Instrument Development Programs In Support of NASA'S Planetary Science Missions

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NASA Planetary Science

***Strategic Objective*: Ascertain the *content*, *origin*, & *evolution* of the solar system and the potential for *life* elsewhere.**

It seeks to address this objective with five fundamental goals:

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

Spacecraft Based Science Instrument Programs

- Two major planetary science instrument programs within the NASA's Planetary Science Division (PSD)
  - Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO)
  - Maturation of Instruments for Solar System Exploration (MatISSE)

Basic Instrument Development Strategy

PICASSO → **MatISSE** → **Flight Instrument**

I have this crazy idea

I can make it work

How did we ever do without it?

TRL 1-3 → **TRL 4-6** → **TRL 7-9**

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
  - PICASSO18 Step 1 proposals were due on : Sept 20, 2018
  - PICASSO18 Step 2 proposals are due: Nov 20, 2018
- The budget is ~$3.5M per year
  - Average Award ~ $250 - $300K/year
  - Typically ~ 12 Awards
  - PICASSO17: 106 proposals were reviewed and 13 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, currently completed reviewing MatISSE18 proposals
- The budget is ~$6 M per year
  - Average Award ~ $1 M/year
  - Typically ~ 6 Awards
  - MatISSE16: 62 proposals were reviewed and 8 Awards were made

Instruments Being Developed for Venus

- Planetary Heat-Flux Sensor for Venus (14-PICASSO14_2-0100)
  - Michael Pauken – JPL
- High Temperature Electronics (14-PICASSO14_2-0093)
  - Gary Hunter – NASA GRC
- Airborne Electromagnetic Sounding of the Interiors of Venus, Mars, and Titan (15-PICASSO15_2-0079)
  - Bob Grimm – SWRI
- Piezo-Electric Micro Valve for Atmospheric Descent Sampling (16-PICASSO16_2-0044)
  - Jurij Simcic – JPL
- Universal MEMS Seismometer (17-PICASSO17_2-0029)
  - Karl Yee – JPL
- Development of far-UV-sensitive silicon imaging arrays for compact UV instrumentation (17-PICASSO17_2-0083)
  - Philippa Molyneux – SWRI

TRL 6 Instruments Adapted for Venus

- Europa Short Wavelength InfraRed Spectrometer - Radiation and Planetary protection Maturation ESWIRS-RPM (Robert Green/JPL)
- Development of an Instrument to Measure Turbulent Eddy Fluxes in Planetary Atmospheres (Scott Rafkin/SWRI)
- Planetary Instrument for Submillimeter-wave Surface and Atmospheric Reconnaissance and Research in Orbit (PISSARRO) (Goutam Chattopadhyay/JPL)
- Development of Large Format Rad-Hard Focal Plane Arrays and Readouts for Thermal Radiometer for Europa Clipper Mission (Matt Kenyon/JPL)

Ultra Compact Short Wavelength Infrared imaging Spectrometer (UC-SWIRS)

PI: Robert O. Green / Jet Propulsion Laboratory

TRL = 6

Platform: Compatible with Venus Lander, Balloon, or Orbiter

Key Capabilities:

- Spectral range: 0.4 to 5 microns
  - full range or subset
- Spectral sampling: 10 nm
  - adaptable to requirements
- Radiometric range: 0 to specific saturation
- Radiometric sampling: 16 bits
- Spatial swath: ~5 to 45 degrees
  - adapted to requirements
- Spatial sampling: 0.1 to 1 milliradians
  - adapted to requirements)

Key Advantages over State of the Art:

- Collects measurements with full spectral and image content
- Multiple octaves of spectrum collected with single detector and instrument
- Nominal mass: 3kg
  - function of exact requirements
- Nominal power: 3 W
  - function of environment
- Onboard compression/analysis

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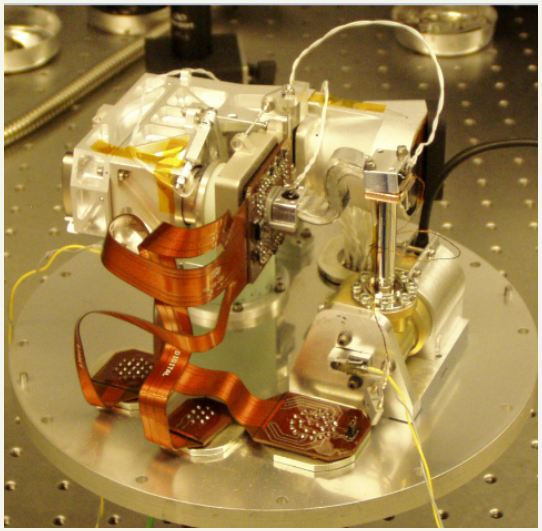
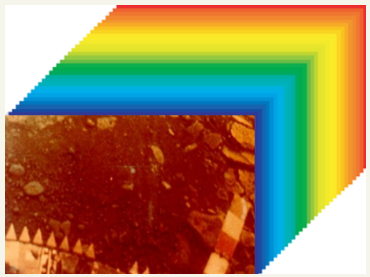
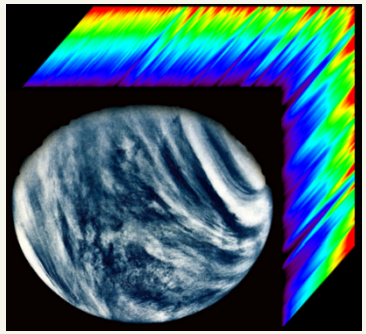


UC-SWIRS engineering model. UC-SWIRS can be configured for lander, Balloon or Orbiter science investigations.



Example UC-SWIRS Lander image cube



Example UC-SWIRS Orbiter image cube

New Science Enabled:

- Spectroscopy from the visible through short wavelength infrared with image coverage
- A broad range of material composition and process investigations
- Specific science investigations are a function of the platform and refined requirements

Venus: Trace Gas Measurements with an Eddy Flux Option

PI: Scot Rafkin/Southwest Research Institute TRL = 6

Platform: Lander, Balloon, or Probe! Choose one, two or all three!

Key Capabilities:

- Integrated acoustic anemometer and laser spectrometer for eddy flux measurements of momentum, energy and trace gases.
- Spectrometer available as stand alone instrument for key trace gas measurements (SO_2, OCS, H_2SO_4, H_2O, CO, H_2S, HCL…) with necessary accuracy and sensitivity.
- Rapid measurement: > 1 Hz
- Modular subsystem design is easily adaptable to different platforms and even other planets.

Key Advantages over State of the Art:

- Fast response to capture fine structures.
- Up to 8 unique channels; expansion possible.
- Robust against corrosion, high temp and press.
- Low Resource (<1 W, < 1 kg).
- Onboard data processing minimizes data volume.
- Solid state laser and optics, no moving parts.
- Can be integrated with acoustic anemometer for simultaneous wind and eddy flux measurements.

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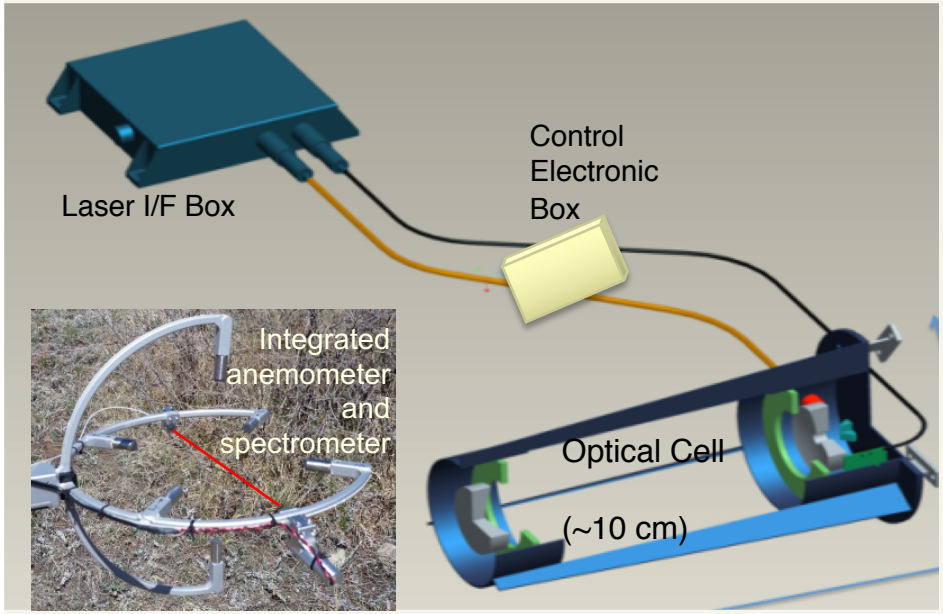

Figure Caption: Modular instrument design. Optical cell with patented mirror design is ~10 cm in length. Can be integrated on to an acoustic anemometer for eddy flux measurements. Integrated acoustic anemometer and laser spectrometer (with laser path shown by red line) undergoing field testing (inset, above).

New Science Enabled:

- Rapid measurement of multiple trace gases to capture fine structure on descent or fast variations on a balloon or at the surface.
- Simultaneous measurement of key chemical species to assist in closure of chemical cycling.
- Addition of eddy flux provides dynamical source term for momentum, heat and mass.

Submillimeter-Wave Spectrometer Instrument for Venus Exploration

PI: Goutam Chattopadhyay/Jet Propulsion Laboratory **TRL = 5**

Platform: Venus Orbiter

Key Capabilities:

- A submillimeter-wave limb sounder providing unique data on the atmospheric physics and composition of Venus' atmosphere.
- High-resolution submillimeter-wave spectrometer instrument allows sub-ppb sensitivity for trace species, direct temperature, pressure, wind measurements.
- High-TRL instrument matured through MatISSE investments.
- Flight heritage: based on proven technologies from SWAS, Herschel, EOS Aura, and Rosetta MIRO instrument.

Key Advantages over State of the Art:

- MIRO was 19 Kg and needed 88 W DC of power. This instrument uses weighs less than 7 Kg and needs less than 12 W of DC power.
- Uses state-of-the-art CMOS all digital back-end spectrometers and low-power frequency synthesizer.

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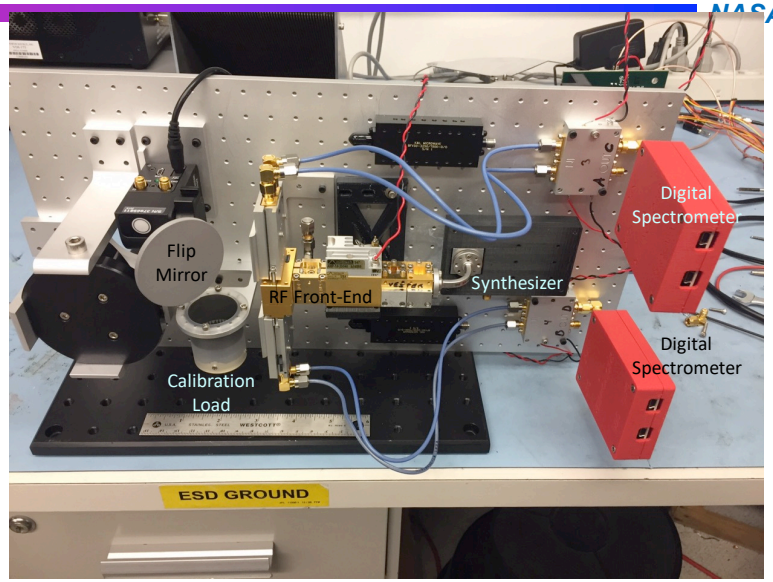

High-TRL low-mass and power (12W) highly-integrated submillimeter-wave spectrometer for Venus exploration. The entire instrument can fit-in 2U form factor.

New Science Enabled:

- Provide elemental and isotopic compositions of species in Venus' atmosphere, especially the noble gases and nitrogen-, hydrogen-, carbon-, and sulfur-bearing species.
- Provide the knowledge of how the global atmospheric circulation patterns of Venus differ from those of Earth and Mars.
- Provide information related to the key processes, reactions, and chemical cycles controlling the chemistry of the middle, upper, and lower atmosphere of Venus.
- Determine how solar energy drives atmospheric circulation, cloud formation, and chemical cycles that define the current climate on terrestrial planets.

Venus Climate Sounder

PI: Matt Kenyon/Jet Propulsion Laboratory

TRL = 5

Platform: Orbiter

Key Capabilities:

- **CRITICAL HERITAGE:** Venus Climate Sounder (VCS) builds on Mars Climate Sounder (MCS) w/ simple mods to achieve half scale height limb profiling from low, polar, circular Venus orbit
- **BETTER DESIGN:** Keeps MCS excellent radiometric stability and accuracy but uses only one telescope (smaller/simpler)
- **RELIABLE & CHEAP(ER):** No cooler or active cooling of anything

Key Advantages over State-of-the-Art:

- **PERFECT PITCH:** Use new large format thermopile array with 2x smaller pixel pitch to achieve FOV
- **COVERS ALL WAVELENGTHS:** Detectors measure from 0.3-100 um with near perfect efficiency
- **LONG STARES AT LIMB:** Negligible low-frequency (1/f) noise in detector-signal chain allow for long integration times for high signal-to-noise

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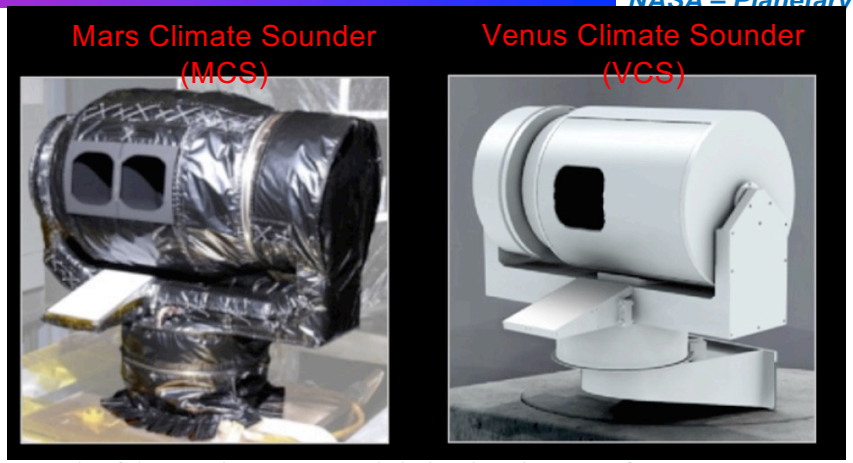

Figure: (Left) MCS has returned daily global maps of temperature, pressure, dust and ice from Mars, from the surface to 80km for more than 11 years. (Right) VCS incorporates all the design features of MCS for high accuracy radiometry, but utilizes a modern thermopile array that reduces the FOV by 2x and includes 10 spectral channels in a single telescope.

New Science Enabled: Address Decadal Science:

(i) How do the global atmospheric circulation patterns of Venus differ from those of Earth and Mars?
(iii) What are the influences of clouds on radiative balances of planetary atmospheres, including cloud properties: microphysics, morphology, dynamics and coverage?

- Global structure of middle atmosphere mapped with half scale height (2-3 km) vertical resolution from the cloud tops to 110 km, both day and night.
- Global variation of temp, pres, aerosol opacity and water vapor over day/year
- Improved understanding of the structure and circulation of the middle atmosphere of Venus