NASA SBIR 2021 Phase I Solicitation

S1.07 In Situ Instruments/Technologies for Lunar and Planetary Science

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC, MSFC

Scope Title:

In Situ Instruments/Technologies for Planetary Science

Scope Description:

This subtopic solicits development of advanced instrument technologies and components suitable for deployment on in situ planetary and lunar missions. These technologies must be capable of withstanding operation in space and planetary environments, including the expected pressures, radiation levels, launch and impact stresses, and range of survival and operational temperatures. Technologies that reduce mass, power, volume, and data rates for instruments and instrument components without loss of scientific capability are of particular importanceâ€”for both conventional missions as well as for small-satellite missions. In addition, technologies that can increase instrument resolution and sensitivity or achieve new andÂ innovative scientific measurements are solicited. For examples of NASA science missions, seeÂ https://science.nasa.gov/missions-page. For details of the specific requirements see the National Research Council report "Vision and Voyages for Planetary Science in the Decade 2013-2022" (http://solarsystem.nasa.gov/2013decadal/), hereafter referred to as the Planetary Decadal Survey). Of particular interest are technologies to support future missions under the New Frontiers and Discovery programs.

Specifically, this subtopic solicits instrument development that provides significant advances in the following areas, broken out by planetary body:

- Mars:Â
    - Subsystems relevant to current in situ instrument needs (e.g., lasers and other light sources from UV to microwave, x-ray and ion sources, detectors, mixers, mass analyzers, and front-end ion/neutrals separation/transport technologies, etc.) or electronics technologies (e.g., field-programmable gate array (FPGA) and application-specific integrated circuit (ASIC)

    - implementations, advanced array readouts, miniature high-voltage power supplies).
    - Technologies that support high-precision in situ measurements of the elemental, mineralogical, and organic composition of planetary materials.
    - Conceptually simple, low-risk technologies for in situ sample extraction and/or manipulation including fluid and gas storage, pumping, and chemical labeling to support analytical instrumentation.
    - Seismometers, mass analyzers, technologies for heat flow probes, and atmospheric trace gas detectors. Improved robustness and g-force survivability for instrument components, especially for geophysical network sensors, seismometers, and advanced detectors (intensified charge-coupled devices (iCCDs), photomultiplier tube (PMT) arrays, etc.).
    - Instruments geared towards rock/sample interrogation prior to sample return.Â Sensors to measure dimensions of laser ablation pits in natural rock samples with unprepared rough surfaces to support geochronology measurements on rock samples collected by a rover (spatial and depth resolution of 10 ÂµmÂ or better from a working distance of tens of centimetersÂ desired to characterize ~1-mm-deep by ~0.5-mm-wide pits).
- Venus:Â
    - Sensors, mechanisms, and environmental chamber technologies for operation in Venus's high-temperature, high-pressure environment with its unique atmospheric composition.
    - Approaches that can enable precision measurements of surface mineralogy and elemental composition and precision measurements of trace species, noble gases, and isotopes in the atmosphere.
- Small bodies:
    - Technologies that can enable sampling from asteroids and from depth in a comet nucleus, improved in situ analysis of comets.
    - Imagers and spectrometers that provide high performance in low light environments.
    - Dust environment measurements and particle analysis, small body resource identification, and/or quantification of potential small-body resources (e.g., oxygen, water, and other volatiles;Â hydrated minerals;Â carbon compounds;Â fuels;Â metals;Â etc.).
    - Advancements geared towards instruments that enable elemental or mineralogy analysis (such as high-sensitivity x-ray and UV-fluorescence spectrometers, UV/fluorescence systems, scanning electron microscopy with chemical analysis capability, mass spectrometry, gas chromatography and tunable diode laser sensors, calorimetry, imaging spectroscopy, and laser-induced breakdown spectroscopy (LIBS).
- Saturn, Uranus, and Neptune and their moons:
    - Components, sample acquisition, and instrument systems that can enhance mission science return and withstand the low temperatures/high pressures of the atmospheric probes during entry.Â Note thatÂ in situ instruments and componentsÂ focused on ocean worlds life detection are specifically solicited

in S1.11 and are encouraged to be submitted to S1.11.

- The Moon:
  - This topic seeks advancement of concepts and components to develop a Lunar Geophysical Network as envisioned in the Planetary Decadal Survey. Understanding the distribution and origin of both shallow and deep moonquakes will provide insights into the current dynamics of the lunar interior and its interplay with external phenomena (e.g., tidal interactions with Earth). The network is envisioned to comprise multiple free-standing seismic stations that would operate over many years in even the most extreme lunar temperature environments.
  - Technologies to advance all aspects of the network including sensor emplacement, power, and communications in addition to seismic, heat flow, magnetic field and electromagnetic sounding sensors are desired.
  - This topic also seeks technologies for quantifying lunar water and measuring the D/H ratio in lunar water. Several evidences point to the presence of water ice at cold spots in the permanently shadowed regions at the lunar poles, with estimated abundance of ~5 to 10 wt%.

Novel instrument concepts are encouraged particularly if they enable a new class of scientific discovery. Technology developments relevant to multiple environments and platforms are also desired. Proposers should show an understanding of relevant space science needs and present a feasible plan to fully develop a technology and infuse it into a NASA mission.

Expected TRL or TRL Range at completion of the Project: 3 to 5
Primary Technology Taxonomy:
Level 1: TX 08 Sensors and Instruments
Level 2: TX 08.3 In-Situ Instruments/Sensor
Desired Deliverables of Phase I and Phase II:

- Analysis
- Prototype
- Hardware
- Software

Desired Deliverables Description:

The Phase I project should focus on feasibility and proof-of-concept demonstration (TRL 2-3). The required Phase I deliverable is a report documenting the proposed innovation, its status at the end of the Phase I effort, and the evaluation of its strengths and weaknesses compared to the state of the art. The report can include a feasibility assessment and concept of operations, simulations and/or measurements, and a plan for further development to be performed in Phase II.

The Phase II project should focus on component and/or breadboard development with the delivery of specific hardware for NASA (TRL 4-5). Phase II deliverables include a working prototype of the proposed hardware, along with documentation of development, capabilities, and measurements.

State of the Art and Critical Gaps:

In situ instruments and technologies are essential bases to achieve Science Mission Directorate's (SMD's) planetary science goals summarized in the Planetary Decadal Survey. In situ instruments and technologies play indispensable role for NASAâ€™s New Frontiers and Discovery missions to various planetary bodies (Mars, Venus, small bodies, Saturn, Uranus, Neptune, Moon, etc.).

There are currently various in situ instruments for diverse planetary bodies. However, there are ever-increasing science and exploration requirements and challenges for diverse planetary bodies. For example, there is urgent need for exploring RSL (recurring slope lineae) on Mars andÂ plumes from planetary bodies, as well as a growing demand for in situ technologies amenable to small spacecraft.

To narrow the critical gaps between the current state of art and the technology needed for the ever-increasing science/exploration requirements, in situ technologies are being sought to achieve much higher resolution and sensitivity with significant improvements over existing capabilities with lower mass, power, and volume.

Relevance / Science Traceability:

In situ instruments and technologies are essential bases to achieve SMD's planetary science goals summarized in the Planetary Decadal Survey. In situ instruments and technologies play an indispensable role for NASAâ€™s New Frontiers and Discovery missions to various planetary bodies.Â

In additionÂ to Phase III opportunities, SMD offers several instrument development programs as paths to further development and maturity. These include the Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Program, which invests in low-TRL technologies and funds instrument feasibility studies, concept formation, proof-of-concept instruments, and advanced component technology, as well asÂ the Maturation of Instruments for Solar System Exploration (MatISSE) Program andÂ the Development and Advancement of Lunar InstrumentationÂ (DALI) Program, which invest in mid-TRL technologies and enableÂ timely and efficient infusion of technology into planetary science missions.

References:

- Li et al.:Â â€œDirect evidence of surface exposed water ice in the lunar polar regions,â€Â *PNAS*Â 115 (2018), 8907-8912,Â https://www.pnas.org/content/pnas/115/36/8907.full.pdf
- Colaprete, A., Schultz, P., Heldmann, J., Wooden, D., Shirley, M., Ennico, K., andÂ Goldstein, D.: â€œDetection of water in the LCROSS ejecta plume,â€Â *Science*, 330 (2010), 463-468.
- Schultz, P. H., Hermalyn, B., Colaprete, A., Ennico, K., Shirley, M., andÂ Marshall, W. S.: â€œThe LCROSS cratering

experiment,â€Â *Science*, 330 (2010),Â 468-472.

- PaigeÂ et al.:Â â€œDiviner Lunar Radiometer Observations of Cold Traps in the Moonâ€™s South Polar Region,â€Â Â *Science*, 330 (2010),Â 479-482.

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