Planetary Instrument Concepts for the Advancement of Solar System Observations Program
Abstracts of Selected Proposals
(NNH16ZDA001N-PICASO)

Below are the abstracts of proposals selected for funding for the PICASO program. Principal Investigator (PI) name, institution, and proposal title are also included. Eighty five proposals were received in response to this opportunity. On April 12, 2017, 12 proposals were selected for funding. On June 9, 2017, three additional proposals were selected.

M Abedin/NASA Langley Research Center
Standoff Ultra-Compact Raman (SUCR) system Development for faster daytime mineralogy and Raman Imaging
16-PICASO16_2-0012

Raman spectroscopy can positively identify organic molecules, biomarkers, biominerals, water, water containing minerals, and minerals that are of high interest to NASA and directly serve the goal of finding evidence for past life on Mars and other planets. Micro-Raman systems are capable of performing fine-scale mineralogy; hence, they are being actively proposed as instruments on planetary rovers for in situ analysis. Most of the micro-Raman systems for planetary exploration are implementation of traditional Raman technology that is designed for dark laboratory use. These Raman systems have the following characteristics (1) they require sample collection, (2) they will require shielding of daylight background radiation. In addition, presence of mineral and biological luminescence significantly affect the Raman signal. Due to the use of continuous wave (CW) lasers and non-time gating detection approach, it will also be difficult to distinguish the biofluorescence from the mineral phosphorescence. These limitations will significantly lower the science return from these micro-Raman systems in terms of number and variety of samples that can be analyzed on Mars.

Under this proposal, we propose to develop an innovative Standoff Ultra-Compact Raman (SUCR) instrument in collaboration with the University of Hawaii, which will use the superior pulsed time gated Raman technology capable of operating in daylight while minimizing contribution from mineral phosphorescence. SUCR will provide a superior micro-Raman instrument for future NASA missions. The development of SUCR will require improvements in both remote Raman and ultra-compact Raman technologies and the implementation of line imaging for faster Raman context imaging and map collection. The SUCR system will be able to quickly collect (1 s/spectrum) high quality in situ Raman spectral images in the daytime, from distances of several centimeters, with no need for samples collection. For example, the SUCR instrument will allow for fine scale context mineralogy of drilled cores, layer structures, and trenches. In addition, SUCR will be able to detect any micron size biomarker in situ with its faster search and

scan mode (0.1s). Furthermore, we will demonstrate that SUCR can be used to detect the past life forms, to utilize fluorescence to distinguish biological from non-biological sources, and to show the system improvement with respect to existing systems. Under this project, the TRL of the proposed SUCR instrument will advance from TRL 2 to TRL 4.

F Scott Anderson/Southwest Research Institute
Identification of optimal ablation wavelength and pulse-durations for improved in-situ dating
16-PICASO16_2-0090

Science goals
Under PIDDP, NSF, and internal funding, we have developed an instrument called CODEX (the Chemistry, Organics and Dating EXperiment) to search for evidence of past life on Mars, reveal the history of habitability, and ascertain how the local geology evolved; these are also key scientific goals for the Moon, other planets, and asteroids. CODEX is uniquely able to analyze the microscopic chemical and organic makeup of a sample in spatial context, while simultaneously determining its age.

The instrument uses nanosecond laser pulses to ablate ions and neutrals, which can be measured directly or via secondary ionization. Recently, experiments using ultrashort pulse laser ablation have demonstrated significant improvement in measurement precision and accuracy, and new technological developments have resulted in significant reductions in the required size, power, and mass of lasers capable of producing these ultrashort pulses. These improvements primarily have been demonstrated with laser ablation mass spectrometry (LAMS), and in laser desorption inductively coupled plasma mass spectrometry, techniques that rely on the production of ions and micro-particulates. Because CODEX uses LARIMS, which measures neutrals, we suspect that using ultrashort pulse ablation would improve the precision and accuracy of our measurements. However, little is yet known about the production of neutrals using ultrashort pulses; some work suggests that fractionation of neutrals is reduced as well. Thus, in this proposal we will test and assess whether ultrashort pulses can improve LARIMS dating as well.

Methodology
In this proposal we will rent and compare several femto- and pico- second lasers for ion and neutral production in our prototype instrument, and identify the optimal parameters for improving the accuracy of chemical, organic, and radiometric measurements. We will explore a parameter space including wavelength, pulse-length, peak power, the effect of multiple shots, fluence, sample/standard composition, production of long-live excitation states, and the impact of plasma generation. The laser systems under consideration will include small systems consistent with the possibility of future development for spaceflight. The resulting chemistry, organics, and dating measurements are particularly applicable for missions to Mars, the Moon, and possibly Vesta.

Relevance
Our measurements are relevant to multiple NASA goals for Mars and the Moon, such as:
A) For Mars, the NRC Decadal Survey (DS) specifically supports: long-term development of instruments ... focusing on the most important future in situ measurements... [including] ... in situ geochronology experiments [National Research Council, 2012];
B) MEPAG Goals III.A.3-10, but especially 3, specifically call for Constrain[ing] the absolute ages of major Martian crustal geologic processes... and the cratering rate. ... This investigation could be approached with both in situ and returned sample analysis... ;
C) For the Moon, the NRC DS has a primary goal of: Determin[ing] the chronology of basin-forming impacts and constrain[ing] the period of late heavy bombardment in the inner solar system, and thus address[ing] fundamental questions of inner solar system impact processes and chronology [National Research Council, 2012].

F Scott Anderson/Southwest Research Institute
Extending In-Situ Dating to New Geochronometers: Pb-Pb, Sm-Nd, Re-Os, and Lu-Hf
16-PICASO16_2-0096

Goals
This proposed work will extend laser ablation resonance ionization spectrometry (LARIMS) from the previously demonstrated rubidium-strontium (Rb-Sr) geochronology system to four other radiogenic systems, enabling in-situ, concordant age determinations to be made on extraterrestrial bodies in the solar system. This capability addresses a critical need to provide dating information to fulfill NASA s goal of understanding the history of the solar system. Advantages include providing an independent test of concordance, while expanding the potential range of samples that can be successfully measured. Testing for concordance is important because individual isotopic dating systems can be biased by a variety of factors. These biases are frequently distinct for different radiometric systems. In addition to extending LARIMS to additional geochronology systems, an existing backup laser system will be advanced from TRL 2 to TRL 3.

Objectives
This proposal addresses the important NASA goal to understand the history and evolution of the solar system. The time of key events in solar system history are poorly constrained by current samples, giving impetus to future missions with sample return and in-situ (landed) dating measurements. An issue for in-situ radiometric measurements is the desire for testing concordance, i.e. the ability to validate the measured age of a sample by using multiple dating systems. We have demonstrated LARIMS by dating several samples using the Rb-Sr method and we have completed preliminary work that demonstrates the technique can be extended to Pb-Pb geochronology. The objective of this proposal is to perform measurements that enable us to assess LARIMS capabilities

with other geochronology systems and to determine and overcome obstacles to developing in-situ measurements based on these systems in future missions. This work, in combination with our successful (Rb-Sr) dating program, our recent lead-lead (Pb-Pb) dating study, and our preliminary samarium-neodymium (Sm-Nd) spectroscopy measurements, will complete a systematic study to assess the potential range of radiometric dating approaches for LARIMS analyses using a suite of geochronology dating systems, including Rb-Sr, Pb-Pb, Sm-Nd, rhenium-osmium (Re-Os), and Lutetium-Hafnium (Lu-Hf).

Daniel Austin/Brigham Young University
A Printed Circuitboard Analyzer for Characterizing the Charge and Mass of Martian Dust
16-PICASO16_2-0005

We propose development of a device that will directly measure both the electrical charge and the mass of atmospheric dust particles on Mars. Such measurements have never before been made on Mars, but are critical to understanding the possible effects of dust on human Mars activities and in situ resource utilization. These measurements will also inform models of weathering and atmospheric effects on Mars.

The device consists of an array of image charge detectors made using printed circuit boards. Particle charge is measured directly for each grain that enters the instrument. Mass is determined by electrostatically slowing the particle in a region between two detection arrays.

The proposed effort seeks to develop this device from TRL 2 to TRL 3, including testing with charged Mars dust simulant. The proposal includes development of a low-noise amplifier that greatly exceeds the performance of the heritage Amptek amplifier.

Science goals of the proposed device include measurement of the electrical charge and mass of a large number of individual dust grains that are blown through the instrument. It will also be possible to include a pump or blower and force particle-laden air through the instrument.

The proposed research is directly relevant to Mars exploration and science. Electrostatic adhesion of dust is expected to be an issue in human exploration of Mars (sticking to astronaut suits as occurred during lunar surface missions, possible respiratory effects, etc.) and also to mechanical operations such as ISRU processing of the Martian atmosphere to produce oxygen. Prior measurements constrained general size distributions via optical scattering, but neither charge nor mass has been directly measured. Further, no instruments have been selected on any upcoming Mars missions (ExoMars, Mars2020, InSight) that are able to make these measurements. Thus the proposed work directly advances our understanding of the dust properties and processes on Mars. Further, the proposed effort falls best into the PICASSO program because if the

TRL level development, the fact that this is instrument development, and the planetary-specific targets for the instrument type.

Terry Hurford/NASA Goddard Space Flight Center
Development of a Prototype for the Thermal Infrared Composite Imaging Spectrometer (TIRCIS) instrument
16-PICASO16_2-0101

OBJECTIVES: A major challenge for infrared remote sensing instruments of cold outer solar system targets is simultaneously detecting surface composition as well as surface temperatures. For cold targets <200K, the weak solar insolation results in thermal emission being in the far-IR. Given compositional signature are sensed in mid-IR, the science instrument needs a broad spectral grasp extending to the far-IR. The instrument development proposed here will determine surface composition and temperature of cold targets by using two focal planes to measure simultaneously both the mid- and far-IR. The objective of the proposal is to develop to TRL 3 a versatile infrared imaging spectrometer, spanning the spectral wavelength range 7 to 50 µm, with spectroscopic measurements in the 7-14 µm range and radiometric band measurements spanning 7-50 µm. This instrument is ideal for missions to airless bodies, including but not limited to Triton on a future Neptune Flagship-class mission, Trojan Asteroids, Enceladus or Io New Frontiers class missions. This instrument will build on substantial existing heritage and investments at GSFC, including the Voyager IRIS, Cassini CIRS, and recently a Thermal IMager for Europa Reconnaissance and Science (TIMERS) concept developed under Instrument Concepts for Europa Exploration (ICEE). The proposed instrument development will provide NASA a cold target optimized thermal imaging spectrometer to study cryovolcanism, heat flow, composition, and terrain. The innovative dual-focal plane design provides simultaneous mapping at mid and far IR wavelengths. The baseline design uses a custom 4-line 32 thermopile pixel array and a 384x288 pixel microbolometer array. The instrument has the capability to resolve temperature contrast to an accuracy of better than or equal to 2 K for surface temperatures greater than 70 K. The instrument can also provide 7-14 µm spectra of the surface with a spectral resolution of 200-350.

METHODOLOGY: The thermal imaging spectrometer proposed here will build on substantial work that has already been done at GSFC on thermal instruments. In particular, this proposal will develop the key measurement concept namely the thermopile focal plane, which measures thermal radiation with multiple channels from 7-50 µm and allows some light to pass into a optical backend that measures the spectra from 7-14 µm. This backend consists of an Offner spectrometer that incorporates a grating and images a slit onto a microblomter array. Designed for pushbroom operation, the spacecraft velocity will be used to map the surface. The project has a work plan to develop the instrument over 3 years to TRL 3. We will begin with optical, mechanical and focal plane subsystem development, and finish with fabrication of key components to demonstrate key elements and provide a proof of concept of instrument capabilities.

RELEVANCE: The proposed instrument development project responds directly to the PICASSO goal to conduct planetary and astrobiology science instrument feasibility studies, concept formation, proof of concept instruments, and advanced component technology development. The specific missions that we are targeting are a Flagship-class mission currently under study by the Ice Giants Science Definition Team and also New Frontiers missions to Io, Enceladus and Trojan asteroids. We will achieve this goal through development of a proof of concept prototype. Through infrared thermal mapping of planetary surfaces, this instrument will directly address science questions raised in the 2013 Decadal Survey for Planetary Sciences.

Soon Sam Kim/Jet Propulsion Laboratory
Rover Mounted Dielectric Spectrometer for Planetary Exploration
16-PICASO16_2-0015

Science Goals: In situ subsurface exploration is a key goal for NASA future planetary missions and astrobiology. Specific targets include searching for volatile-bearing minerals on Mars, and subsurface ices in permanently shadowed craters at the lunar poles. Ground penetrating radar (GPR) experiments, which have been selected for ESA s ExoMars mission and NASA s Mars 2020 mission, are adept at providing information regarding subsurface ice and stratigraphy. We propose to develop a rover mounted dielectric spectrometer (RDS) instrument that provides complementary measurements of subsurface material composition at radio frequencies. The proposed instrument will detect small concentrations of molecular species with permanent dipole moments such as chemically bound water, i.e., hydrate minerals. This capability will provide future rovers with the ability to rapidly assess the scientific potential of field sites for subsurface sampling, in situ analysis and sample return. Compared with a visible/IR camera or a spectrometer, which are limited to surface mineralogical features and could be obscured by dust and weathering products, RDS will detect subsurface hydrate minerals as well as surface exposed ones along the rover traverse down to 5 m depth.

Objectives: We will develop a miniature dielectric spectrometer which will be combined with a ground penetrating radar (GPR) that has been already developed to TRL 4. Through the PICASSO program, the dielectric spectrometer will be advanced from its current TRL 2 to TRL 4, and integrated with the GPR. At the end of program, the combined RDS/GPR instrument will achieve TRL 4, with a low mass (1.5 kg), and low power consumption (5 W). This compact instrument can be deployed on a rover for detection of subsurface ice and hydrate minerals.

Technical Approach: The principle of a dielectric spectrometer is based on the characteristic absorption of radio frequency (RF) power by water moieties of hydrated minerals. Conventional laboratory dielectric spectrometers require small amounts of samples placed inside sample cells, however our miniature dielectric spectrometer will obtain data by scanning over the surface (at 1 m above ground) without sample

preparation. Up to 5 m depth, the dielectric spectrometer will detect subsurface as well as surface exposed hydrate minerals with a RF scan range of 0.8 MHz -10 MHz, and at the same location, the GPR will detect subsurface ice and stratigraphy, operating at 800 MHz center-frequency to 5 m depth. Thus, the RDS/GPR instrument will detect water-ice and hydrate minerals combined with stratigraphic information. Compared with neutron spectrometer which detects the presence of hydrogen atoms up to a depth of 1 m, our proposed instrument has deeper penetration (5 m) and will provide molecular information characteristic of ice and hydrated minerals.

Methodology: We have already developed a miniature ground penetrating radar (GPR) supported by PIDDP (1999-2001), MIDP (2003-2005) and ESR&T (2005). For this task, we will utilize the already developed GPR (TRL 4) without further development. The main technical emphasis will be on the advancement of the miniature dielectric spectrometer (Currently @ TRL 2) to TRL 4, and integration of the spectroscopic data with GPR stratigraphy. Mounted on a rover, the dielectric spectrometer and GPR combination will take data at the same location. Both data sets will be tagged and displayed along with odometer readings of the rover traverse. Our expertise on RF instrumentation of GPR will leverage the development of the proposed RDS spectrometer.

Relevance: When matured through current PICASSO and next by MatISSE program, the RDS/GPR instrument will make crucial contributions for future planetary science missions such as Discovery, New Frontiers, Lunar and Mars exploration missions, in support of the objectives of the NASA Science Mission Directorate s Planetary Science Division.

Anupam Misra/University Of Hawaii at Manoa
Compact Color Biofinder (CoCoBi) for fast, non-contact detection of bio-markers, biomolecules and polyaromatic hydrocarbons in Ocean Worlds
16-PICASO16_2-0032

We have developed a prototype instrument called Standoff Biofinder which is able to detect biomolecules and bio-markers from a collection of rocks and minerals in a large area with detection time of 0.1 s. The Standoff Biofinder takes advantage of the short lifetime of bio-fluorescent materials to obtain real-time images showing the locations of biological materials among luminescent minerals in a geological context. The instrument works in daylight as well as nighttime conditions and bio-detection capability is not affected by the background light. The Standoff Biofinder instrument will be suitable for locating fluorescent polyaromatic hydrocarbons, amino acids, proteins, bacteria, biominerals, photosynthetic pigments, and diagenetic products of microbial life both on dry landscapes as well as on Ocean Worlds of the outer Solar System (e.g., Enceladus, Europa, and Titan).

At present, the images provided by the prototype biofinder are black and white images displaying the morphology and concentrations of biological molecules. In this proposal, we propose to develop the next generation of the instrument, Compact Color Biofinder (CoCoBi) which will provide color fluorescent images of biological species in a target area. One of the advantages of the color biofinder over the present biofinder system would be ability to differentiate multiple biological materials in a target area which may contain a mixture of biological species in various concentrations. CoCoBi will be helpful in identifying the biological materials based on their fluorophore colors, along with morphologies and concentrations. In addition, the color-biofinder will be significantly miniaturized in size and will be an ideal search for life future mission instrument. CoCoBi will be designed to look for ppm levels of biomaterial from a standoff distance of several centimeters in a geological setting, as well as in water and ice, with detection time less than 1 s. An important feature of the Standoff Biofinder instrument is its capability to detect biomolecules which are deeper in water and ice, without sample collection. The CoCoBi instrument will be useful for locating a biological material during future NASA rover, lander, and crewed missions to Moon, Mars, Jupiter, Venus, Enceladus, Europa, Titan, asteroids etc. Additionally, the instrument can be used for non-contact, non-destructive detection of biological materials in priceless samples obtained from sample return missions from other planets and asteroids.

Under this project, the TRL of the proposed compact color biofinder instrument will advance from TRL 2 to TRL 4.

Paul Sava/Colorado School of Mines
Seismic Orbital Laser VibrometEr (SOLVE)
16-PICASO16_2-0002

The goal of our project is to develop methodology for imaging the interiors of small planetary bodies using seismic waves acquired with laser vibrometers (LV) from orbit, without landers. We will develop and prove the LV methodology, from data acquisition to 3D imaging, for determining the detailed seismic structure of comets, asteroids and small moons. This capability will allow scientists to understand a small body without the risk or cost of landing, enabling seismology as a remote sensing mission. Current knowledge of small body interiors is inferred [Binzel et al 2003; Asphaug et al 2009] and unknown in detail. Direct knowledge of internal structure will constrain theories for the origin and evolution of small bodies, as emphasized in the Planetary Science Decadal Survey, and will inform methods for deflection or disruption of hazardous near-Earth objects (NEOs).

Penetrating radar can image icy comets [Sava et al 2015] but does not work well on conductive rocky asteroids. Seismology is effective for imaging the interiors of rocky and icy objects alike, with high resolution and accuracy, and is used widely in terrestrial exploration and global geophysics. However, seismology is limited in robotic space missions because it requires sensitive instruments to be deployed and anchored on the

surface. The SEIS instrument on the inSight mission will record the general seismic activity of Mars as a single, complex, ground-coupled instrument, but it cannot provide the necessary coverage for 3D interior seismic imaging of the planet. On a small body the problem is worse, since no mission has ever landed and anchored to a comet or asteroid. Arrays of seismic landers are possible, but at high cost, risk, and complexity.

We advocate seismic sensing using laser vibrometers [Donges & Noll 2015]. This technique is used in industrial non-destructive testing to detect minute oscillations with high bandwidth and accuracy, and with no direct contact with the studied object. At a comet or asteroid, LVs can function as remote-sensing seismometers with the following advantages:
- measure vibration from a distance: no landers and anchors required;
- have no data ambiguity associated with lander-surface coupling;
- are robust, proven instruments with no complicated mechanical components;
- can characterize ground oscillations at many distributed locations;
- the stable platform in orbit is not affected by ground noise and microgravity.

The proposed instrument definition study has three broad objectives:
1. Develop specifications for an orbital LV seismometer usable around a small body: (a) define laser power requirements for comet and asteroid optical reflectivities; (b) specify lens geometry to achieve small laser spots on the surface from different orbital radii; (c) design orbital conops strategies with sufficient observation time at each survey location. [PI Sava & CoI Asphaug]
2. Adapt 3D seismic imaging to LV seismic data: (a) simulate full wavefields consistent with orbital LV acquisition; (b) develop methods for LV seismic imaging for passive (e.g. tidal dissipation; thermal cracking; nucleus venting) or active sources; (c) correct for laser beam orientation relative to the target surface; (d) acquire multicomponent seismic data with LVs at different vantage points (multiple spacecraft). [PI Sava]
3. Demonstrate LV seismology on a small body subject to passive or active sources: (a) build realistic internal model structures for Phobos and 67P/C-G as type examples; (b) evaluate optimal acquisition and processing parameters; (c) quantify the attainable resolution and required mission duration. [CoI Asphaug & PI Sava]

The proposed SOLVE instrument will be usable for any mission to a small body under the Discovery or New Frontiers programs. This PICASSO project will bring the SOLVE TRL from 2 to 3, resulting in a fully-defined instrument and data processing flow, to be further developed in a MAtISSE funded project.

Robert Short/SRI International
Membrane Extraction for Space Applications
16-PICASO16_2-0078

Goals & Objectives: Detection of extant life and assessment of habitability on ocean worlds is a high scientific priority for NASA. However, many of the analytical

techniques commonly used to indicate signs of life rely on detection of complex, refractory biomolecules that may be low in abundance or difficult to sample. Gases, including light hydrocarbons and volatile organic compounds (VOCs) are a more plentiful and equally relevant set of analyte species that can be occluded in water and ice as both products of metabolism and indicators of habitability. These compounds (e.g., CO2, CH4) have been linked directly with biological activity on Earth in permanently ice-covered lakes in the Arctic and Antarctic. Our objective is to investigate a low-power variation of an extraction interface used routinely on Earth for laboratory and in situ analyses of gaseous, semivolatile, and water-soluble biosignatures from liquid samples. Specifically, we propose to further the technical readiness level (TRL) and reduce risk for a static (i.e., non-flowing sample) membrane introduction mass spectrometry (MIMS) interface for ultimate use in space applications, including lander missions with limited power budgets on ocean worlds. Membrane extraction is used in the well-established MIMS systems routinely deployed in Earth s oceans to detect light hydrocarbon, gases, and VOCs for scientific studies, and for resource and risk management. However, functionality of a static system has not been demonstrated at the breadboard level.

Approach & Methodology: Traditional MIMS interfaces use a flow-through or flow-over scheme in which water samples are pumped over a gas-permeable hydrophobic membrane. A small fraction of volatile and relatively nonpolar analytes dissolve into the membrane as the water passes it, diffuse through it, and evaporate into the vacuum of the mass spectrometer (a process known as pervaporation), whereupon they are ionized and sorted by mass for identification and quantification. We propose a lower power MIMS interface that obviates the need for a power-hungry sample pump and reduces the volume of water needed for analyses. This static interface will receive liquid samples from which a large fraction of the volatile species will be extracted and delivered to a mass spectrometer (or possibly some other analytical instrument). The extraction method could ultimately be coupled with a gas processing system, including enrichment cells or gas chromatography, to concentrate volatiles of interest for analysis by mass spectrometry and other detectors. We will evaluate the efficacy of the static extraction approach and optimize the design and operation for quantification of relevant analytes. Our approach will evaluate (1) a variety of interface designs and membrane materials, including the commonly used polydimethylsiloxane (PDMS) and (2) sample concentration alternatives on the vacuum side of the membrane interface. For these studies the prototype MIMS interfaces will be coupled to a laboratory linear quadrupole mass filter system.

Program Element Scope & Suitability: The membrane extraction system will be applicable for analysis of both solid ices (after melting) and liquids that may be found on a variety of ocean worlds. We respond directly to the NASA PICASSO solicitation (Program Element C.12) to develop and reduce the technical risks of component technologies so that they may later be proposed in response to Program Element C.13: Maturation of Instruments for Solar System Exploration (MatISSE). The analyte extraction and concentration capabilities of the proposed static membrane extraction system and its ability to provide analytes to a wide range of payload instruments are strategically aligned with the anticipated goals of an Ocean Worlds mission, specifically

to search for biomarkers and evidence of extant life and to provide an in situ assessment of habitability.

Jose Siles/NASA Jet Propulsion Laboratory
Comets Observation & Mapping Enhanced Terahertz Spectrometer/Radiometer (COMETS)
16-PICASO16_2-0054

We propose to develop in 3 years the receiver front-end (RFE) of COMETS: A low-power dual-band passively cooled integrated array spectrometer/radiometer for fast mapping of cometary comas & surfaces. Recent advances in technology, fabrication techniques and passive cooling systems allow us, for the 1st time, to propose submillimeter-wave multi-pixel instruments within the mass, size and power expected for planetary instruments and with a factor of 5 improvement in sensitivity with regards to the state-of-the-art (SOA). The operation principle is very similar to that of JPL s MIRO instrument on Rosetta, but COMETS will represent an important step forward: A much higher resolution and the possibility of perform instantaneous maps of the cometary coma. In MIRO, mapping requires scanning of the single beam by motion of the Rosetta spacecraft, which is a slow process that provides results strongly affected by the comet rotation. COMETS will take instantaneous snapshots due to its multi-pixel architecture and it will measure outgassing and abundances of volatiles from the cometary nucleus (H20, CH3OH, CO & NH3) and fundamental isotope ratios 17O/16O and 18O/16O + D/H in water.

COMETS will be a high-spectral-resolution (>106) heterodyne spectrometer/radiometer featuring both a 16-pixel receiver for continuum/spectroscopic measurements in the 240 GHz range and a 16-pixel receiver for water mapping in the 560 GHz range. The two bands will be integrated onto a single ultra-compact RFE housing using a novel concept called "on-chip diplexed frequency mixer" that allows to share a common local oscillator system and enhances the bandwidth of SOA mixers by more than a factor of two without degrading the receiver sensitivity. The RFE will also feature novel ultra-advanced silicon-micromachined adaptative array lenses to integrate the illumination correction with the RFE. The lenses guarantee the necessary illumination of the primary telescope (both bands) to acquire instantaneous maps of the comas. These advances, together with CMOS electronics developed at JPL under previous tasks, will simplify enormously the optics and instrument design, leading to the first multi-pixel high-resolution heterodyne planetary instrument with low power, mass and size.

The science of COMETS will expand significantly from that of MIRO/Rosetta: the ability to measure in real-time 2D-maps of the coma will allow to constrain directly coma model parameters, instead of relying on coma models for the interpretation of the data. COMETS can take instantaneous snapshots due to its multi-pixel architecture. In addition, COMETS will characterize outgassing and abundances of volatiles from the cometary nucleus (H20, CH3OH, CO and NH3) and fundamental isotope ratios 17O/16O

and 18O/16O + D/H in water using 2 frequency ranges, with a silicon-based lens array that will enable the acquisition of maps with the same footprint and spatial resolution at each frequency. It will also characterize the nucleus subsurface to depths of several millimeters or more. The COMETS RFE can be also used for remote water mapping and surface reconnaissance of ocean worlds like Enceladus and Europa.

The study of comets is one of the hot topics in the Decadal Survey in all 3 areas: building new worlds, planetary habitats and workings of solar systems: What were the initial stages, conditions and processes of solar system formation and the nature of the interstellar matter that was incorporated?, What were the primordial sources of organic matter, and where does organic synthesis continue today?, What solar system bodies endanger and what mechanisms shield Earth s biosphere?. Future planetary missions that could benefit from this technology would be any flyby, comet-encounter, comet surface sample return mission. In addition, planetary missions to ocean worlds would benefit from this technology.

The proposed work will advance the TRL of front-end of COMETS from 2 to 4.

Jurij Simcic/JPL/Caltech
Piezo-Electric Micro Valve for Atmospheric Descent Sampling
16-PICASO16_2-0044

Gas inlet systems for planetary-probe mass spectrometers (MSs) are required to admit gas at a relatively constant mass-flow despite the probe experiencing many orders of magnitude of ambient pressure change during the descent from vacuum to the terminal measurement altitude. A novel variable conductance valve based on micro-electro-mechanical systems (MEMS) technology, and utilizing a piezo-electric actuator is proposed herein as an ideal solution for such inlet system which can be coupled to an MS of choice for the selected atmospheric descent probe. Our piezo-electric microvalve (PEMV) will build on the heritage of a similar device that was developed at JPL 12 years ago for high-pressure gas micropropulsion applications [1-3], and was specifically optimized for proportional flow control of liquid or gas propellant, with measured He leak rates of 5e-3 sccm at 800 psi in its normally closed position. It was tested up to pressure difference of 5e4 Torr and could operate up to 125 degrees C. During static operation it consumed 8mW of power when valve was fully opened. Although never used for flight application or its original purpose, this device exhibited excellent characteristics needed for a constant mass-flow inlet system. Our idea is to slightly modify already proven design of the micropropulsion piezo-electric valve to allow for a fine regulation of a mass flow around the optimal value of 5e-7 TorrL/s in the pressure range of 1e2 - 1e5 Torr. That involves changing the number and dimensions of seat rings and adjustment of the tensile strength of the silicon membrane. After valves being manufactured, we will couple them to the JPL QIT-MS [4] and test their performance in desired pressure-temperature range.

The principal investigator will be Jurij Simcic who has a lot of practical lab experience in the field of quadrupole ion trap mass spectrometry, atomic and molecular physics and in designing electromagnetic lenses. He is a cognizant engineer for the QIT-MS for the Spacecraft Atmospheric Monitor (S.A.M.) and working on the Atmospheric Constituent Explorer System (ACES) Homesteader project for the maturation of constant mass flow inlet subsystem. Co-I, Byunghoon Bae is a MEMS expert that has more than 12 years of design, fabrication, and testing experience. He was a Co-I for the MEMS GC/MS PIDDP project, and the PI of NASA SBIR Ph II/II-E projects for the development of a MEMS-GC system for Cabin Air monitoring. He was also the PI of Army STTR Ph I/II projects for Micro-burner Based Flame Ionization Detectors (Micro-FIDs) for Micro-scale Gas GCs, which led to development of a portable lunch box micro-GC/FID/TCD detectors. He invented unique electrostatic microvalves that survived more than 46 million cycles. Currently in charge of developing MEMS PC/GC chips for S.A.M. flight project. Second Co-I Choonsup Lee, is also a MEMS Technology expert at JPL and one of the authors of the micropropulsion piezo-electric valve. He has extensive experience in the design and characterization of MEMS-based microsensors and microactuators such as thermal inkjet printheads, force-balanced tunneling microaccelerometers, infrared detectors, silicon microlenses, MEMS-based band-pass filters, microvalves, nanochannels, lateral field emission devices, and other MEMS/NEMS devices. Currently, he is working on terrahertz silicon waveguide technology. Third Co-I, Dragan Nikolic has experience in theoretical modeling in plasma, atomic and molecular physics and mass spectrometry calculations. He will be performing computational fluid dynamics (CFD) modeling to optimize the future valve design.

[1] Journal of Microelectromechanical Systems, Vol. 13, No. 5, October 2004
[2] Journal of Microelectromechanical Systems, Vol. 15, No. 3, June 2006
[3] Sensors and Materials, Vol.19, No.1 (2007) 001-018
[4] J. Am. Soc. Mass Spectrom. 25(11), (2014)

Alex Soibel/Jet Propulsion Laboratory
Non-saturating, simultaneous multiband, infrared imager
16-PICASO16_2-0074

We will develop a multiband imager that obtains simultaneous two-dimensional imaging at short-, mid- and long-infrared wavelengths. Moreover, this instrument will deliver non-saturating, wide dynamic range images of transient, rapidly-changing events. These capabilities enable a new range of previously unobtainable high science value planetary observations. In particular, this imager will enable study of high temperature volcanism on Io (and possibly Venus).

Scientific justification: The thermal emission from Io s volcanoes contains compositional information which reflects the state of Io s interior, with implications for the zone of habitability within the jovian system; for the identification of volcanically-active exoplanets; and for constraining the composition of hypothesized erupting lava on Venus.

Io s extraordinary volcanism presents unique observational challenges. Thermal emission radiance from Io s volcanoes spans more than six orders of magnitude and volcano behavior is highly unpredictable. Based on past experiences with Galileo instruments, two criteria must be met to measure the eruption temperature of Io s dominant silicate lavas (likely between 1400 K and 1900 K) and therefore meet the science objectives of a New Frontiers Io Observer mission. The first criterion is obtaining unsaturated, multi-wavelength data of the hottest (>1400 K) exposed areas present. The second is obtaining these multi-wavelength data simultaneously and quickly, overcoming uncertainty introduced into temperature measurements caused by rapid cooling between observations (a problem with Galileo SSI).

Current state of the technology: In the ideal application scenario, infrared imagers and spectrometers would provide high resolution images containing spectral and temporal information with high signal-to-noise ratio and infinite dynamic range. The currently existing technologies are capable of providing only two out of three types of information. For example, the currently deployed imaging spectrometers only acquire one-dimensional spatial image and utilize scanning to obtain a two dimensional image. This results in a time delay between obtaining data at different wavelengths for different points in the image, which is highly undesirable when a target event (e.g. a volcanic eruption) is changing faster than the data acquisition time. Also, these instruments can be saturated if the signal is higher than anticipated. With volcanic eruptions for example, the strength of the thermal emission is impossible to predict.

Proposed technology: The new technology proposed here is required to observe rapidly-changing transient events of unknown magnitude of thermal emission and areal extent without saturating the imager. The proposed work will develop two new technologies: (1) a faceted mirror design of infrared imager (2) a digital focal plane array. The faceted mirror design will deliver excellent, science-grade quality, two-dimensional images at nine spectral channels. The digital focal plane array will enable non-saturating, very high dynamic range (>100dB) infrared imaging at high operating temperature with excellent spatial uniformity and long term stability. This revolutionary advance in the digital focal plane array performance will be achieved by use of two recent technological breakthroughs: digital read-outs circuits with internal counter and high operating temperature barrier infrared detector.

Objectives: (1) Demonstrate a non-saturating digital focal plane array covering 1-10¼m spectral range (2) Develop a faceted mirror multiband imager providing simultaneous, time resolved images at 9 spectral channels with high spatial resolution. (3) Validate that developed imager meets requirement for an Io Observer New Frontiers mission

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Xu Wang/University of Colorado
The Development of A Double Hemispherical Probe for The Advancement of Space Plasma Measurements
16-PICASO16_2-0040

Science goals and objectives. Langmuir probes have been widely used onboard spacecraft (SC) for characterizing the space plasma density, temperature and SC potential using their current-voltage (I-V) curves. However, plasma environments in space are complex. When they interact with SC and in-situ Langmuir probes, localized plasmas will be generated around the probes and influence their measurements. These localized plasma environments are often anisotropic/inhomogeneous. We propose a novel Double Hemispherical Probe (DHP), which is an upgrade from a traditional single spherical probe (SSP). The DHP is composed of two identical hemispheres that are electrically insulated back to back and swept with the same potential biases simultaneously. When using the total current from two hemispheres, the DHP works identical as the SSP. However, the information derived from the differences between the I-V curves of the two hemispheres will greatly enhance the capability and accuracy for the ambient plasma characterization. The DHP has advantage over the traditional single Langmuir probes in the following anisotropic/inhomogeneous scenarios: 1) The probe may be immersed in the SC sheath due to its limited boom length. The DHP is able to identify and mitigate these effects on the probe measurements; 2) The photo- and/or secondary electron emission from the SC and probe itself are usually a significant contamination to the probe measurements, which can be better characterized using the DHP and removed from its I-V curves; 3) Ions generally have a drift speed relative to the SC. Using the developed Mach probe theories, the DHP is able to more accurately characterize the flowing ions; 4) When the SC zooms in dust-rich plasma environments, dust impact on the probe and SC will create localized plasma sources. The DHP is more capable to analyze and minimize the dust impact effects on the probe measurements. In addition, new coating materials for the probe surface will be validated to mitigate the surface oxidation problem in an oxygen-rich plasma environment. In summary, the objectives of our research are: 1) To enhance the capability and accuracy of the characterization of space plasmas by developing a novel Double Hemispherical Probe; 2) To develop new coating materials for mitigating the probe surface oxidation problem. Our science goal is to improve the understanding of space plasmas in harsh environments, including low-density plasmas, high surface-emission environments, dust-rich and oxygen-rich plasmas.

Methodology. We will build a prototype DHP, which mechanical design and electric circuitries take heritage from the current mature SSP technologies. The prototype DHP will be examined and studied using existing small-scale plasma chambers, the Colorado Solar Wind Experiment device and the dust accelerator facility at our NASA SSERVI/IMPACT laboratory at the University of Colorado-Boulder. The data analysis methods will be developed and validated with the experimental results. The new coating materials for the probe surface will be validated using oxygen plasmas and coated on the prototype probe.

Relevance to this program. The proposed DHP development will significantly improve the capability and accuracy for characterizing space and planetary plasma environments. The proposed instrument addresses several NASA s planetary science strategic goals and the goals in the decadal survey in 2013-2022. The entry level of the DHP development is between TRL 2 and 3, and the exit level is TRL 5 at the completion of the proposed technology. The proposed instrument development is highly relevant to the scope of this program and several potential NASA missions defined in the decadal survey.

Robert Winglee/University of Washington
Sample Return Instrumentation for Small Solar System Bodies
16-PICASO16_2-0003

To date, return sampling (except for the Moon) has been limited to surface samples which have been modified by solar wind interactions, and/or micrometeor impacts. This proposal seeks to use the kinetic energy of an approaching spacecraft to produce a self-ejecting core sample of the first few meters from small solar system objects. This sub-surface core will be the first of its type and will provide new information the content, origin and evolution of the solar system and the potential for life elsewhere. It will also provide new information as to why asteroids appear to have additional cohesive forces that prevent rotational break up, and determine variations in the composition from the capture of different bodies. The system will be also be able to capture organic compounds (if present), which will aid in understanding the origins of life.

The system also has the advantage that it requires less wet mass relative to soft-landing drilling approaches. The system operates in the velocity regime of 300-600 m/s which is typical of spacecraft approach speeds to an asteroid prior to any braking. At this speed impact pressures are sufficient to exceed the tensile strength of most rocks and allow the penetrator to bury into the sample to several feet, yet it is sufficiently slow to allow for the penetrator to remain intact after the impact. Entry ports in the nosecone of the penetrator allow material to flow into the center core where it will be collected by a sample return system. The bounce energy from the impact is sufficient to cause the collected sample to be ejected from the impact site of speeds of a few 10 s m/s. Depending on the escape velocity of the solar system object, the system would be optimize for pick up in space or for surface retrieval. The penetrator system and sample ejection have been demonstrated giving it an initial TRL of 3 through optimization of the system for different rock material still has to occur. The retrieval system is only at the concept stage and will require radar location and electromagnetic pickup.

This proposal seeks to advance these subsystems to TRL 3 or greater through modeling, laboratory testing and field prototyping. This effort will include (a) modeling to validate performance of different impact angles, (b) the ability of successful penetration irrespective of the hardness and roughness of the target terrain, (c) the collection of sample and its ejection within the sample return canister after impact and (d) demonstration of the ability to recover the sample return canister onto the main payload.

Through these efforts, we will fully demonstrate core rock sample that is self-ejected under a variety of different rock impacts and impact velocities thereby demonstrating the versatility of the system for multiple NASA applications.

Shanshan Yu/Jet Propulsion Laboratory
Millimeter-wave spectrometer for chirality and relative abundance determination of amino acid biomarkers
16-PICASO16_2-0055

The search for life is a high-priority science objective in the 2013 Decadal Survey paper Vision and Voyages for Planetary Science in the Decade 2013 2022. The paper recommends (page 240) a detailed characterization of organics to search for signatures of biological origin, such as molecules with a preferred chirality or unusual patterns of molecular weights as a key future investigation for determining the possibility of life beyond Earth. While mass spectrometry has often been proposed for measuring the abundance patterns of molecular weights, it lacks the chirality detection capability required for chiral analyses of chiral molecules such as amino acids, and cannot uniquely identify specific structure-based isomers such as fatty acids. Current chirality detection technologies all involve complicated sample isolation and/or chemical derivatization processes.

The novel millimeter-wave chirality detection spectrometer (ChiralSpec) advances key technologies to enable chirality detection and discrimination of structural isomers with a simple instrument. ChiralSpec is applicable to mission focus areas such as Enceladus, Europa, Titan, and Mars. It could be used on planetary in-situ probes to measure amino acids, fatty acids, and other organic molecules in the gas phase or brought into the gas phase. Two of the unique advantages of ChiralSpec are (1) it can analyze the mixture of gases without separating them first; and (2) it has an extraordinary capability for distinguishing isomers.

ChiralSpec employs an innovative microwave three-wave mixing technology for chirality detection and the cavity resonance technology for sensitivity enhancement. ChiralSpec can be operated under two modes: (1) survey mode, with the instrument acting as a traditional microwave spectrometer to characterize chemical composition and quantify abundance of planetary samples; and (2) chirality detection mode, with the instrument determining which enantiomer is in excess and how much it is in excess for each existing chiral molecule.

ChiralSpec contains two parts: a polarized pulsing transmitter and receiver system, and a three-axis resonator chamber. We will design ChiralSpec covering the 75 215 GHz region and perform chirality experiments first with a volatile chiral molecule propylene oxide at room temperature, and then with an nonvolatile amino acid alanine at 77 K. Our implementation develops and demonstrates ChiralSpec measurement technologies in the millimeter-wave region:

(1) Design and fabricate the polarized pulsing transmitter and receiver system
(2) Design and fabricate the three-axis resonator chamber
(3) Integrate the pulsing system and the resonator chamber
(4) Perform laboratory chirality experiments to demonstrate ChiralSpec s sensitivity.

ChiralSpec has entry TRL2 and exit TRL3. The period of performance is 3 years with a start in CY2017.