



NASA SBIR 2021 Phase I Solicitation

S1.11 In Situ Instruments/Technologies and Plume Sampling Systems for Ocean Worlds Life Detection

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC

Scope Title:

In Situ Instruments/Technologies and Plume Sampling Systems for Ocean Worlds Life Detection

Scope Description:

This subtopic solicits development of in situ instrument technologies and components to advance the maturity of science instruments and plume sample collection systems focused on the detection of evidence of life, especially extant life, in the ocean worlds (e.g., Europa, Enceladus, Titan, Ganymede, Callisto, Ceres, etc.). Technologies that can increase instrument resolution and sensitivity or achieve new and innovative scientific measurements are of particular interest. Technologies that allow collection during high-speed (>1 km/sec) passes through a plume are solicited as are technologies that can maximize total sample mass collected while passing through tenuous plumes. This fly-through sampling focus is distinct from S4.02, which solicits sample collection technologies from surface platforms.

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 importance.

Specifically, this subtopic solicits instrument technologies and components that provide significant advances in the following areas, broken out by planetary body:

- General to Europa, Enceladus, Titan, and other ocean worlds: Technologies and components relevant to life detection instruments (e.g., microfluidic analyzer, microelectromechanical systems (MEMS) chromatography/mass spectrometers, laser-ablation mass spectrometer, fluorescence microscopic imager, Raman spectrometer, tunable laser system, liquid chromatography/mass spectrometer, X-ray fluorescence, digital holographic microscope-fluorescence microscope, antibody microarray biosensor, nanocantilever biodetector, etc.). Technologies for high-radiation environments (e.g., radiation mitigation strategies, radiation-tolerant detectors, and readout electronic components), which enable orbiting instruments to be both radiation hard and undergo the planetary protection requirements of sterilization (or equivalent).
 - Collecting samples for a variety of science purposes is also sought. These include samples that allow for determination of the chemical and physical properties of the source ocean, samples for detailed characterization of the organics present in the gas and particle phases, and samples for analysis for biomarkers indicative of life. Front-end system technologies include sample collection systems and subsystems capable of capture, containment, and/or transfer of gas, liquid, ice, and/or

mineral phases from plumes to sample processing and/or instrument interfaces.

- Technologies for characterization of collected sample parameters including mass, volume, total dissolved solids in liquid samples, and insoluble solids. Sample collection and sample capture for in situ imaging. Systems capable of high-velocity sample collection with minimal sample alteration to allow for habitability and life detection analyses. Microfluidic sample collection systems that enable sample concentration and other manipulations. Plume material collection technologies that minimize risk of terrestrial contamination, including organic chemical and microbial contaminants. These technologies would enable high-priority sampling and potential sample return from the plumes of Enceladus with a fly-by mission. This would be a substantial cost savings over a landed mission.
- Europa: Life detection approaches optimized for evaluating and analyzing the composition of ice matrices with unknown pH and salt content. Instruments capable of detecting and identifying organic molecules (in particular biomolecules), salts and/or minerals important to understanding the present conditions of Europa's ocean are sought (such as high resolution gas chromatograph or laser desorption mass spectrometers, dust detectors, organic analysis instruments with chiral discrimination, etc.). These developments should be geared towards analyzing and handling very small sample sizes (μg to mg) and/or low column densities/abundances. Also of interest are imagers and spectrometers that provide high performance in low-light environments (visible and near-infrared (NIR) imaging spectrometers, thermal imagers, etc.), as well as instruments capable of improving our understanding of Europa's habitability by characterizing the ice, ocean, and deeper interior and monitoring ongoing geological activity such as plumes, ice fractures, and fluid motion (e.g., seismometers, magnetometers). Improvements to instruments capable of gravity (or other) measurements that might constrain properties such as ocean and ice shell thickness will also be considered.
- Enceladus (including plume material and E-ring particles): Life detection approaches optimized for analyzing plume particles as well as for determining the chemical state of Enceladus icy surface materials (particularly near plume sites). Instruments capable of detecting and identifying organic molecules (in particular biomolecules), salts and/or minerals important to understand the present conditions of the Enceladus ocean are sought (such as high resolution gas chromatograph or laser desorption mass spectrometers, dust detectors, organic analysis instruments with chiral discrimination, etc.). These developments should be geared towards analyzing and handling very small sample sizes (μg to mg) and/or low column densities/abundances. Also of interest are imagers and spectrometers that provide high performance in low-light environments (visible and NIR imaging spectrometers, thermal imagers, etc.), as well as instruments capable of monitoring the bulk chemical composition and physical characteristics of the plume (density, velocity, variation with time, etc.). Improvements to instruments capable of gravity (or other) measurements that might constrain properties such as ocean and ice shell thickness will also be considered.
- Titan: Life detection approaches optimized for searching for biosignatures and biologically relevant compounds in Titan's lakes, including the presence of diagnostic trace organic species, and also for analyzing Titan's complex aerosols and surface materials. Mechanical and electrical components and subsystems that work in cryogenic (95 K) environments; sample extraction from liquid methane/ethane, sampling from organic "dunes" at 95 K, and robust sample preparation and handling mechanisms that feed into mass analyzers are sought. Balloon instruments, such as IR spectrometers; imagers; meteorological instruments; radar sounders; solid, liquid, and air sampling mechanisms for mass analyzers; and aerosol detectors are also solicited. Low-mass and low-power sensors, mechanisms and concepts for converting terrestrial instruments such as turbidimeters and echo sounders for lake measurements, weather stations, surface (lake and solid) properties packages, etc. to cryogenic environments (95 K). Other ocean worlds targets may include Ganymede, Callisto, Ceres, etc.

Proposers are strongly encouraged to relate their proposed development to:

- NASA's future ocean worlds exploration goals (see references).
- Existing flight instrument capability, to provide a comparison metric for assessing proposed improvements.

Proposed instrument architectures should be as simple, reliable, and low risk as possible while enabling compelling science. 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 program.

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 NASA's ocean worlds exploration goals. There are currently some in situ instruments for diverse ocean worlds bodies. However, there are ever increasing science and exploration requirements and challenges for diverse ocean worlds bodies. For example, there are urgent needs for the exploration of icy or liquid surface on Europa, Enceladus, Titan, Ganymede, Callisto, etc., and plumes from planetary bodies such as Enceladus.

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, and at the same time with lower resource (mass, power, and volume) requirements.

Relevance / Science Traceability:

In situ instruments and technologies are essential bases to achieve Science Mission Directorate's (SMD) planetary science goals summarized in Decadal Study (National Research Council's Vision and Voyages for Planetary Science in the Decade 2013-2022.) In situ instruments and technologies play indispensable role for NASA's New Frontiers and Discovery missions to various planetary bodies.

NASA SMD has two programs to bring this subtopic technologies to higher level: PICASSO and MatISSE. The Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Program invests in low-TRL technologies and funds instrument feasibility studies, concept formation, proof-of-concept instruments, and advanced component technology. The Maturation of Instruments for Solar System Exploration (MatISSE) Program invests in mid-TRL technologies and enables timely and efficient infusion of technology into planetary science missions. The PICASSO and MatISSE are in addition to Phase III opportunities.

References:

- For the NASA Roadmap for Ocean World Exploration see: <http://www.lpi.usra.edu/opag/ROW>
- In situ instruments and technologies for NASA's ocean worlds exploration goals see:

<https://www.nasa.gov/specials/ocean-worlds/>

- NASA technology solicitation, see ROSES 2016/C.20 Concepts for Ocean worlds Life Detection Technology (COLDTECH) call:

<https://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId={5C43865B-0C93-6ECA-BCD2-A3783CB1AAC8}&path=init>

- Instrument Concepts for Europa Exploration 2 (final text released May 17, 2018; PDF):

<https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=628697/solicitationId=%7B17B73E96-6B65-FE78-5B6384C804831035%7D/viewSolicitationDocument=1/C.23%20ICEE2%20Schulte%20POC.pdf>