception, planning algorithms, robotic simulations, software integration.

**R4. LORNA – Aerial vision navigation**

JPL have been developing concepts for a future helicopter on Mars: one that is an independent mission carrying a science payload. One part of the developments focuses on the autonomy algorithms needed to complete the flights required for a target science mission. The LORNA project focuses on vision-based algorithms for state estimation, localization, and landing site detection/evaluation.

Work on the project will involve a combination of algorithm development, testing in simulation, testing on datasets, preparing hardware for flight demonstrations, and supporting field tests.

Useful skills/experience include: ROS (Robot Operating System), calibrating and operating custom drones (mechanical, electronics, Px4/Ardupilot), OpenCV, computer vision, robotic simulations, software integration.

**Discipline/stream preference:**

Science

[x]  Geology

[x]  Organic Chemistry

[x]  Inorganic Chemistry

[x]  Geography

[x]  Atmospheric science

[x]  Planetary science

[x]  Astronomy

Robotics

[x]  Mechanical Engineering

[x]  Mechatronic Engineering

[x]  Aerospace Engineering

[x]  Electrical Engineering

[x]  Software Engineering