DAY ONE

TUESDAY, DECEMBER 1, 2026

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NASA Planetary Science Division Overview

This presentation will provide science and programmatic updates from across NASA's Planetary Science Division (PSD) and its portfolio of missions and research programs. Future opportunities will also be discussed.

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SMD Technology Priorities

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Mars Exploration Program Technologies

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In-Situ X-ray Instrumentation for Mineral Identification and Elemental Imaging

The “eXtra-Terrestrial Regolith Analyzer” (XTRA) is a next-generation X-ray Diffraction / X-ray Fluorescence (XRD/XRF) instrument that is half the volume, mass and power of the CheMin instrument currently operating in Gale Crater, Mars. In XTRA, XRD data can be collected using either a Charge Coupled Device (flight qualified) or an array of four Hybrid Pixel Detectors (currently under development). HPDs allow for improved 2-θ resolution, do not require deep cooling, are radiation hard, and can accommodate exponentially higher flux rates than the CCD detector used in CheMin. XRF data are collected using a flight-qualified Silicon Drift Detector (SDD). XTRA’s 28 kV high voltage power supply is derived from that used in the PiXL instrument on the Mars 2020 mission, and X-rays are generated with a miniature cathode-grounded microfocus X-ray tube developed jointly with rtw Roentgen at no cost to NASA. A miniature powdering drill and PlanetVac powder delivery system have been developed to protoflight levels by HoneyBee Robotics for use with XTRA. XTRA has been proposed in instrument suites for NASA’s Commercial Lunar Payload Services (CLPS) opportunities as well as other flight programs.

The “Mapping XRF Spectrometer” (MapX) is a full-frame imaging XRF spectrometer that provides postage stamp-sized images of the elements present in a regolith sample. MapX has no moving parts and is either placed on or hovered just above the regolith surface to be imaged. MapX uses a flight-qualified X-ray Micro-Pore Optic (MPO) lens to provide a true 1:1 image of elements fluoresced from the sample onto its CCD detector. Early prototypes utilize X-ray tube sources to fluoresce test samples. The MapX deliverable and future flight instruments are designed to use zero-power 244Cm radioisotope sources (used in all APXS instruments). 244Cm radioisotope sources are under development for MapX (and an APXS instrument called “LunaPIX”) at Lawrence Livermore National Laboratories (LLNL) and will be tested in our prototype instruments in 2027.

Individual components developed for XTRA and MapX have been assembled in differing configurations by our team to yield first-of-their-kind X-ray instruments for X-ray Computed Tomography (XCITE3D, this conference), and down-looking rover mounted XRF spectrometers.

Components: high voltage power supply TRL 6+; X-ray tube TRL 5; hybrid pixel detectors TRL 6+; micro-pore optic TRL 6+; silicon drift detector TRL 6+; ^{244}Cm radioisotope sources TRL 3. Instruments: XTRA XRD/XRF TRL 5+, MapX TRL 5+, both with cryovac testing scheduled to reach TRL 6. Funded through ASTID, PICASSO, MATISSE, DALI and SBIR awards.

PRESENTATION DAY ONE · DECEMBER 1 — **Composition & Spectroscopy**

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Lunar Raman Deep Ultraviolet Visible Spectrograph (DUVIS) Concept

Raman spectroscopy is well suited to both volatile and mineralogical investigations of the lunar surface. The Lunar Raman Deep-Ultraviolet Visible Spectrograph (DUVIS, pronounced “du-viz”) is a dual-wavelength Raman instrument concept under development. Its primary objective is to measure the D/H ratio of water ice in polar micro cold traps, via the relative strengths of O–D and O–H stretching bands, to constrain the sources and evolution of lunar water. The same spectra will survey the relative abundances of non-water volatiles and organic species trapped alongside the ice to further constrain their origins. At non-polar sites, LR-DUVIS will identify major and trace mineral phases to reveal regional histories shaped by impacts, volcanism, and space weathering. DUVIS uses a single spectrograph and detector fed by two fiber-coupled excitation channels: deepUV (266 nm) and visible (532 nm). Both lasers were developed by Fibertek in partnership with TOPTICA Photonics. Comparing spectra from the two channels separates Raman signals from fluorescence for each species. Both channels share a common focusing-lens sensor head that interrogates 50–100 µm spots within the workspace of a lander, rover, or Artemis astronaut workstation. A low-cost commercial camera in the sensor head, paired with 19 LEDs at different wavelengths, provides multispectral context and fluorescence imaging around each sampled spot.

Presently completing the extended fourth year by April 2027 with numerous components and subsystems built and tested at TRL 5 or 6, but not yet integrated for system level TRL 6 environmental testing, planned for next fall with SwRI internal funds. DALI Project 22-DALI22_2-0042, 80NSSC23K0842.

PRESENTATION DAY ONE · DECEMBER 1 — **Composition & Spectroscopy**

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Mid-IR absorption made easy: detection of minerals and organics in-situ

Optical Photothermal Infrared (OPTIR) spectroscopy is an emerging technique that enables the collection of mid-infrared absorption spectra at sub-micron spatial resolution with little to no sample preparation. By combining an infrared excitation laser with a visible probe laser, OPTIR overcomes the diffraction limitations of conventional infrared spectroscopy while retaining access to the diagnostic absorption features used for mineralogical and organic characterization. Under the ORIGINS project, we have adapted this technology for planetary science applications and demonstrated its capability on minerals, planetary regolith simulants, meteorites, and cryogenic organic-bearing ice samples. The technology enables non-contact detection of minerals, hydrated phases, and organic compounds while preserving spatial context at scales relevant to planetary materials. Recent developments include a compact laboratory prototype and the successful co-location of Raman and OPTIR measurements, providing complementary mineralogical and organic information from the same sampling location. This presentation will discuss the current state of the technology, lessons learned during development, and pathways toward future planetary mission applications.

Laboratory prototype (ORIGINS) developed for planetary science applications, with co-located Raman and OPTIR measurements demonstrated and a compact prototype architecture developed. Current Technology Readiness Level: TRL 4. Funding 2021-2026: NASA Science Mission Directorate, PICASSO, Award Number 80NSSC22K1231.

PRESENTATION	DAY ONE · DECEMBER 1	Composition & Spectroscopy

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New Evolving LIBS Capabilities for Ultralight Instruments for Geochemical and Icy Regolith Characterizations

Following our highly successful deployment of LIBS instruments ChemCam and SuperCam on Mars, we are pursuing much smaller instruments ("MicroLIBS," 1.5-2 kg) to fit small lunar rovers, Mars helicopters, and outer solar-system missions. Simultaneously, we are greatly evolving the science capabilities, firstly by developing and demonstrating elemental composition micro-mapping similar to PIXL on M2020 but including light elements H, Li, C, N, and O in a smaller, simpler package. Our lab paper (Manelski et al. doi 10.1029/2026JE009769) demonstrated detection of mineral grain details with a ~5x5 mm major-element map of a lunar highlands breccia in a lunar environment (vacuum). Meanwhile, tests of an assembled flight-like microLIBS instrument are currently involving LANL and IRAP (Toulouse). LIBS is the only fine-scale elemental composition technique that can simultaneously quantify ice abundances and major elements. As such it is highly important for lunar polar exploration. We have just taken delivery of a cryogenic (tested to minus195°C) vacuum chamber at Purdue. However, since we are at the end of our current funding, we are eagerly awaiting an appropriate NASA solicitation so we can raise the TRL on this important aspect of lunar polar resource exploration.

Laser-induced breakdown spectroscopy (LIBS), TRL 9 (ChemCam, SuperCam). MicroLIBS (1.5-2 kg, complete advanced prototype), TRL 4-5, going to 6. LIBS quantification of ice-regolith mixtures in vacuum, TRL 2-3. Funding: NASA PICASSO 80NSSC24K1420 to Purdue, in its final year; CNES and CNRS for French development of MicroLIBS; LANL internal LDRD for US development. No funding yet for cryogenic development.

PRESENTATION	DAY ONE · DECEMBER 1	Composition & Spectroscopy

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A Selective High-Resolution Metamaterial Filter for Infrared Spectroscopy

We present initial work towards an angle-invariant spectral filter that can be used for imaging/spectroscopic instruments on Planetary Science missions. Modern advances in nano-fabrication methods enable innovative optics such as this to tailor the behavior of light passing through. We will present a notional instrument concept incorporating this filter, as well as motivating science to move from state-of-the-art ~10 nm spectral resolution to higher spectral resolution (e.g. 1-3 nm) where needed. We will discuss instrument trades for a metamaterial filter-based instrument as relevant to Enceladus, Comet, Centaur, and Uranus and its moons.

Science simulations complete. Filter architecture changed from the original proposal. Initial filter fabrication and test complete: TRL 3. Instrument trades underway. Funded by PESTO/PICASSO: 80NSSC23K1324.

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Automated Lander Planetary Analog Composition Analyzer (ALPACA)

The Automated Lander Planetary Analog Composition Analyzer (ALPACA) instrument targets organic and amino acid characterization for future icy world landed missions. ALPACA is well-suited for icy ocean worlds (i.e., Enceladus and Europa) where the front-end Biosignature Preparation for Ocean Worlds (BioPOW) system utilizes ion exchange chromatography to de-salt samples and purify organics and potential biosignatures such as amino acids and passes the purified samples for chemical derivatization and subsequent separation and detection by a micro-electro-mechanical system gas chromatograph (MEMS GC). The MEMS GC uses etched silicon components to significantly reduce the size, weight, and power (SWaP) of the GC separation system. This talk will focus on the recent detection of amino acids with a micro-photoionization detector (μ-PID), representing a drastic reduction in the detector sensor mass, volume, and power. Soon in the ALPACA project, prototypes of BioPOW and the MEMS GC will be coupled to demonstrate capabilities and amino acid limits of detection for the overall ALPACA system.

BioPOW and the MEMS GC are both at TRL 4, near 5, with an integration test scheduled for the January to February timeframe. Planetary Science and Technology Through Analog Research (PSTAR), Award Number 80NSSC25K7720.

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Search-for-Life Instrumentation Study

The search for life beyond Earth remains one of the most compelling scientific priorities identified in the 2023 Planetary Science and Astrobiology Decadal Survey, Origins, Worlds, and Life (OWL) (National Academies of Sciences, Engineering, and Medicine, 2023). Habitable environments at Mars, Europa, Enceladus, and possibly others in our solar system (and outside of it) are extreme, low-energy environments, yet may harbor life and its signatures. This study sought to address two questions: Are current techniques and instrumentation capable of detecting biosignatures after accounting for losses or concentration effects from geophysical material transport, sample collection, and processing? What scientific knowledge and technology gaps could be closed to improve the robustness of biosignature measurements? To investigate these questions, we constructed an end-to-end Fermi-style model that started with whole-cell inventory values for Martian permafrost and the oceans of Europa and Enceladus based on terrestrial analog studies of permafrost and polar oceans. Estimates were then made for biosignature loss or concentration across multiple geophysical transport pathways, sample collection and handling approaches, processing techniques, and measurement workflows. The biosignature density or quantity ultimately delivered to an instrument was then compared against estimated detection limits to determine whether a signal would be measurable. Study findings identify gaps associated with particular biosignatures and measurement workflows, as well as cross-cutting needs including: improving constraints on biosignature levels within the habitable environment of origin and effects of geophysical transport; maturation of technologies for sample collection from depth, plume sample handling, and sample concentration techniques; development of shared front-end sample processing steps common to multiple measurement approaches; and improvements to instrument flight suitability and measurement sensitivity for complex samples. Addressing these science and technology gaps would enable significant progress toward flight-ready instruments capable of detecting biosignatures at extremely low abundances in the intriguing, potentially habitable environments of Mars, Europa, and Enceladus.

This study was funded by NASA PESTO, contract 80MSFC20D0004.

PRESENTATION	DAY ONE · DECEMBER 1	Sampling

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Enceladus Plume Capture

Plume Ice Capture of Organics (PICO): Sample collection for in situ biosignature analyses.

PICO is a sampler that collects ice from the Enceladus plume and delivers an aqueous sample to an instrument for solution-based analyses. Particular emphasis is placed on enabling trace organic characterization for potential biosignature detection. PICO would be deployed on the outside of a spacecraft, either transiting the plume from orbit, or deployed on the moon's surface. PICO then closes its chamber lid, and captured ice residue is recovered in a small volume of clean processing water via a microfluidic handling system. Our experiments and simulations of small ice particle impacts into metals previously showed that capture efficiency of organics varies with the ice particle size, speed, and target material. PICO features an optimized capture surface which provides efficient recovery of captured residue. Capture performance is being measured in a newly commissioned test chamber providing a suitable Enceladus analog ice plume in a cryogenic, vacuum environment.

TRL status: the PICO system is at TRL 4. The first generation PICO was fabricated and completed thermal vacuum testing, and the capture surface demonstrated efficient fluidic recovery performance. The main challenge for raising TRL is testing in a relevant Enceladus plume environment, addressed directly with support from MatISSE. PICO capture plates are in a third round of analog plume capture tests; the fluidic design has been optimized with simulations and validated empirically; the capture chamber design underwent detailed reviews. System performance testing is planned for the next round of analog plume testing in 2027. TRL 6 exit criteria require demonstration of the capture of amino acids from doped ice particle impacts, at the size and speed relevant to the Enceladus plume, and their subsequent recovery in a few microliters of water.

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Instrumentation for In-Situ Surface and Subsurface Lunar Science

Advancing lunar surface science requires instrumentation that resolves the near-surface environment and the subsurface. We present two Honeybee Robotics instruments: the Lunar Weather Array (LWA), a distributed surface-deployed sensor suite that characterizes near-surface dust across spatial baselines relevant to resolving transient and localized phenomena; and OptiDrill, an instrumented auger with an embedded optical system and viewing window that enables spatially correlated mineralogical and microtextural observations of subsurface materials as a function of depth. Together, LWA and OptiDrill provide a surface-to-subsurface measurement capability that supports in-situ resource utilization prospecting, volatile characterization in and around permanently shadowed regions, and ground-truth validation of orbital remote-sensing datasets.

Lunar Weather Array: current TRL 4 prototype being built, final hardware to be developed to TRL 6, funded under DALI award 80NSSC25K7422. OptiDrill: TRL 4 prototype built and tested under PICASSO award 80NSSC23K0024.

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Aqueous and Organic-Based Sample Processing Systems: Enabling Search-for-Life and Habitability Assessments

NASA Ames develops fluidic sample-processing systems to enable search-for-life-and-habitability instrumentation suites to achieve optimal performance, while minimizing total system mass, volume, and energy requirements. Sample sizes from a few microliters to tens of cubic centimeters are supported, implementing processing capabilities including: sample retrieval from a collection system; reagent, buffer and standard reconstitution and metered delivery; sample comminution to facilitate extraction of molecular targets; extraction of organics from regolith using organic solvent(s) at elevated temperature and pressure; extraction of water-soluble compounds and salts from regolith; filtering out particles, whether to analyze them or to prevent their interference with other analyses; sample dilution or concentration (to dryness, if required); degassing/de-bubbling liquids; removing salts; adjusting pH or ionic strength; adding dyes or molecular labels to facilitate analysis; capturing and staining particles for microscopy; and delivering metered sample and calibrant aliquots to multiple instruments. We will describe two sample-processing systems: (1) the SPLIce (Sample Processor for Life on Icy worlds) family of fluidic systems that have focused, to date, on samples and conditions anticipated at the icy moons Enceladus and Europa, and (2) the ExCALiBR (Extractor for Chemical Analysis of Lipid Biomarkers in Regolith), designed to extract organic “molecular fossils” from drilled regolith samples on Mars. The overarching principle in the development of these systems is that the science goals and objectives, along with key mission parameters, drive the selection of a complementary and broadly capable suite of life-search instruments, while the requirements of those instruments to deliver reliable and optimal performance drive the design, critical features, and functional requirements of the sample-processing system.

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GenAI for Spacecraft Design and Development: A PESTO Study

NASA faces mounting pressure to reduce spacecraft development cost and schedule while maintaining technical excellence amid increasingly complex missions and constrained budgets. Generative AI offers potential pathways to improve efficiency, yet the technology landscape is dominated by extraordinary claims that make it difficult for decision makers to distinguish genuine near-term capabilities from aspirational promises.

This presentation shares findings from a NASA Planetary Exploration Science Technology Office (PESTO) study that provides systematic assessment of GenAI specifically for spacecraft design and development in mission Phases A through D. We employed a multi-method approach combining extensive research and ideation; expert interviews across NASA centers, aerospace companies, and GenAI vendors; participation in the Text-to-Spaceship Symposium at Goddard Space Flight Center; and hands-on pilot demonstrations applying commercial GenAI tools to a Mars helicopter design problem. We will discuss what capabilities are ready for deployment today, where fundamental gaps remain, and what organizational factors most influence successful adoption.

This work was funded by PESTO in 2026. A follow-on pilot study is currently underway, looking to more concretely demonstrate the state of the art and potential impact of this technology on spacecraft design.

PRESENTATION	DAY ONE · DECEMBER 1	Mobility & Autonomy

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ERNEST Autonomous Mobility with Reinforcement Learning

We are developing autonomous surface mobility for rugged terrain planetary exploration. ERNEST is a 4-wheel rover with a two degrees-of-freedom active suspension that can drive over steep slopes, sand ripples, and wheel-height step obstacles. Unlike passive suspension rovers that automatically adapt to the terrain, ERNEST will require on-board intelligence to take advantage of its superior mobility capabilities to operate on Mars. We use a Reinforcement Learning (RL) approach to enable this capability. The RL algorithm is trained within a high-fidelity dynamics simulator replicating the terramechanics and topography of challenging terrain features ERNEST is expected to handle. The trained algorithm is then deployed on the vehicle and tuned to successfully drive over the challenging terrain. Our plan in FY27 is to extend the range and difficulty of terrain, and demonstrate the autonomous mobility at a Mars analogue site to achieve TRL 5 demonstration of this technology.

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Active Inference Meets Formal Methods: Exploration with High-latency, Low-bandwidth Communication

Algorithms for autonomous decision-making typically under uncertainty rely on known intermediate state/action rewards, as well as priors on states and observations to improve data efficiency. These are brittle with imperfect/uninterpretable models, limited data, or multi-objective tradeoffs, necessitating human supervision to re-shape priors, rewards, observations, and/or policies. However, such interventions are also data and computer intensive, and thus incompatible with high-latency/low-bandwidth communications and limited on-board capabilities for deep space exploration. I will review the development of alternative autonomy architectures that combat these issues with active inference and formal methods, which strike a healthy balance between autonomous operation and human scientific input/interpretability at a distance with minimal data and compute. The first set of methods uses contextual multi-arm bandits to maximize science returns from noisy measurement data, based on asynchronously updated “science shopping lists”. The second set of methods leverages the structure of repetitive multi-objective tasks with unknown rewards and costs to explore optimal plans along prioritized Pareto points, informed by supervisor preferences and operational/safety constraints.

TRL: 3-4. Sponsors: NASA COLDTech Program under Grant #80NSSC21K1031 and in collaboration with JPL under NASA contract 80NM0018D0004.

PRESENTATION	DAY ONE · DECEMBER 1	Mobility & Autonomy

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Collaborative Autonomy for Planetary Exploration

Teams of autonomous robots can expand planetary science by collecting distributed measurements, mapping surface and subsurface structure, and exploring terrain with complementary mobility capabilities. Realizing this potential requires robots to coordinate their actions despite uncertain terrain, imperfect state estimates, communication constraints, and limited resources. This talk will present approaches to collaborative autonomy that connect science objectives with onboard planning, sensing, and control. Drawing on my contributions to NASA’s Cooperative Autonomous Distributed Robotic Exploration (CADRE) project, I will discuss autonomous exploration and coordinated rover motion for distributed ground-penetrating radar measurements. I will then highlight ongoing research at Georgia Tech’s Aerospace Stochastic Robotics and Exploration (AstroX) Lab on planning and control under uncertainty, resilient state estimation, and robotic mobility on granular terrain. A central theme is how robots can balance gathering information with making safe progress toward mission objectives, adapting their actions as new observations reveal environmental hazards or changes in system performance. The talk will also highlight experimental evaluation in our planetary terrain facility, where granular terrain and controlled lighting support testing under challenging conditions. I will conclude with opportunities to extend collaborative autonomy to heterogeneous robot teams for lunar surface and subsurface investigations.

The CADRE autonomy system has been integrated with flight hardware and validated in ground experiments. Flight hardware construction and environmental testing are complete; the lunar technology demonstration is pending. The formal project-assigned numerical TRL requires confirmation. Funding: NASA Game Changing Development (GCD) program, Space Technology Mission Directorate.

PRESENTATION	DAY ONE · DECEMBER 1	Mobility & Autonomy

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Commercial Rovers for Planetary Science: From CLPS Lunar Missions to Mars

Honeybee Robotics is building a family of small rovers for planetary science missions and commercial lunar exploration. Two ~100 kg rovers are in development under NASA's Commercial Lunar Payload Services (CLPS) initiative. The CP-21 rover will fly on Firefly Aerospace's Blue Ghost Mission 3 in 2028. It will carry the Lunar-VISE instrument suite across the Gruithuisen Domes, a rare example of silicic volcanism on the Moon, on a traverse of ~1.1 km. The ~100 kg CT-4 rover was selected in March 2026 with Intuitive Machines. This rover will carry NASA's Near Infrared Volatile Spectrometer System (NIRVSS) on a 2 km traverse at the lunar south pole in 2030 to measure volatiles. Other, smaller ~25 kg rovers are in development to support Blue Origin's Artemis mission. Our design philosophy to enable low cost and therefore high cadence exploration is not to create standard rovers, but instead to create standard subsystems. We then adapt the rover structure around the specific view factors and keep out zones to optimize performance for specific instrument suites and sensors. We also work with lander primes to build in excess capability to enable commercial ride-along payloads, as well as no-mass software demonstrations or data sales. We are now also applying the same approach to Mars. Under NASA's Mars Exploration Program STRIDE solicitation, Honeybee was selected in 2026 to mature a relatively affordable commercial Mars rover. The concept adapts elements from the CLPS rover vehicles and considers commercially sourced radioisotope power in addition to solar-powered architectures. This talk covers the rover programs, architectures, how payloads are accommodated on them, and lessons from designing, building, and testing the CP-21 rover thus far.

CP-21 (Moon, 2028): in flight development, past Critical Design Review, funded by NASA CLPS through a subcontract to Firefly Aerospace. CT-4 (Moon, ~2030): selected March 2026, funded by NASA CLPS through a subcontract to Intuitive Machines. Commercial Mars rovers: selected July 2026 under NASA ROSES-2025 STRIDE.

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Mars Aerial and Ground Global Intelligent Explorer (MAGGIE)

This project conducts a mission feasibility study for a novel global mobility Mars exploration platform: Mars Aerial and Ground Intelligent Explorer (MAGGIE). MAGGIE is a compact fixed-wing aircraft with ultra-high productivity efficiency powered by solar energy to fly in the Martian atmosphere. It has vertical take-off/landing (VTOL) capability enabled by advanced deflected slipstream CoFlow Jet (CFJ) technology. MAGGIE is designed to have a gross weight of 125 kg, payload of 20 kg, wing span of 14.12 m, and a total range of 42,011 km with level cruise for one Martian year mission. It cruises at a Mach number of 0.17 at an altitude of 1000 m with a service ceiling of 12 km. CFJ Active Flow Control (AFC) would be the enabling technology to operate in Mars' low Reynolds number (Re < 105) conditions with a very high cruise lift coefficient of CL = 3.24 and aerodynamic efficiency of 5.76. Rocket launch and EDL (entry, descent, landing) for MAGGIE are feasible by using Vulcan Centaur, NASA's SLS (B2), or SpaceX Starship. There are three types of flight trajectories for MAGGIE based on the science missions: 1) Level Cruise: cruise at 1000 m altitude for a range of 125.8 km per charge, suitable for meteorology or ice measurements; 2) Climb-and-Glide: climb to service ceiling of 12 km and then glide to ground for the longest range of 139.84 km per charge, useful for long range flight to the regions where EDL is challenging, like the southern highlands; 3) Climb-and-Spiraling Glide: climb to the service ceiling above the location of interest and then descend via spiral-glide, suitable for magnetic field measurements. All three trajectories can incorporate "scout-and-land" flight missions. Based on the survey of the science landscape conducted in this study, a potentially ground breaking representative mission enabled by the long range and high payload capacity of MAGGIE is developed to address four atmospheric and geophysical science objectives: 1) Determine the timing of the ancient Martian core dynamo; 2) Distinguish between competing hypotheses on the distribution of midlatitude ice on Mars; 3) Localize sources of methane emission identified on the Martian surface; 4) Characterize dynamics of the Martian lower atmosphere. MAGGIE would be the first mission to enable widespread exploration of the ancient Southern Highlands of Mars and would provide a substantial leap in capability for NASA's exploration of the Red Planet. This conceptual study indicates that the MAGGIE concept and its science mission are feasible.

TRL: 2. NASA Funding: this project is sponsored by NASA NIAC Grant Number 80NSSC24K0647.

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Demonstration of a Tunable Infrared Spectroscopic Imaging Lidar (TINSIL) for 4D Volatile Mapping at Kilometer Ranges

We have developed an active-illumination spectral imager to map lunar volatiles and hydration abundance regardless of illumination or thermal conditions. The Tunable Infrared Spectroscopic Imaging Lidar (TINSIL) combines the continuous wideband spectral sampling of a passive spectrometer with the active reflectance and ranging capabilities of a lidar. TINSIL provides a comprehensive reflectance experiment to map the abundances of lunar volatiles including H2O, CO2, NH3, CH4, and H2S at ranges of several meters to kilometers in line of sight. TINSIL's spectroscopic pulsed laser reflectance measurements (1.5 to 3.5 µm) avoid the complications of surface thermal emission and solar illumination and provide accurate measurements at any temperature, location, and time of lunar day, with the highest quality measurements from the regions of greatest scientific interest: the cold, dark permanently shadowed regions (PSRs) near the poles. This capability will answer science questions related to the presence, concentration, and distribution of surface volatiles at the exploration scale, give context to orbital measurements that sample large areas, and provide crucial volatile prospecting data to accelerate and optimize ISRU and Artemis surface sampling efforts. We will report on development towards TRL 4 of our TINSIL system including tunable laser and camera development and performance, reflectance spectroscopy demonstrations, and plans for continued development, expected system performance, and size, weight, and power.

Current status and TRL: tunable laser and HgCdTe camera tested at the breadboard level in a laboratory environment, both subsystems TRL 4. Funding: ROSES PICASSO award (22-PICASSO22-0001).

PRESENTATION	DAY ONE · DECEMBER 1	Mapping

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ELSA — Exploration Lidar Sensor Assembly

The Exploration Lidar Sensor Assembly (ELSA) is a multi-functional 3D imaging lidar that has been developed through a JPL led effort with industry partnership (Octave Federal), funded through SMD and RTMD LAND programs. In the Descent, Deorbit and Landing phase, ELSA provides long range altimetry from 10's of kilometers range to touchdown and real-time high density fully processed 3D terrain maps (4M pixels over 100m region in <2s) that can be processed by the flight computer to detect hazards and identify safe sites for landing. The hybrid detection capability of ELSA allows for scaling of performance with altitude by trading update rate and mapping resolutions. ELSA provides NASA a new sensor capability through a commercial partner (Octave) that directly addresses shortfalls identified in the NASA Civil Space. It would provide landers, both robotic and manned, the ability to localize the spacecraft accurately with respect to the terrain, map and detect hazards in real-time with little or no prior information on the terrain. Given the directive to land and explore the South Pole of the Moon, the challenging lighting conditions that will be encountered will most certainly require an illumination-invariant approach for navigating to and mapping the highly hazardous regions. For Mars missions, the ability of the ELSA sensor to penetrate dust and detect the surface would expand the surface access times for landers which currently are limited to a small window around the annual dust season. ELSA would provide a land-anywhere, land-anytime capability to a multitude of NASA missions. In this talk we will provide an overview of ELSA, present a summary of prior field test results and discuss the state of maturation of flight-capable ELSA.

Current TRL: approximately 6 (NASA TRAIT). Funding sources: SMD Europa Lander, RTMD LAND, SPLICE and AGNS.

PRESENTATION	DAY ONE · DECEMBER 1	Mapping

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Radar Mapping on the Moon: Adding the Third Dimension to Lunar Prospecting

Critical to successful operations on the Moon are adequate site characterizations. Imaging below 1 m and at a range of resolutions are critical for science, lunar prospecting, and future resource production. Two key surveying technologies exist. First, lunar prospecting with an orbital SmallSat that overcomes existing challenges in guidance, control, and navigation and includes a high-frequency radar sounder to characterize the upper 10s of meters of the Lunar subsurface. Advanced Compact Orbiting Radar for luNar sounding (ACORN, TRL 4-5) operates at 40-70 MHz and 15x the Lunar Radar Sounder resolution. Optical navigation using crater topography and radar sounding of the Moons surface can be paired to produce a terrain-based navigation system to accurately locate the SmallSat and its data. A high-resolution, fast gravity solution model can optimize guidance control solutions autonomously allowing a range of orbits. With these solutions, a SmallSat capable of determining ice content within the full regolith column is feasible. Second, a rover-based low size, weight, and power ground penetrating radar (GPR) system for precise local mapping at a landing site. Deep Regolith Sounder Crosspole (DRS-X) GPR is capable of frequencies up to 1.3 GHz and is TRL7. Rover based GPR can be collected along closely spaced transects to assemble grids of data to bridge the prospect to resource scale level of mapping. Using both systems together, absolute radiometric calibration is possible in two complementary ways: 1) geologic ground truth wherein a GPR can locally characterize the structure and properties of the ground to help calibrate the response of the orbital radar surface return, and 2) radiometric reference wherein one can design a radiometric link between the ground and orbital radars to provide a reference signal for absolute calibration. A prospecting strategy of global coverage from orbit and denser surveying in target locations maximizes opportunity.

PRESENTATION	DAY ONE · DECEMBER 1	Mapping

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Swath-Mapping Lidar for Lunar Exploration and Science (SMiLES)

SMiLES (Swath-Mapping Lidar for Exploration and Science) is a next-generation orbital lidar that acquires continuous, gapless topographic and reflectance swaths of the lunar surface at 0.5-meter resolution from 50-km altitude. A wavelength-tunable laser and diffraction gratings enable non-mechanical steering of the beam across 256 cross-track positions at 840 kHz. SMiLES produces 128m-wide pushbroom-like swaths using active laser illumination at ~1550nm. Impervious to lighting conditions, it measures from orbit the topography and normal albedo uniformly across the surface, including in permanently shadowed regions. SMiLES can address key lunar science objectives related to lunar volatiles, young volcanism and tectonics, and interior structure. It can also support surface exploration, by providing sub-meter reconnaissance, hazard mapping, and volatile assessment. The instrument builds on deep GSFC heritage in planetary laser altimetry, and is currently funded by the PESTO DALI program for maturation from TRL-4 to TRL-6. We will present the progress made in this project, now in its second year, and future plans.

In the second year of a three-year DALI project. Opto-electronics box built; optical transceiver assembly designed and key elements procured. Funding: DALI (DALI24_2-0012).

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SpIRRL: Spectroscopic Infrared Reflectance LIDAR

The Spectroscopic InfraRed Reflectance LIDAR (SpIRRL) is an eight band multispectral orbital reflectance and ranging lidar operating between 1.6 and 3.2 microns. SpIRRL's band selection is optimized for the detection and quantification of water ice in regions of permanent shadow and hydroxyl globally. Carrying its own light source, SpIRRL is immune to ambient lighting conditions and can map ice even in the coldest of Permanently Shadowed Regions where too little light is available for passive spectroscopy. This makes SpIRRL ideal for understanding dynamics of ice in PSRs by making repeat measurements for surfaces over their entire range of temperatures and lighting conditions. The instrument can also detect ice deposited by spacecraft traffic, being sensitive to nm thick coatings of ice on silicate grains. SpIRRL can also map hydroxyl globally from the hottest location on the Moon to the lunar night side. SpIRRL's data are collected differentially so lunar thermal emission is removed from the data without the need for a model, so SpIRRL's data are pure reflectance. Application of SpIRRL data will immediately solve the question of dynamics of hydroxyl that are currently plagued by uncertainty in thermal emission removal from passive data. SpIRRL's underlying technology is highly flexible and compounds including organics and supervolatiles could be targeted for a range of mission opportunities.

All SpIRRL subsystems are currently TRL 5 or higher. A complete SpIRRL integrated system will undergo environmental testing before the end of the project, raising the system to TRL 6. SpIRRL is funded by the DALI program grant 22-DALI 22_2-0008.

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DAY TWO

WEDNESDAY, DECEMBER 2, 2026

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Moon Base: Strategic Investments to Close Architecture Gaps

Establishing an enduring presence in the lunar South Pole region requires innovation and knowledge gain across NASA, industry, academia, and international partners. To better communicate the types of research and development that will empower Moon Base development, NASA publishes architecture-driven data and technology gaps. The agency prioritizes these gaps, establishing a roadmap that empowers phased implementation of Moon Base infrastructure and systems. In this presentation, Moon Base systems engineer Audrey Morris-Eckart overviews the gaps, identifying opportunities for organizations to collaborate with NASA to help close them.

KEYNOTE	DAY TWO · DECEMBER 2	Keynote

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RTMD Innovation Program Office Overview

The presentation provides an overview of the Innovation Program Office's (IPO) role in accelerating America's next generation of space innovation. We explore what we aspire to achieve by advancing innovations and innovators to address NASA's most compelling technical challenges and create opportunities for broader national benefit; how we do it through a diverse portfolio of programs and mechanisms; and the outcomes we deliver, from advancing NASA mission capabilities and strengthening the space economy to creating partnerships, commercial applications, and developing the next generation of leaders. We also illustrate how these investments translate into tangible mission impact while also generating technologies with applications well beyond space exploration, including benefits here on Earth.

KEYNOTE	DAY TWO · DECEMBER 2	Keynote

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Exploration Science Strategy and Integration Office Technologies

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Ultra-Compact Terahertz Instruments for Planetary Observations

There has been only a handful of terahertz planetary science instruments that were baselined for space missions in recent years. The primary reason is that the terahertz heterodyne spectrometer instruments are relatively more power hungry and require more mass and volume compared to instruments at other frequencies.

Over the last several years, groups around the globe have made tremendous strides in reducing mass, volume, and power requirements for terahertz heterodyne instruments by focusing on innovative component developments and packaging solutions. Usage of commercial silicon foundries to develop low-power CMOS based components as well as low-profile antenna technology developments helped in this regard. As a result, it is possible to field highly-compact and low-power high spectral resolution heterodyne instruments for various planetary applications for space missions.

These developments have led to the consideration of using other platforms such as balloon-borne, SmallSats, and CubeSats. Traditionally, SmallSats and CubeSats and their related instrumentation development was primarily done by university undergraduate student teams. However, in recent years, the international space agencies have been actively looking into CubeSats and SmallSats as useable platforms to supplement main missions as well as use them for standalone scientific missions. NASA has flown such missions even to Mars for providing communication infrastructure during entry-descent-landing [1].

Development of compact and low-power terahertz scientific instruments for planetary applications, particularly on SmallSat and CubeSat platforms, poses a host of challenges: the lack of available space, severe restrictions on DC power availability, and antenna size limitations are some of them. For example, one has to be innovative in the design of the antennas as traditional high gain reflector antennas (for scientific payload as well as for data communication) are not practical for these platforms. Deployable antennas are preferred; however, even though some efforts are being made in this area, such antennas at terahertz frequencies are either not available yet, or the performance is not satisfactory. In recent years, metasurface and lens based low-profile antennas have been getting a lot of attention to address some of these challenges.

At JPL, we have developed a fully functional submillimeter-wave standalone scientific instrument for planetary science applications. The modular instrument architecture we adopted allows the instrument to be used for standard planetary science missions to the outer-planets, asteroids, or comets, and on CubeSat/SmallSat platforms.

Specifically, we have developed a low-mass (~2 kg) and low-power (~5W) 500-600 GHz high-resolution spectrometer instrument capable of remotely measuring water isotopes and deuterium/hydrogen (D/H) ratios on comets. The broadband instrument can also do trace-gas spectroscopy at this band. The instrument's 18 cm diameter aperture (which can be easily changed to larger diameter aperture, if required) consists of a novel low-profile leaky-wave lens-based antenna with a waveguide feed. We also have developed a low-profile reflector-based antenna that can be implemented instead of the lens antenna if so desired. A microelectromechanical system (MEMS) based calibration switch is integrated along with a variable temperature waveguide-based calibration load, all of which are integrated with the receiver front-end. A low-power (~300 mW) CMOS-SoC-based synthesizer at W-band with Schottky diode-based frequency multipliers generates the LO signal to pump a Schottky-diode based subharmonic mixer with state-of-the-art mixer noise temperature (~1000K). We have also developed a low-power (~1.5 W) CMOS-based backend spectrometer with 3 GHz available bandwidth and 4096 channels. This allows the overall instrument mass and power to be in the range ideal for implementation on planetary/cometary missions to outer planets. We have flown this instrument on a balloon-borne platform for technology demonstrations and TRL advancement.

In this presentation, we will provide the design and implementation of the 500-600 GHz spectrometer instrument with details of innovative packaging solutions, antenna technology, and low-power backend solutions suitable for future planetary science missions.

PRESENTATION	DAY TWO · DECEMBER 2	Composition & Spectroscopy

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The Advanced Multispectral Infrared Microimager (AMIM): A new tool for future in situ exploration of the Moon and Beyond at the Microscale

Future missions to the surfaces of the Moon, Mars, and other planetary surfaces such as small bodies and Ocean Worlds will need instruments that can maximize scientific return, but maintain low mass, size, and power so they can be accommodated on mass and power-constrained landers or rovers. To maximize science return, instruments that can provide crucial information about mineralogy, volatiles and ices, and organics in situ in a spatially-correlated microtextural context, are important for characterizing the geology of planetary surfaces, prospect for potential resources, and enable the selection of the highest value samples for analysis with other instruments and/or for potential return to Earth.

We have developed the Advanced Multispectral Infrared Microimager (AMIM), a compact visible-infrared multispectral microscope, for future landed planetary missions that provides spatially-correlated mineralogical and microtextural information of rocks and soils in situ at the microscale. AMIM will be able to characterize the geology near the lander or rover, support traverse characterization, and facilitate the selection of samples for onboard analysis with other instruments or potential sampling for return to Earth.

AMIM consists of an illumination system composed of compact, low-power multispectral LED arrays coated with narrow-bandpass filters (> 35 wavelengths with FWHM ≤ 50 nm), an adjustable focus mechanism capable of focusing from a distance of few cms (spatial resolution ≤ 30 µm/pixel) to infinity with z-stacking and high depth of field, and a visible-infrared camera capable of imaging from the visible to the midwave-infrared (VIS-MWIR, currently 0.45 - 3.6 µm). This wavelength coverage has wide applicability for the detection of minerals, including igneous and oxide minerals, hydrated minerals, and salts, ices, and organics, important for planetary exploration.

AMIM's compact design enables it to be deployed at the end of a robotic arm, belly on a compact rover or lander, or glovebox inside a space habitat, allowing it to support a variety of robotic and human missions. Thus, AMIM would provide many of the capabilities that are commonly associated with orbital instruments such as CRISM or M3, but at a size and mass comparable to current arm-mounted microscopic imagers for landed science, a powerful tool for future landed missions to the Moon and beyond.

AMIM was developed and matured to TRL 6 for future missions to the surface of the Moon through NASA DALI Award 80NSSC21K0742.

PRESENTATION	DAY TWO · DECEMBER 2	Composition & Spectroscopy

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An In-situ Nuclear Spectrometer with 3D Resolution

The In Situ Nuclear Spectrometer with 3D Resolution (INSPECT3R) is a compact, 3D elemental imaging system for planetary exploration based on the Associated Particle Imaging (API) technique.

This active neutron interrogation instrument achieves centimeter-scale spatial resolution (8 cm × 8 cm × 10 cm) over volumes of up to 50 cm × 50 cm× 40 cm—surpassing the capabilities of existing in-situ planetary nuclear spectrometers. INSPECT3R enables non-destructive, volumetric mapping of elemental composition, resolving layered structures and subsurface heterogeneities while suppressing all environmental background signals through coincidence detection. We present a series of experiments with lunar regolith simulants demonstrating INSPECT3R's ability to identify and localize key elements and buried objects with high precision. This technology offers transformative potential for future planetary science and astrobiology missions and for In Situ Resource Utilization (ISRU) activities on the Moon and elsewhere, providing a new dimension of spatially resolved geochemical analysis critical to surface missions.

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Compact Gamma-Ray and Neutron Spectrometers: From Lunar Flight to Field Prospecting

Gamma-ray and neutron spectrometers are sensitive to hydrogen and bulk elemental composition in the top tens of centimeters to a meter of a planetary surface. Orbital instruments map these quantities at scales of tens of kilometers, but resource prospecting and surface science need measurements at the scale of a traverse. Our group develops compact gamma-ray and neutron spectrometers for both flight and field use. The Miniature Neutron Spectrometer (Mini-NS), built by Radiation Monitoring Devices and ASU, flew on the LunaH-Map CubeSat as an Artemis I secondary payload in November 2022 and validated the performance of its CLYC (Cs2LiYCl6:Ce) detectors in cis-lunar space. The Lunar-VISE Gamma-Ray and Neutron Spectrometer (GRNS) builds on that design, pairing a bare and a gadolinium-shielded CLYC detector to detect both gamma rays and neutrons. Its flight unit completed vibration and thermal vacuum qualification in 2026 and will operate on a rover at the Gruithuisen Domes in 2028. In the field, we have deployed a portable cosmic-ray neutron sensor, with paired moderated and bare detectors, at Alvord playa in Oregon, the Jornada Experimental Range in New Mexico, and the Namib Desert. Like passive neutron instruments on the Moon and Mars, the sensor relies on neutrons produced naturally by cosmic rays, and the paired detectors can be used to constrain near-surface hydrogen and its distribution with depth. We have also used a handheld NaI(Tl) and CLYC gamma-ray and neutron detector to map K, Th, and U across silicic and basaltic terrains in the San Francisco Volcanic Field as an analog for Lunar-VISE. We will present results from the flight and field instruments and discuss how they apply to prospecting for lunar resources.

The CLYC detector technology is at TRL 9, flown in the Mini-NS on LunaH-Map, funded by NASA SIMPLEx (awards 80NSSC18K1385 and 80NSSC21K0116). The GRNS instrument configuration is at TRL 6. GRNS is funded through the Lunar-VISE investigation, selected under NASA PRISM for delivery on CLPS task order CP-21; ASU's work is under subaward GR107263 from UCF.

PRESENTATION	DAY TWO · DECEMBER 2	Composition & Spectroscopy

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Mahina Multispectral Imager: Snapshot Camera for the Moon and Beyond

The Mahina Multispectral Camera is a COTS-based visible-near-IR snapshot imager for lunar landers or rovers ("Mahina" is the Hawaiian word for "Moon"). MahinaCam employs a custom pattern filter installed on a CMOS focal plane, with filters in three wavelengths arranged in a Bayer-like pattern. This approach achieves multispectral capability without moving parts. The baseline wavelengths (430, 750, 940 nm) are sensitive to key features of the Moon's reflectance spectrum, and thus allow the composition (FeO and TiO2 content) and optical maturity (OMAT) of the rocks and soils in the scene to be mapped. The low-cost instrument thus provides a combination of reconnaissance morphologic imaging with spectral parameter mapping, ideal for a panoramic or stereo camera. The instrument is expected to have a mass of <500 g in a volume ~8.6 × 9.6 × 11.1 cm (including the camera housing, electronics, and custom fore-optics). It will consume <3.5 W during imaging. Note that the filter set could be tailored for specific landing sites (lunar polar highlands, lunar maria) or for other destinations in the solar system (Mars, asteroids, etc.).

The COTS camera design is final, with delivery expected in early 2027. The custom pattern filters have been fabricated and the fore-optics lenses ordered. Two complete units will undergo TVac and vibe testing (GEVS) to establish TRL 6, plus radiometric calibration. Supported by the NASA Development and Advancement of Lunar Instrumentation (DALI) program, grant 80NSSC23K0840.

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Luminescence spectroscopy on the Moon and Mars

Time-resolved luminescence spectroscopy has demonstrated the utility of identifying trace elements and minerals on the surface of other planets. Recent results include those from the Perseverance rover SuperCam instrument, which identified corundum on the surface of Mars. Luminescence is very sensitive to bio-organics that have very short luminescence lifetimes, and certain minerals with trace Cr, Mn, and rare Earths with long luminescence lifetimes; time-resolved spectroscopy separates out these signals. Luminescence imaging with the OrganiCam instrument will also expand this capability by highlighting where zones of both bio-organics and luminescent minerals lie in rocks. Because this technique can be performed without sample preparation, and from standoff distances of a few meters, OrganiCam will become a powerful tool for in situ surveying and triaging prior to sampling by more complex and resource intensive instruments to find life on Mars, critical minerals on the lunar surface, and organics in lunar cold traps.

OrganiCam is currently TRL 4 and in the third year of the project to mature the instrument to TRL 6 for Mars and the lunar South Pole, expected by mid-2027. Funded by NASA MATISSE program grant 22-MATISE22-2-0014.

PRESENTATION	DAY TWO · DECEMBER 2	Composition & Spectroscopy

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Magnetometer Science and Instrument R&D at JPL

An overview over magnetometer-related quantum sensing efforts at JPL. We have several technologies in development at JPL, including lower-TRL magnetometers based on Rubidium hot gas, as well as optically or electrically addressed wide band-gap semiconductor related quantum spin solid state sensors, with very low SWaP, but challenges concerning performance metrics. On the higher end of the TRL scale, the JPL compact vector helium magnetometer outperforms flight heritage systems while adding autocalibration capabilities, at the cost of increased SWaP.

SiC-based quantum solid state magnetometers, SiCMAG (electrically addressed, TRL 3), PICASSO 2017-2020. Optically Pumped Solid-State Quantum Magnetometer OPuS-MAGNM (optically addressed, TRL 3), PICASSO 20-PICASO20_2-0044, 2022-2025. Rubidium magnetometers (TRL 2), ongoing NRO funding. Compact Vector-Helium Magnetometer (CVHM, TRL 5), NOAA-funded electronics maturation effort 2024-2025.

PRESENTATION	DAY TWO · DECEMBER 2	Geophysics

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OpGrav - Precise Small Body Mass Measurements during High-Speed Flybys

Mass is a fundamental property of asteroids and comets and is important for determining the composition and density. This instrument development, OpGrav, enables mass measurements from high-speed flyby missions that don't require the spacecraft to stop and orbit the asteroid. With OpGrav, a single spacecraft can measure the mass of many (10+) small bodies in a flyby tour. The instrument consists of a precise dispenser mechanism that sends a white spherical test-mass to pass very close to the surface of the body. By tracking the test-mass with an on-board telescope, we can measure the asteroid or comet's gravitational effect on its motion and solve for the unknown asteroid or comet mass. In this talk, we will present the current hardware and testing progress to date and spacecraft accommodation requirements.

OpGrav is currently completing its second year of a three-year MatISSE development. The current prototype has undergone extensive redesign and just completed functional testing by deploying the test-mass spheres vertically from a high-bay. Engineering Model fabrication begins next spring. The current system mass is 11 kg for a 4-sphere dispenser and all associated hardware. MatISSE Grant, Award Number 80NSSC25K7270.

PRESENTATION	DAY TWO · DECEMBER 2	Geophysics

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The Seismometer to Investigate Interior Asteroid Structure (SIIAS)

Asteroid interiors preserve evidence of their formation, collisional evolution, and response to external forces, yet their internal structure and mechanical properties remain poorly constrained. The Seismometer to Investigate Interior Asteroid Structure (SIIAS) project is developing instrumentation and deployment technologies to enable seismic investigations of these small bodies. Led by the University of Arizona in partnership with Silicon Audio and Honeybee Robotics, SIIAS combines sensitive optical seismic sensors with Thumper, a penetrator designed to emplace instrumentation beneath an asteroid's surface and establish mechanical coupling in a low-gravity environment. Complementary numerical modeling examines seismic sources and wave propagation in rubble-pile interiors to connect instrument capabilities with potential measurements of asteroid structure. This presentation will describe progress in sensor development, deployment-system maturation, and modeling, and discuss the opportunities these technologies create for investigating asteroid interiors and informing planetary defense.

Broadband and short-period optical seismic sensors have demonstrated TRL 6. The Thumper penetrator and launcher deployment-system maturation has achieved TRL 6. Funding: NASA's Maturation of Instruments for Solar System Exploration (MatISSE) program, award 80NSSC23K0174.

PRESENTATION	DAY TWO · DECEMBER 2	Geophysics

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X-ray Computed-Tomography Imager for Targeted Exploration in 3D (XCITE3D)

Motivation X-ray computed tomography (XCT) is a standard laboratory tool for nondestructive 3D analysis of planetary materials [1]. A single scan yields porosity, particle size distribution, grain shape and packing, modal mineralogy, and internal structure, and the sample survives intact for further analysis. Returned samples from Apollo to OSIRIS-REx are routinely imaged by XCT. Yet the physical state of material on a planetary surface, such as regolith packing and structure and pore-filling ice, can be altered or lost during sampling, transport, and curation, and only a small fraction of what is encountered can be returned.

Instrument Concept XCITE3D (X-ray Computed-Tomography Imager for Targeted Exploration in 3D) is a compact, fixed-geometry conebeam XCT for lunar and Martian landers. A 50 kV microfocus tungsten X-ray source and a CsI(Tl)-scintillator-coupled CMOS detector sit on either side of a 1.5 cm-diameter sample tube. The sample rotates through 360° for projection acquisition (~1.5–2 h per scan); projections (1.3–2.1 GB per scan) are downlinked and reconstructed on Earth at sub-100 µm voxel resolution, which minimizes on-board processing and storage. A lander-provided sampler (e.g., Honeybee Robotics PlanetVac, flown on CLPS Blue Ghost M1) delivers material to the tube; granular samples are ejected by N2 flush and coherent cores by push-rod, allowing 4–8 scans per lunar day with no consumables. Current best estimates are 8 kg, 36 × 29 × 21 cm, 35 W during a scan (50 W peak, 7 W idle), compatible with CLPS-class landers.

Development to Date XCITE3D builds on eight years of NASA-funded prototype development under two programs, both of which reached TRL 4. The PICASSO-funded Mars In-Situ Tomography (MIST) instrument features a 25 kV source and a CMOS camera modified for X-ray detection rotating around a Honeybee Robotics coring drill to image 25 mm diameter Mars ice cores [2]. The SBIR-funded Planetary In-Situ X-ray Imager (PIXI) uses a 25-50 kV source, a rotating sample stage, and a converted industrial CMOS X-ray camera to image dense rock (Fig. 1). XCITE3D derives directly from PIXI.

PIXI data on basalt cores show morphologic and mineralogic detail comparable to commercial laboratory XCT, at lower resolution and source power (Fig. 2). Prototype data on volcanic samples have been processed with standard XCT data analysis tools to quantify clast porosity, vesicle fabric, and the abundance and size distribution of minor phases such as ilmenite—the same products the flight instrument will return.

Flight Heritage The X-ray source assembly (tube plus low- and high-voltage controller) inherits architecture and packaging from the Mars 2020 PIXL 28 kV source, operating on Mars since 2021, adapted to 50 kV operation with proven HVPS modifications and a larger industrial ceramic-metal microfocused X-ray tube. Stepper-motor driver electronics derive from OSIRIS-REx OCAMS.

Mission Applications Sample triage for return: on-surface XCT can prioritize which samples to cache, raising science yield per kilogram of return mass (e.g., Artemis, Mars, and small-body sample return). Icy and volatile-bearing cores: polar regolith and ice cores imaged frozen and intact, recording pore-scale ice distribution in its original state and providing a pre-return baseline (e.g., Mars Life Explorer, lunar polar landers). Regolith physical properties: porosity, size-frequency distribution, grain morphology, and fine-fraction content for science, geotechnics, and ISRU feedstock. 3D petrographic context: modal mineralogy and clast-in-matrix texture of basalts, breccias, and impact glasses. Nondestructive evaluation: in-situ inspection of sintered-regolith and 3D-printed ISRU products for porosity and defects.

Path to TRL 6 The TRL 6 plan (~36 months) qualifies a 50 kV source engineering model (EM) including the high-voltage power supply, and in parallel a detector EM (CMOS, scintillator, fiber-optic plate, camera electronics) integrated with the stage and motor driver. Each is tested in thermal-vacuum, vibration, and radiation, then integrated with the sample-handling subsystem for system-level testing in a lunar-relevant cryovac chamber. We seek mission teams, lander and sampling-system providers, and technologists interested in incorporating XCITE3D into upcoming lunar, Mars, and sample-return opportunities.

TRL 4 on two prototype programs, with a plan to TRL 6. NASA PICASSO (MIST; project #17-PICASO17_2-0094, award #80NSSC18K1591) and SBIR (PIXI; award #80NSSC19C0161).

PRESENTATION	DAY TWO · DECEMBER 2	Geophysics

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Entry and Descent Model and Technology Development for Science Missions

NASA's Entry Systems Modeling (ESM) project and the broader Entry Modeling & Instrumentation (EM&I) portfolio develop the cross-cutting models, simulation tools, validation datasets, and enabling technologies for Entry, Descent, and Landing (EDL) of planetary science missions across the Solar System. This presentation will provide an overview of recent advances in aerothermodynamics, thermal protection system modeling, entry vehicle dynamics, uncertainty quantification, and flight instrumentation that are aiming to provide mission risk reduction and to enable new mission architectures. Examples will be drawn from ongoing applications to Dragonfly, DAVINCI, Mars exploration concepts, and future outer planet missions. The talk will highlight how sustained investments in validated modeling, experimental facilities, and technology maturation are improving confidence in EDL system performance while expanding the capabilities available to future science missions.

PRESENTATION	DAY TWO · DECEMBER 2	Entry, Descent & Landing (EDL)

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SMD Relevant EDL Technology Investments in the RTMD/LAND portfolio

This presentation will highlight several Entry, Descent and Landing Technology Investments within the current RTMD Space to Surface Access (LAND) portfolio with relevance to potential planetary exploration missions. LAND has four main investment areas: Entry Modeling and Instrumentation (EMI), Descent Systems (DSS), Guidance and Navigation systems (GNS), and Landing Systems & Environments (LSE). Examples from each will be discussed

Since this talk is an overview of several technologies, there is no unique answer to the TRL question. All technologies discussed were funded as part of the STMD Game Changing Technologies Program and continue under RTMD/LAND.

PRESENTATION	DAY TWO · DECEMBER 2	Entry, Descent & Landing (EDL)

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Entry System Technologies

This talk reviews the current state of entry systems and thermal protection systems (TPS) supporting the next New Frontiers and future low-cost Mars missions. It examines which technologies are emerging, which are mature and available, and which may no longer be available, while emphasizing the importance of maintaining a diverse TPS portfolio for varied mission profiles. The presentation explores both the supply-chain and sustainability challenges, along with the commercial adoption of NASAdeveloped technologies as potentially balancing one another. New innovations, including the MERINO (Materials Engineered for Re-entry using Innovative Needling Operations) family of TPS and Ames's new infusion oven and robotic needling capabilities, are aimed at preserving and advancing core TPS expertise within NASA while addressing gaps created by atrophied TPS such as PICA. The talk concludes with a TPS Technology Readiness Assessment in preparation to support New Frontiers proposers and risk boards ahead of the AO release.

The talk will cover several entry system technologies and their current TRL status, including HEEET, 3MDCP, C-PICA, PICA-D and MERINO. These were mostly funded by STMD and by SMD-PSD in some cases.

PRESENTATION	DAY TWO · DECEMBER 2	Entry, Descent & Landing (EDL)

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Global Reference Atmospheric Model (GRAM)

Global Reference Atmospheric Models (GRAM) Suite is an engineering-level model that provides atmospheric outputs given a location and time. GRAM is often integrated into flight simulations for entry, descent, and landing (EDL), aerocapture, aerobraking, and other aero-assist applications and has been used for mission design analysis for most planetary missions. It is also often counted upon for operations support. GRAM Suite was refactored from several different code bases into a unified framework with APIs for Fortran, C, C++, MATLAB, and Python with Science Mission Directorate support. Additionally, development for GRAM Suite continues, with model data improvements based on the latest scientific consensus on atmospheres for Venus, Earth, Mars, Jupiter, Saturn, Titan, Uranus, and Neptune. This talk will discuss recent developments in GRAM Suite and give a glimpse into future development that the GRAM team is pursuing.

PRESENTATION	DAY TWO · DECEMBER 2	Entry, Descent & Landing (EDL)

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Lunar Capillary Absorption Spectrometer (LuCAS) demonstrating sensitive volatile abundance and isotope analysis

The design, production, testing, and demonstration of a new, complete instrument for lunar volatile analysis will be detailed. LuCAS consists of two primary sub-systems: (1) a sample handling system (SHS), which uses a cold trap to collect volatiles that are later metered to (2) a Capillary Absorption Spectrometer (CAS), which uses infrared spectroscopy to precisely quantify abundance AND isotope ratios. The complete system was specifically developed to measure H2O: δD, δ18O and CO2: δ13C, δ18O to constrain models on source, depletion, contamination, and cycling of lunar volatiles. The precision and accuracy needed for scientifically useful measurements required careful consideration of potential isotopic fractionation effects that can bias the measurement results. In addition, to isotope ratios, LuCAS is also capable of abundance measurements of H2O, CO2, H2S and SO2. The system has been developed from TRL4 to TRL6 culminating with high fidelity demonstrations inside a thermal vacuum chamber in which measurements were taken of volatiles evolved from cold, simulated regolith using a mission relevant drill.

The system has been developed from TRL 4 to TRL 6, culminating in high fidelity demonstrations inside a thermal vacuum chamber, most recently an end-to-end demonstration in October 2026 with cold simulated regolith, a drill and Flight-Forward LuCAS all inside the chamber. Funding: NASA DALI Award 80NSSC24K0698 and NASA SBIR Phase II Award 80NSSC22CA165.

PRESENTATION	DAY TWO · DECEMBER 2	Atmospheres & Volatiles

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The Saturn Composition Tunable Laser Spectrometer (SCTLS) Concept

A Saturn atmospheric probe is one of the candidate missions under the anticipated NASA New Frontiers 5 opportunity. High-priority science objectives for most probe concepts require accurate abundance and isotopic measurements of photochemical species over a descent to at least 10 bar with highly constrained instrument mass, power, and volume allocations. The Saturn Composition Tunable Laser Spectrometer (SCTLS) is an instrument designed to measure key photochemical molecules, including but not limited to CH4, NH3, CO, and H2, as well as selected isotopologue ratios. Measurement of H2 also provides the means to determine the He abundance indirectly through the residual between the total gas number density and the measured molecular constituents. SCTLS combines relevant subsystems from mature (TRL 6+) terrestrial, Mars, and lunar laser spectrometer designs to provide high measurement sensitivity in a compact instrument. These technologies include an all-reflective beam alignment module (patent pending) to align multiple laser outputs into a common optical path and a patented compact, dense pattern multipass cell providing 10 m of effective absorption path length.

SCTLS instrument concept: TRL 4, incorporating subsystem technologies with TRL 6+ heritage. All-reflective multichannel beam alignment module and no fiber. Compact, dense pattern multipass optical cell: patented design providing 10 m effective absorption path length. Current development supported through Southwest Research Institute internal institutional funding.

PRESENTATION	DAY TWO · DECEMBER 2	Atmospheres & Volatiles

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Mini-MARLI, a small lidar for measuring atmospheric wind and aerosol profiles from Mars Orbit

The Mars science community has identified atmospheric wind measurements as a key objective for a future Mars orbiter. To meet this need we previously developed a prototype of the MARLI lidar to measure the height-resolved wind and aerosol profiles. MARLI is a pulsed 1064-nm direct detection lidar designed for a polar orbit and to be pointed ~30° from nadir. This allows measuring the height resolved Doppler shift caused by wind in the aerosol backscatter. Although our work on MARLI showed it is practical for space, its mass and power are large given NASA's new emphasis on smaller Mars missions. To reduce the mass and power we recently developed a newer version called Mini-MARLI. It uses a similar measurement approach but uses newer technology: a pulsed semiconductor-based laser that emits near 780 nm and more sensitive single photon counting detectors. These reduced the lidar' mass and power and improved the resolution of the wind measurements. Our lidar measurement model shows that for typical Mars aerosol distributions the wind speed errors are 2-3 m/sec in the atmosphere's lowest 30 km. We have developed a low power breadboard of the lidar and used it to demonstrate aerosol and wind profiling measurements from our laboratory. The presentation will give overviews of the lidar design, the lidar breadboard and its demonstration measurements and the model predicted measurement performance in Mars orbit.

Measurement approach based on MARLI, which was matured to TRL 5-6. Mini-MARLI uses commercial semiconductor lasers and detectors that have already flown in space. A breadboard of a lower power version was used to successfully demonstrate the key measurement capabilities and resolutions. The TRLs of the Mini-MARLI lidar subsystems range from 4 to 8, with a median of 6. NASA programs: MARLI, 2013 PICASSO award; MARLI, 2016 MATISSE award; Mini-MARLI, 2024 Mars Exploration Program Technology award.

PRESENTATION	DAY TWO · DECEMBER 2	Atmospheres & Volatiles

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Two micron differential absorption lidar for pressure measurement on Mars

Recent advances in millijoule-class pulsed fiber lasers at 1.96 µm make a compact spaceborne differential absorption barometric lidar for Mars feasible. We present a concept that uses the 1.96 µm CO_2 absorption band, with the online wavelength placed in the trough between two adjacent absorption lines. Because the absorption cross section is locally flat there, the measurement is insensitive to small laser frequency variations, which relaxes the laser frequency stability requirement. The design uses a smaller telescope and lower pulse energy than conventional lidars to reduce cost for future Mars missions. The lidar measures column CO_2 absorption optical depth, column CO_2 abundance, surface pressure, and the vertical distribution of dust and clouds. Combining the surface pressure with temperature profiles from atmospheric sounders through the barometric (hypsometric) equation yields atmospheric pressure profiles.

PRESENTATION	DAY TWO · DECEMBER 2	Atmospheres & Volatiles

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Radioisotope Power Systems (RPS) for Planetary Exploration: Current Capabilities and Future Developments

Radioisotope Power Systems (RPS) enable missions in environments where solar power is impractical, such as the outer solar system, shadowed regions, and long-duration surface missions. Current technologies include the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) for power and heat, and Light Weight Radioisotope Heater Units (LWRHUs) for thermal control. This presentation will highlight existing RPS capabilities and ongoing advancements in dynamic power systems, like Stirling converters, which promise greater efficiency, improved fuel use, and support for future high-demand, long-duration missions.

Multi-Mission Radioisotope Thermoelectric Generator (MMRTG): TRL 9. Light Weight Radioisotope Heater Units (LWRHUs): TRL 9. Stirling Converters (up to 2-year duration): TRL 6.

PRESENTATION	DAY TWO · DECEMBER 2	Power

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PRESENTING AUTHOR	Elor, Gilly	AFFILIATION	Stone Aerospace	EMAIL	gilly.elor@stoneaerospace.com

Power over Fiber to Enable a Lunar Underground eXplorer (LUX)

Lunar lava tubes represent some of the most scientifically compelling yet uncharted frontiers in the inner solar system. Exploring these subterranean voids is crucial for establishing future long-term human lunar habitats, as they offer natural shielding against radiation, impacts, and extreme thermal fluctuations.

However, their exploration presents unprecedented robotic challenges: completely unknown 3D topographies, the absence of solar energy, and the impossibility of wireless communication due to non-line-of-sight attenuation. To overcome these challenges Stone Aerospace is developing the Lunar Underground eXplorer (LUX) mission architecture. We propose to explore and map the Mare Tranquillitatis pit (MTP) with the lunar equivalent of an aerial drone: a non-polluting, propulsively stabilized non-ballistic autonomous exploration vehicle. This architecture springboards off terrestrial analog missions utilizing Autonomous Underwater Vehicles (AUVs) exploring unstructured 3D environments. LUX will also be equipped with a self-deployed fiber-optic waveguide to enable non-line-of-sight signal and data transfer and optical Power-over-Fiber (PoF) delivery. Our current analysis indicates that these technologies will enable kilometer-plus subsurface explorations. The LUX mission will further serve as a testing ground for technology which will also overcome signal and power challenges in future lunar bases.

Navigation and Mapping: When communication delays, unpredictable terrains or strict mission timelines prohibit human-in-the-loop driving, robotic systems must recognize and exploit opportunities in unknown environments autonomously. The LUX vehicle will leverage proven 6-DOF hovering capabilities and LiDAR- based Simultaneous Localization and Mapping (SLAM) to navigate the unmapped lunar cave environment.

Communication & Data Transfer: A thin optical waveguide fed from an on-vehicle spooler will connect LUX back to a surface lander or rover. This enables continuous, high-speed data transmission out of the cave, allowing a lander to relay high-resolution spatial and environmental telemetry back to Earth. Even if the vehicle is eventually lost, the data acquired will have already been transmitted out of the cave.

Power: Traditional batteries are too massive for the required mission durations, and solar power is completely unavailable underground. Furthermore, standard electrical tethers become prohibitively heavy and rigid even over short distances. To solve this, we introduce laser PoF, where a multi-kilometer fiber-optic tether delivers continuous high-energy power from a surface-based laser to LUX's onboard systems. Power will never be the limiting factor.

Enhanced Green Propulsion: Unlike ballistic hoppers, continuous thrust control is necessary for obstacle avoidance and mapping. Normally, a mission of this class would use high specific impulse hypergolic propellants. However, such fuels generate a variety of byproducts and unburned propellant which would contaminate the pristine cave, hindering scientific objectives. Thrust and maneuvering must be accomplished with a low specific impulse inert cold-gas or "green" monopropellant. PoF-delivered optical energy fed into the propellant stream can be used to increase the gas temperature as it generates thrust. This enables longer missions with less onboard fuel.

Alignment: The LUX mission and its supporting R&D address NASA's technical gaps, Artemis, Moon-to-Mars objectives, and lunar base needs, particularly in construction, mobility, power, and sustained human occupancy. LUX's versatility stems from its ability to navigate non-ballistic, optimized trajectories without external navigation aids. Alternatively it can be operated under supervised autonomy or astronaut override.

Funding & TRL: NASA NIAC Phase I Grant Number 80NSSC26K0825; An Astraeus Space Institute grant; and Stone Aerospace IR&D. LUX is currently TRL2

PRESENTATION	DAY TWO · DECEMBER 2	Power

PRESENTING AUTHOR	Bergman, Dean	AFFILIATION	Honeybee Robotics, a Blue Origin Company	EMAIL	dbergman@blueorigin.com

Development of a 10 kW Power Tower system for Moon Base

Continuous power through the long polar nights is one of the main limits on sustained science at the lunar south pole. Solar arrays mounted near the surface are shadowed by local terrain for much of the lunar day. This talk presents Honeybee Robotics', a Blue Origin Company, Power Tower, a deployable vertical solar array and energy storage system. It raises sun-tracking solar arrays and a mast-tip payload 20 m or more above a lunar surface to capture near-horizon sunlight that ground-level systems can't reach. The system grew out of the Lunar Array, Mast, and Power System (LAMPS), which Honeybee developed under NASA's Game Changing Development (GCD) Vertical Solar Array Technology (VSAT) program and took from TRL 4 to TRL 6, ending with full-scale deploy-and-retract testing in thermal vacuum in NASA JSC Chamber A. The talk covers the DIABLO self-interlocking band mast, the masthead and pleated array deployment, the test campaign and lessons learned, and how the architecture is being adapted into Power Tower. Finally, we will discuss what this means for science payloads, which gain a stable, elevated, powered platform for instruments, communications and long-duration surface science.

The LAMPS deployment system reached TRL 6 in 2024, covering the DIABLO mast, umbilical and spool, masthead and solar array arms, validated in TVAC at NASA JSC Chamber A. LAMPS is the only vertical solar array to have completed full-scale deployment in thermal vacuum. Funding: NASA Game Changing Development Lunar Vertical Solar Array Technology, base and option phases; DARPA LunA-10 study.

PRESENTATION	DAY TWO · DECEMBER 2	Power

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Heliophysics Technologies Accelerating NASA’s Moon Base and Planetary Exploration

NASA’s Heliophysics Technology Program (HTP) develops cross-disciplinary instrumentation that directly enables the Agency’s broader human exploration goals. By maturing technologies from the laboratory through to flight-readiness, HTP investments address four critical Moon Base and Planetary Exploration challenges: protecting astronauts and systems from space radiation (e.g., REPTile, BEAM), identifying crucial *in-situ* water and hydrogen resources (e.g., SONTRAC), understanding planetary habitability and atmospheric loss (e.g., AIMSS), and mitigating surface dust and orbital debris hazards (e.g., DUSTER, DENTS). HTP-matured technologies not only enable new discoveries on Heliophysics science missions, but ultimately provide the foundational, flight-proven capabilities essential for safeguarding crews, discovering resources, and ensuring the success of sustained surface operations for NASA’s Moon Base and Planetary Exploration.

Funding: Heliophysics Technology Program.

PRESENTATION	DAY TWO · DECEMBER 2	Power

POSTER SESSION

SHOWN DURING THE LUNCH BREAK ON BOTH DAYS

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Planetary Ice Plume Simulator Development

The Planetary Ice Plume Simulator (PIPS), in commissioning at NASA Goddard Space Flight Center, is intended to enable research on the physical and chemical properties of icy plumes, products of impact into or generation of planetary materials (e.g., regolith) by microscopic icy grains, and studies of dust particles and plumes for Moon/Mars applications. It is also designed to enable testing of instruments for laboratory science study and TRL advancements. The PIPS uses electrospray coupled with electrostatic acceleration in vacuum to generate a stream of ice particles at tunable size, velocity, composition, and with daily experimental turnaround. The PIPS is intended to be operated as a facility available to the planetary science and astrobiology community.

Five years of design alteration and maturation primarily through the IRAD program at GSFC have brought the PIPS from an untested SBIR deliverable to end-to-end validation of particle electrospray, electrostatic acceleration and size/speed measurement in air, and close to demonstration in vacuum. Equivalent maturity is TRL 4. SBIR: 80NSSC18C0056. GSFC IRAD #67, #135 and #53.

POSTER	Room 1 · Stone & Neveu	Poster Session

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TVAC-Radiation Tests on Survival of Microbes in Europan and Enceladan Ices

The exploration of Ocean Worlds, such as Europa and Enceladus, relies heavily on understanding how their extreme surface conditions impact materials and potential biosignatures. To address this need, under the ICAR program, Stone Aerospace has developed engineering infrastructure, experimental setup, and operational management for a pioneering five-year project designed to simulate these extraterrestrial environments. The core technical achievement involves designing and operating advanced cryogenic vacuum chambers capable of safely integrating both ionizing and non-ionizing radiation sources, which were previously infeasible to reproduce in a lab. The experimental methodology utilizes retrofitted liquid nitrogen dewars to maintain temperatures of 80°K and stainless steel vacuum chambers rated for 10-8 Torr. To simulate planetary radiation, the chambers accommodate four distinct sources within the spatial constraints of the dewars: a 100 KeV flood electron beam gun; a 100 KeV X-ray tube, a 100 W Hydrogen Lyman alpha source, and a 180 W Deep Ultraviolet (DUV) source. Critical engineering deliverables include the fabrication of these specialized chambers, in-situ monitoring systems for temperature and radiation dosage, and leaded ionizing radiation shielding. The project features two primary classes of experiments: ICE SLAB and PLUME. ICE SLAB experiments simulate Europa's surface and subsurface by hydraulically compressing shaved, doped, and de-gassed ice to form layered blocks representing the top meter of depth. These test units undergo sequential radiation exposure to evaluate the preservation of biosignatures at various depths. Conversely, PLUME experiments simulate Enceladus' South Pole plumes by injecting microdroplets of ocean water simulants into the vacuum chamber, flash-freezing them into cryo-ices under irradiation for collection on witness plates. The overarching technical objectives include achieving high-fidelity environmental simulations, thermal modeling of irradiated ice, and enabling the unprecedented study of radiation penetration and secondary Bremsstrahlung effects within meter-scale depths. Ultimately, this project establishes a state-of-the-art test bed for generalized astrobiological research under extreme conditions.

Indeed, the need for combined effects facility (including thermal, radiation, ice and regolith) that can be made readily available to the community became apparent. Building on this experimental foundation developed under ICAR, plans are underway to transition and expand the platform into the ALIENS (Advanced Laboratory for Instrumentation and Extraterrestrial Near-surface Simulation) Facility, establishing a centralized, multi-environment simulation hub for the planetary science community. In addition to augmenting the primary Cryo-Vacuum Tower with higher-energy (MeV-class) radiation interfaces and expanded meter-scale analog ice synthesis pipelines, the upgraded facility incorporates two new modular simulation testbeds: the “Moon Box” and the “Mars Box” which will enable studies that will support Artemis and Moon Base priorities. Ultimately, the upgraded ALIENS facility is designed to offer shared, open-access experimental testbeds to support researchers across Solar System Science, Astrobiology, and Planetary Mission Development.

Grant: 80NSSC23K1477. TRL: 6.

POSTER	Room 1 · Stone & Neveu	Poster Session

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AI-driven Adaptive Planetary Mobility for the Moon, Mars, and Beyond

Carl Sagan once wrote: “My most persistent emotion in working with the Viking lander pictures was frustration at our immobility.” We may face an even greater frustration with future landers on the ocean worlds such as Europa and Enceladus. Unlike Viking, these missions represent once-in-a-generation opportunities to explore ocean-world surfaces, and we may not have another chance to return for many decades. Mobility is therefore essential to maximizing scientific return from these extremely precious opportunities. In this talk, I present two mobility concepts that represent both ends of the complexity spectrum. The first is a minimalist CubeSat-based mechanical hopper, which can travel ~1 km with a primary battery and perform in-situ measurements or return samples to the lander. The second is a limbed or snake robot capable of moving vertically, designed to enable access to subsurface oceans. Despite their vastly different levels of complexity, both approaches share a common design philosophy: adaptability to the unknown. By incorporating additional degrees of freedom and onboard intelligence, minimalist and sophisticated systems alike aim to overcome environmental challenges we cannot fully predict. Finally, I will present a proposed lunar technology demonstration mission featuring a CubeSat-based hopper equipped with a miniaturized neutron spectrometer to prospect for water ice in permanently shadowed lunar craters. With surface gravity comparable to Europa, a successful lunar demonstration could provide a crucial stepping stone toward enabling mobility on future icy-world landers.

Mechanical hopper: TRL 2-3, currently funded by the PI’s start-up funding provided by Georgia Tech. Ocean access: TRL 4, funding provided by the NIAC program and JPL’s JNEXT program.

POSTER	Room 2 · Renno & Ono	Poster Session

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Using passive electromagnetic signals to detect sub millimeters orbital debris and micro meteoroids

Ground-based radar and optical telescope reflectance measurements are the primary methods currently used to detect, track and characterize objects in Earth orbit such as active satellites and space debris. These methods cannot be used to routinely track objects smaller than about 10 cm in low Earth orbit (LEO), and about 1 m in geostationary orbit (GEO). We show that nonthermal electromagnetic radiation (NTEM), thermal electromagnetic radiation (TEM), and light scattering (LS) signals, generated by on-orbit hypervelocity collisions, can be used to remotely detect, track, and characterize sub-millimeter space debris either from the ground or from orbit. In addition, we show that these electromagnetic signals can be used to track clouds of debris created by orbital collisions. This is a new concept that has not been used to monitor space debris yet.

POSTER	Room 2 · Renno & Ono	Poster Session

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A Lunar Instrument Package for Surface Radiation Mapping and Active ISRU Prospecting

This presentation describes an instrument suite for characterization of lunar regolith composition and volatile content complemented by monitoring of local space weather. The concept involves a mobile regolith system for surveying and sample extraction, a volatile analysis system using a microsensor array, and stationary radiation detectors to characterize the radiation environment. The mobile system includes a lunar surveying instrument composed of a neutron generator, neutron spectrometer, and gamma-ray spectrometer. The neutron spectrometer and gamma ray spectrometer survey the local regolith with the neutron generator to identify a target sample of interest. A sample (scoop) is obtained by the rover from this regolith which delivers it to a volatile analysis system. The volatile analysis system uses a micro heating element that liberates volatiles for analysis by a multi parameter chemical microsensor array to selectively quantify key species of interest, such as CO, CO2, H2 and H2O. Large-area, robust radiation detectors measure the local radiation environment to understand space weather interactions with the regolith. This combined Lunar Instrument Package is highly relevant to lunar science and exploration, addressing multiple Moon to Mars Science questions and enabling a new approach to lunar surface ISRU prospecting.

This is a proposed concept and not presently funded. Each of the individual instruments is at TRL 5.

POSTER	Room 3 · Peretz, Hunter & Spiers	Poster Session

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ZODIAC-Technology Development in Support of Capturing Celestial Dust and Meteorites

The nearest debris disk is ripe for harvesting. While modern observatories routinely image and characterize debris disks around other stars, these systems are studied exclusively through remote sensing. The Solar System's zodiacal cloud is the only debris disk that can be directly sampled, yet its composition, source partitioning, and temporal variability remain poorly constrained. Debris Disk Evolution: Existing models of debris disks rely on uncertain assumptions regarding the relative contributions of asteroidal, cometary, and interstellar dust sources. Remote observations alone cannot uniquely distinguish among these populations, limiting our understanding of collisional cascades, dust transport, and the long-term evolution of planetary systems. Planetary System Architectures: The production, transport, and processing of dust govern the observable properties of mature planetary systems. Our understanding of how debris disks are supplied and evolve is currently limited by the lack of direct, source-resolved measurements of dust composition and variability.

POSTER	Room 3 · Peretz, Hunter & Spiers	Poster Session

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Accessing the Alien Abyss: Charting a Course for Europa & Enceladus Ocean Exploration

I will be presenting on a recently submitted paper titled “Accessing the Alien Abyss: Charting a Course for Ocean Exploration on Europa and Enceladus,” written during my postdoc at Woods Hole Oceanographic Institution. In the paper, we present a roadmap for the development of future Planetary Ocean Exploration Missions (POEMs) targeting the ice-covered ocean worlds Europa and Enceladus, with the scientific goal of identifying signatures of past or present life within their ocean interiors.

We outline a scientific case for direct ocean access and establish guiding objectives for a science-driven exploration strategy within the oceans of these satellites.

We identify drivers of vehicle design and operation, informed by ocean engineering experience and anticipated spacecraft capacity, to guide future discussions on information and technology gaps.

We discuss how the developments needed now to meet this multi-decadal challenge can be met through strategic partnerships, at the national and international level, and, recognizing the long lead-time and diverse skill sets that will need to be harnessed to implement such a mission, we call out the sustained level of workforce training and knowledge retention that will be required to bring such a generation-spanning planetary ocean exploration mission to fruition.

TRL 1. This work was funded by the Weston Howland Jr. Postdoctoral Scholarship at WHOI.

POSTER	Room 3 · Peretz, Hunter & Spiers	Poster Session

SESSION KEY

PRESENTATION	Composition & Spectroscopy
PRESENTATION	Sampling
PRESENTATION	Mobility & Autonomy
PRESENTATION	Mapping
PRESENTATION	Geophysics
PRESENTATION	Entry, Descent & Landing (EDL)
PRESENTATION	Atmospheres & Volatiles
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