PLANETARY SCIENCE INSTRUMENT DEVELOPMENT PROGRAMS

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Objective

Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere

Science Goals

1. Explore and observe the objects in the solar system to understand how they formed and evolve.
2. Advance the understanding of how the chemical and physical processes in our solar system operate, interact and evolve.
3. Explore and find locations where life could have existed or could exist today.
4. Improve our understanding of the origin and evolution of life on Earth to guide our search for life elsewhere.
5. Identify and characterize objects in the solar system that pose threats to Earth or offer resources for human exploration.

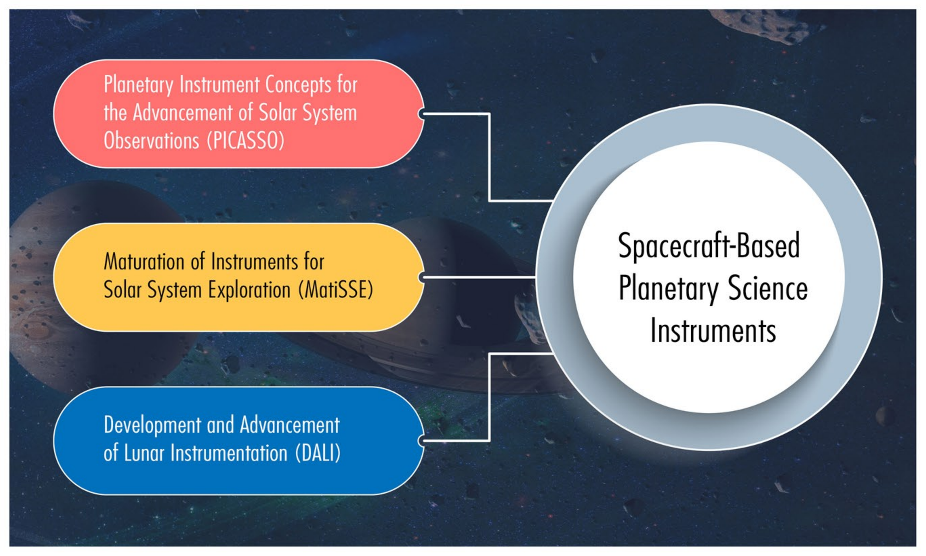
Introduction

NASA's Planetary Science Division (PSD) combined the existing independent technology and science instrument development programs such as the:

- Planetary Instrument Definition and Development Program (PIDDP)
- Mars Instrument Development Program (MIDP)
- Astrobiology Science and Technology for Instrument Development (ASTID) program and
- Astrobiology Science and Technology for Exploring Planets (ASTEP) program

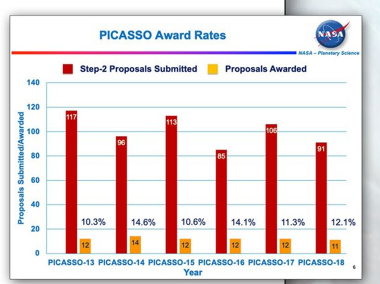
into three sustained, broad-based science instrument development programs that includes new instrument concepts as well as improvements to existing instruments

Spacecraft-Based Science Instrument Development Program



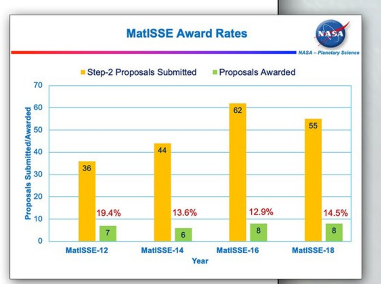
PICASSO

- Goal - to support the development of spacecraft-based instrument components and systems that show promise for use in future planetary missions
- Objective - to develop low TRL instruments for use in planetary science missions to the point where they may be proposed in response to the MatISSE Program
- The entry TRL that PICASSO supports is 1-3
- Proposals are typically sought every year
  - 20-PICASSO Step-1 proposals due: Sept 18, 2020
  - 20-PICASSO Step-2 proposals due: Nov 20, 2020
- The budget is ~$3.5M per year
  - Average Award ~ $250 - $300K/year
  - Typically ~ 12 Awards
  - 18-PICASSO: 91 proposals were reviewed and 11 Awards were made



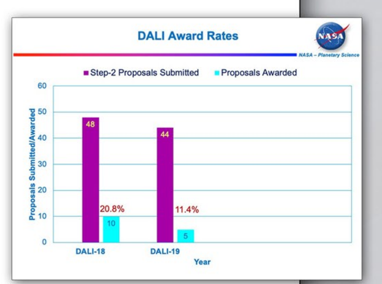
MatISSE

- Goal - to develop and demonstrate planetary science instruments to the point where they may be proposed in response to future announcements of flight opportunity without additional extensive technology development
- Objective - to develop new technologies that significantly improve instrument measurement capabilities for planetary science missions
- MatISSE develops technologies TRL 4-6
- Proposals are typically sought on even numbered years
  - 20-MatISSE Step-1 proposals due: April 17, 2020
  - 20-MatISSE Step-2 proposals due: June 19, 2020
- The budget is ~$6 M per year
  - Average Award ~ $1 M/year – Typically ~ 6 Awards
  - 18-MatISSE: 56 number of proposals were reviewed and 8 Awards were made



DALI

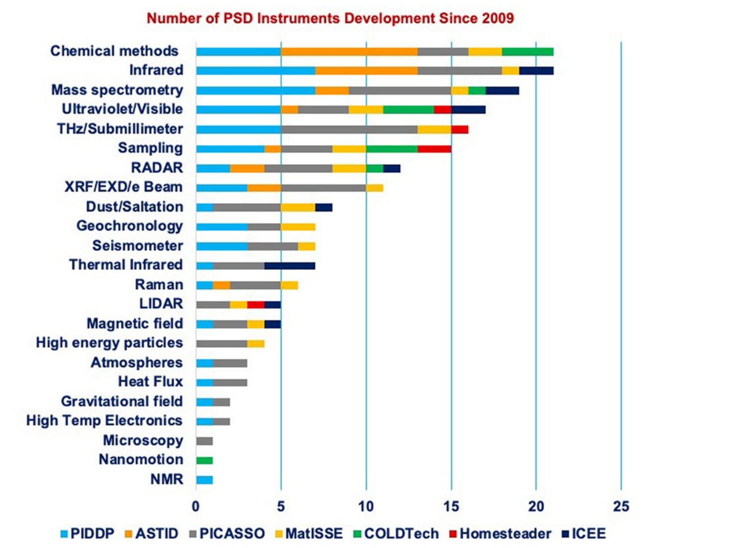
- Goal - to develop and demonstrate lunar science instruments to the point where they may be proposed in response to future announcements of flight opportunity without additional extensive technology development
- Objective - to develop new technologies that significantly improve instrument measurement capabilities for lunar science missions
- TRL that DALI supports are 4-6
- Proposals are typically sought every year
  - 20-DALI Step-1 proposal due: April 17, 2020
  - 20-DALI Step-2 proposal due: June 12, 2020
- Expected budget is ~$1 M per year per award
  - New Awards ~ 5 Awards
  - Max duration of awards: 3 to 4 years
  - 19-DALI: 44 number of proposals were reviewed and 5 Awards were made



Other Relevant Programs

- Although PICASSO, MatISSE and DALI are the main focus of the PSD instrument development programs. PSD does on occasion solicit more narrowly targeted instrument development efforts. For example:
  - Concepts for Ocean worlds Life Detection Technology (COLDTech), which supports the development of spacecraft-based instruments and technology for surface and subsurface exploration of ocean worlds such as Europa, Enceladus, and Titan
  - Instrument Concepts for Europa Exploration 2 (ICEE-2), which supports the development of in struments and sample transfer mechanism(s) for Europa surface exploration.
  - These efforts may be may be either low TRL programs for far term goal, such as with COLD Tech or they may be mid-TRL programs supporting shorter-term goals, such as ICEE-2.
- Additionally, to give some of the would-be competitors for the New Frontiers Announcements of Opportunity (NF AO) a head start, a small round of technology development funding is made available through the Homesteader Program. The goal of this program is to mature proposed technologies and reduce their technical risk such that the accompanying mission concepts are better prepared for the next two NF AOs. This Homesteader opportunity is open to any technology utilized as part of at least one of the seven mission concepts included in the Decadal Survey list recommended for the NF program.

Science Instruments Program Focus



Impact of Planetary Science Instrument Development Programs on NASA Missions

- The impact is visualized by showcasing instruments that are manifested to fly on NASA's science missions
  - Some of these instruments have been developed and matured through NASA's flight instrument development & maturation programs discussed earlier
  - The remaining instruments may have received support from other SMD divisions, other Mission Directorates, or external organizations
  - These examples and the instruments are not to be interpreted as the outcome of an exhaustive study

Ultra Compact Imaging Spectrometer (500-2600 nm)

PI: Diana Blaney/Jet Propulsion Laboratory

- Matured under 12-MatISSE12-0024
- Key advantages:
  - 75 μm/pixel spatial resolution
  - Head mountable on lander/rover arm
  - Low power (<15 W), Low mass (1.65 kg)
  - Electronics (1.0 kg) located in lander/rover body
- New science enabled:
  - Non-destructive technique for remote mineral identification and mapping by measuring the reflected light from a surface.
  - This instrument can be used to investigate Martian, lunar, cometary, and asteroidal geological processes by mapping the composition and spatial relationships between key constituents
  - Technique works at all spatial scales from 10's of microns to 100's of km's
  - Enables linking surface measurements with orbital remote sensing measurements in the same wavelength range
- Co-I's: *Joseph Boardman/Analytical Imaging and Geophysics; Robert Green, Pantazis Mouroulis, Jose Rodriguez, Byron Van Gorp/JPL*

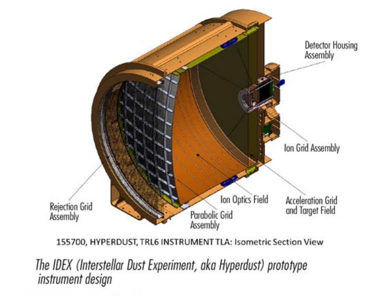
Ultra Compact Imaging Spectrometer instrument (right) and the enclosure (left)

- Mission infusion:
  NASA's Europa Clipper mission will carry an Ultra Compact Imaging Spectrometer also known as Mapping Imaging Spectrometer (MISE). MISE will probe the composition of Europa to identify and map the distributions of its organics, salts, acid hydrates, water ice phases, and other materials. These measurements are expected to inform on the habitability of the European oceans. The MISE science investigation will address the Decadal Survey question: Beyond Earth, are there contemporary habitats elsewhere in the solar system with necessary conditions, organic matter, water, energy, and nutrients to sustain life, and do organisms live there now?

Hyperdust – High-Performance In Situ Dust Analyzer

PI: Zoltan Sternovsky / LASP, University of Colorado

- Matured under 12-MatISSE12-0033
  HyperDust is the next generation dust instrument that builds on the Cassini dust compositional mass spectrometer (CDA) experience. It will have dramatically improved characteristics: ~ four times larger target area, ~ five times better mass resolution, ~five times better sensitivity to dust impacts and full trajectory measurements with unprecedented angular resolution. HyperDust is an alternate to sample-return missions, enabling observations of multiple targets from a single spacecraft. A large variety of missions, flybys, orbiters, and landers are suitable platforms for this dust telescope.
- Key advantages:
  - Size: 52×58×48 cm3; Mass: 9.5 kg; Power: 10W
  - Combines high mass-resolution with large target areas
- New science enabled:
  Enabled analysis of a statistically significant number of cosmic dust particles of interstellar, asteroidal and cometary origin that will lead to the understanding of the formation and evolution of the solar system
- *Co-I's: E. Grün / U of Colorado, K. Maute / U of Colorado, M. Horanyi / U of Colorado, S. Kempf / U of Colorado*



The IDEX (Interstellar Dust Experiment, aka Hyperdust) prototype instrument design

- Mission infusion:
  - The Composition Analyzer part of the Hyperdust instrument also known as the Interstellar Dust Experiment (IDEX) is now in development for deployment on NASA's Interstellar Mapping and Acceleration Probe (IMAP) mission
  - NASA is also developing the Surface Dust Analyzer (SUDA) instrument for the Europa Clipper mission. SUDA carries an ion detector that is based on that developed for Hyperdust. The SUDA instrument will analyze the icy particles originating from the surface of the Jovian moon Europa, and identify the chemicals embedded in the ice, both organic and inorganic

GeMini Plus: A Miniature Gamma-Ray Spectrometer

PI: David Lawrence/Johns Hopkins Univ.-Applied Physics Lab

- Matured under 14-MatISSE14_2-0009
- Key advantages:
  - Single instrument measures neutrons and Gamma-rays
  - Self-healing of in-flight radiation damage
  - On-board digital pulse shaping mitigates radiation damage effects not reversed through annealing (enhances resolution and peak shape)
  - More mechanically robust HPGe sensor
  - Greatly reduced resource requirements (CubeSat size w/o electronics, 2.5 kg, 5.5 W)
- New science enabled:
  - Measures bulk composition and compositional stratigraphy to depths of 10's of cm
  - Superior detection & quantification of elemental lines compared to scintillators (Bismuth Germinate - Lunar Prospector)
  - Capable of 2X higher energy resolution over prior HPGe instruments (MESSENGER)
  - Improved radiation tolerance enables longer missions (outer solar system, etc.)
- Co-I's: *Morgan Burks/Lawrence Livermore Nat Lab., John Goldsten/JHU-APL, Patrick Peplowski/JHU-APL*

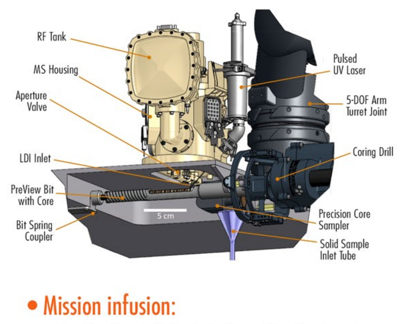
GeMini Plus Gamma-ray detector has a high-purity Ge sensor (gold cylinder) cooled to cryogenic temperatures by a long-life cryocooler (silver cylinders)

- Mission infusion:
  - NASA's Psyche mission carries a Gamma Ray and Neutron Spectrometer (GRNS) (GeMini) to measure the elemental composition of the asteroid 16 Psyche orbiting the Sun between Mars and Jupiter. The Neutron Spectrometer is a separate subsystem and the sensors are identical to those employed on the Lunar Prospector
  - MEGANE (GeMini) investigation on Japan's Mars Moon Exploration (MMX) mission will measure the elemental composition of Mars' moon Phobos,
  - The Dragonfly Titan rotorcraft would carry a GeMini to measure the elemental composition of Titan's surface materials at multiple locations

Linear Ion Trap Mass Spectrometer (LITMS)

PI: William Brinckerhoff/NASA Goddard Space Flight Center

- Matured under 12-MatISSE12-0019
- Key advantages:
  By integrating both Mars-ambient laser desorption and precision subsa-mpling with pyrolysis/gas chromatography of drill cores at fine (≤ 1 mm) spatial scales, LITMS will enable in situ characterization of organics and elements in individual rock core layers and features
- New science enabled:
  LITMS will enable in situ characterization of organics and elements in fine-scale rock core layers and features. This unprecedented level of integrated analytical capability is critically needed to achieve advanced astrobiology objectives at Mars as well as to support selection decisions required for Mars Sample Return
- Co-I's: *Ricardo Arevalo, Daniel Glavin, Paul Mahaffy/ GSFC; Bruce Block/Univ of Michigan; Philip Chu, Kris Zacny/Honeybee Robotics; Ryan Danell/ Danell Consulting; Xiang Li, Veronica Pinnick/UMBC; Friso van Amerom/Mini Mass Consulting*

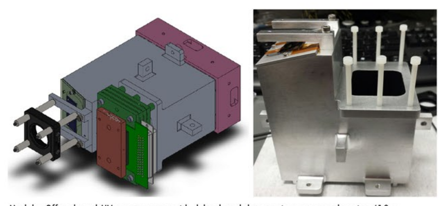


- Mission infusion:
  - The Mars Organic Molecule Analyzer - Mass Spectrometer (MOMA-MS) which is an astrobiology instrument on the 2020 ExoMars Rover mission was initially developed under MatISSE and matured by the mission.
  - The Mass Spectrometer on the Dragonfly mission (Dra-MS) also draws on advancements made by the Goddard team that developed the MOMA-MS

Compact, High Dynamic Range UV Imaging Spectrom

PI: Shouleh Nikzad/Jet Propulsion Lab

- Matured under 16-MatISE16_2-0078
- Key advantages:
  - Delta-doped high quantum efficiency (QE) detector
  - Eliminates MCP detector and associated high-voltage electronics
  - Higher QE detector enables use of the Offner optical design
  - Offner design reduces overall volume compared to typical Rowland Circle-based detectors used with MCP instruments
  - High reflectivity coatings extending well into ultraviolet
- New science enabled:
  Better resolution and better dynamic range makes possible deeper measurements and therefore enables possibilities of discovery
- Co-I's: *Alex Carver/JPL, Bob West/JPL, Pantazis Mouroulis/JPL, Dan Wilson/JPL*



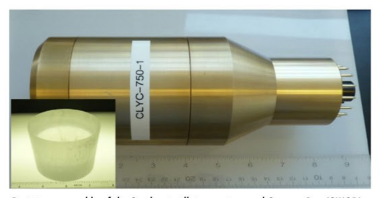
Modular Offner-based UV spectrometer with delta-doped detector in a compact housing (10 x 10 x 10 cm)

- Mission infusion:
  - The Star-Planet Activity Research CubeSat (SPARCS). The mission is to monitor the flares and sunspots of M dwarf stars in the far- and near-ultraviolet to determine how habitable the space environment is for planets orbiting them. NASA's Astrophysics Division supported the SPARCS development
  - The Spatial heterodyne Interferometric Emission Line Dynamics Spectrometer (SHIELDS). The mission is to obtain a spatial map of scattered solar ultraviolet emission from interplanetary hydrogen that has crossed, and been modified by, the ion pile-up along the outer edge of the heliosphere. NASA's Heliophysics Division supported the SHIELDS development

Neutron and Gamma-Ray Spectrometer

PI: Craig Hardgrove/Arizona State University (ASU)

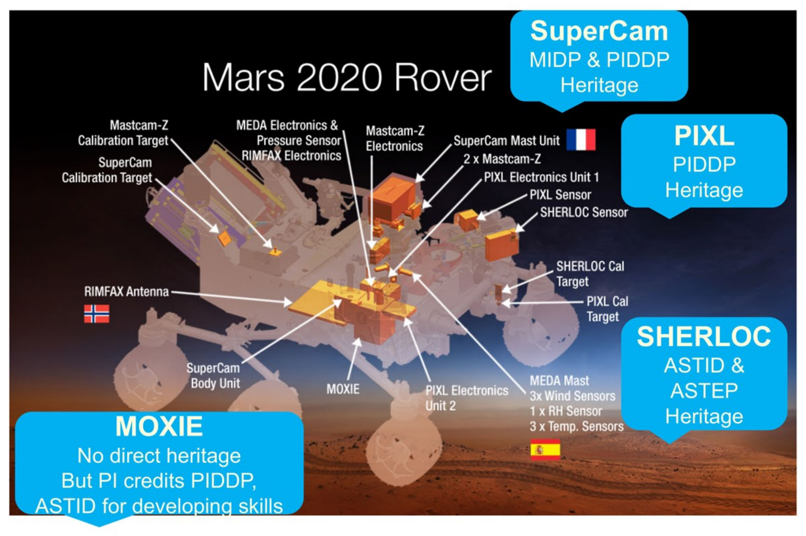
- Matured Under 14-PICASO14_2-0037
- Key advantages:
  - New scintillator material Cs2YLiC16:Ce (CLYC)
  - Single-scintillator Neutron and Gamma-Ray Spectrometer (SINGR)
  - high neutron detection efficiency and excellent energy resolution for Gamma-Rays
  - Self annealing at room temperature
  - Platform independent - Useable either on orbiters (passive mode using cosmic rays as source) or on landers (active mode using a pulsed neutron generator)
- New science enabled:
  - Characterizes the abundance of near-surface hydrogen and rock-forming elements on a variety of planetary missions including Moon, Mars, NEOs, and comets
  - Enables probing of sub-surface up to 50 cm deep
- Co-I's: *Hugh Barnaby/ASU, James Christian, Radiation Monitoring Devices (RMD), Inc., Erik Johnson/RMD, Jeffrey Moersch/Univ of Tennessee, Ann Parsons/NASA GSFC, Thomas Prettyman/Planetary Science Institute, Chad Whitney/RMD, James Bell/ASU*



Prototype assembly of the Single-scintillator neutron and Gamma-Ray (SINGR) Spectrometer with the CLYC detector

- Mission infusion:
  - NASA's Lunar Polar Hydrogen Mapper (LunaH-Map) a 6U CubeSat mission that will carry the SINGR Spectrometer with the CLYC detector
  - The LunaH-Map will fly as a secondary payload on Artemis I (formerly EM-1) of the Deep Space Exploration Systems
  - The LunaH-Map mission will measure hydrogen abundances from a highly elliptical, low-perilune (5-10 km) orbit in order to understand the relationship between hydrogen and permanently shadowed regions, particularly craters, at the Moon's South Pole.

Mars Perseverance Rover and Science Instruments



Mars Perseverance Rover Science Instruments Infusion

- The Mars Perseverance rover mission is part of NASA's Exploration Program, a long-term effort of robotic exploration of the Red Planet. The mission not only seeking signs of habitable conditions on Mars in the ancient past, but also searching for signs of past microbial life itself
  - Three instruments on this rover were matured under various PSD instrument maturation programs
  - Under the PIDDP, ASTID, and ASTEP programs, Jet Propulsion Laboratory matured the development of two instruments selected for the Mars Perseverance rover. These instruments are the Planetary Instrument for X-ray Lithochemistry (PIXL) and the Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC)
  - Under the PIDDP and the MIDP programs, Los Alamos National Labs developed the third instrument, SuperCam

Summary

- The evolution of the instrument development programs in the Planetary Science Division (PSD) within Science Mission Directorate (SMD) is discussed
- Specifically the goals and objectives of the three instrument development programs within PSD are discussed, namely, PICASSO, MatISSE, and DALI
- Additionally, instruments that were developed and matured under current and previous PSD instrument development and maturation programs and selected for flight missions are presented