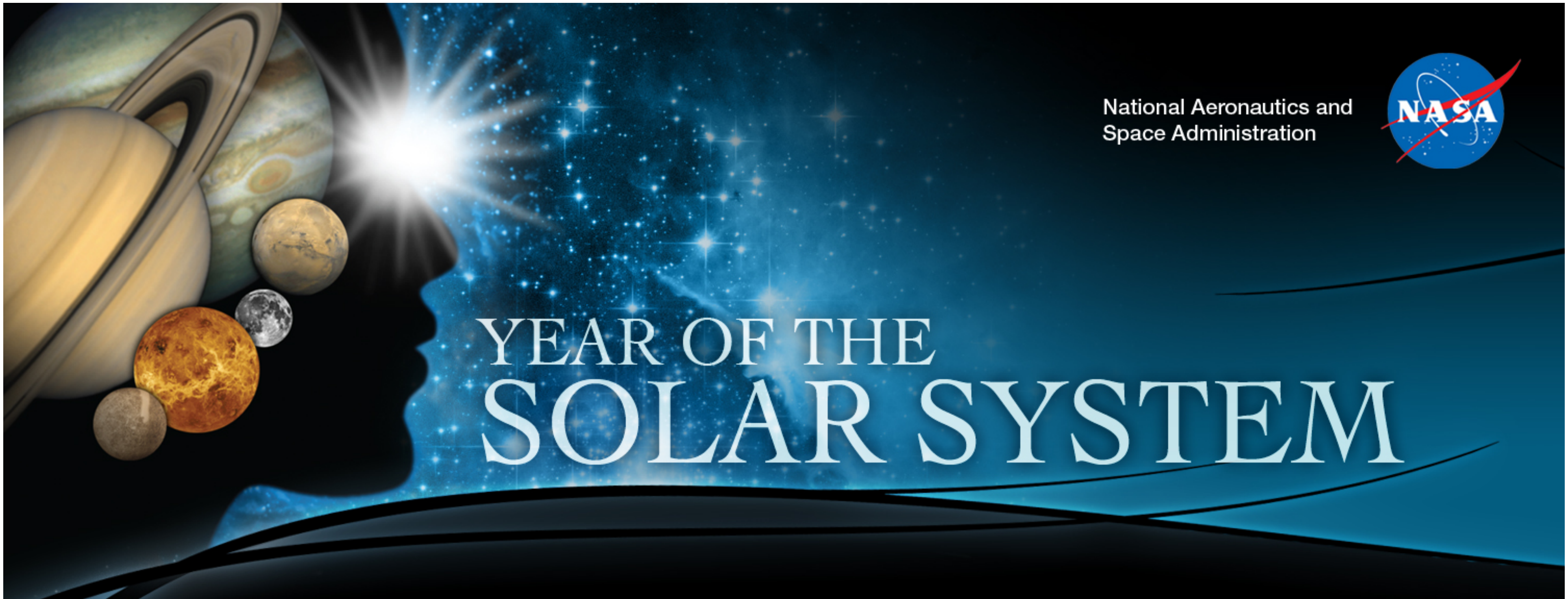


Technology Investments in Venus Exploration

August 30, 2011

NASA Program Officer
Janice Buckner

Technology Program Overview

The Planetary Instrument Definition and Development Program (PIDDP) funds scientific research and engineering efforts focused on the development of innovative instrument systems that show promise for use in future scientific investigations on NASA Planetary Science missions.

Background

- PIDDP has contributed to the development of more than half of all flight hardware flown on or selected for NASA's planetary missions since the program's inception in ~ 1980.

- It is regarded by the scientific and engineering community as a highly successful and critical component of NASA's Planetary Science Division.

PIDDP Activities

TRL 1

- Feasibility studies of emerging techniques or component technologies
- Miniaturization of existing instruments such as rock age dating systems, spectrometers, seismometers, chemical sensors and gas chromatographers
- Development of new detectors, optical elements, supporting electronics
- Laboratory instrument breadboarding, brassboarding, and complete instruments system
- Field demonstrations

TRL 6

"*PIDDP also invests in sample collection and sample handling technologies*."

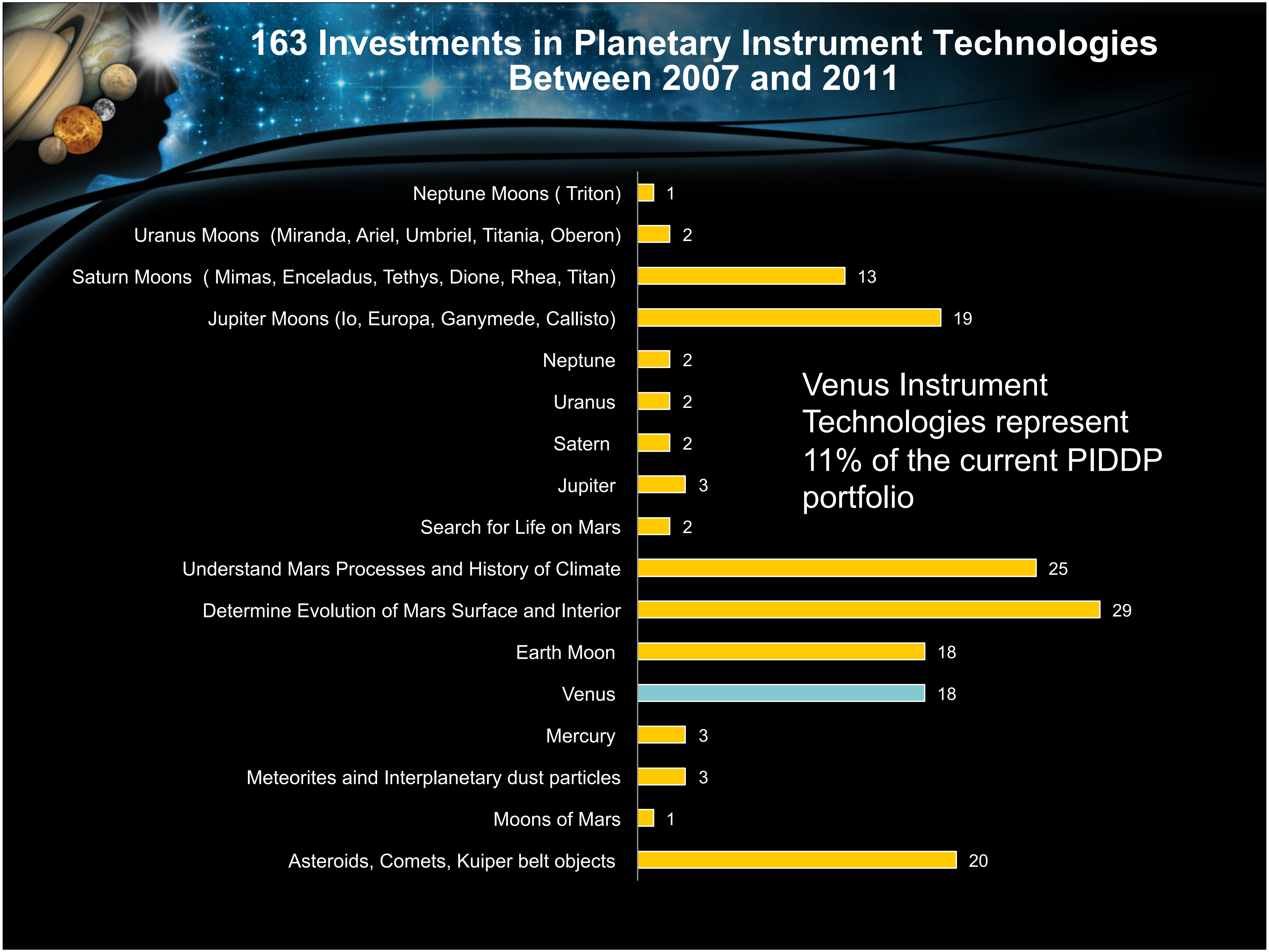
Venus Technologies Sought

High temperature/pressure survivability technologies

- ✓New materials
- ✓Batteries
- ✓Electronics
- ✓Possibly, cooled containers for long-term in-situ missions

Development of robust scientific instruments and sampling systems:

- ✓Age-dating systems
- ✓Spectrometers
- ✓Seismometers
- ✓Sub-surface drilling technologies


163 Investments in Planetary Instrument Technologies Between 2007 and 2011
Neptune Moons (Triton) 1
Uranus Moons (Miranda, Ariel, Umbriel, Titania, Oberon) 2
Saturn Moons (Mimas, Enceladus, Tethys, Dione, Rhea, Titan) 13
Jupiter Moons (Io, Europa, Ganymede, Callisto) 19
Neptune 2
Uranus 2
Satern 2
Jupiter 3
Search for Life on Mars 2
Understand Mars Processes and History of Climate 25
Determine Evolution of Mars Surface and Interior 29
Earth Moon 18
Venus 18
Mercury 3
Meteorites aind Interplanetary dust particles 3
Moons of Mars 1
Asteroids, Comets, Kuiper belt objects 20
Venus Instrument Technologies represent 11% of the current PIDDP portfolio

Measuring Heat Flow on Venus: A Flux Plate Approach
PI: S. Smrekar/ JPL

Technical Objectives:

- Achieve good thermal coupling to the surface while maintaining thermal gradient between sensors

  Approach: Use Carbon Nanotubes (CNTs), which have high thermal conductivity at 460°C, to couple plate to surface

Obtain high measurement precision (rapid equilibrium)

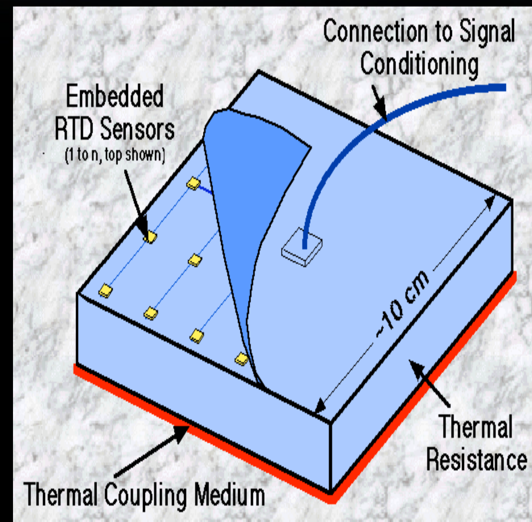
  Approach: keep plate small (current concept ~10 cm by 3 cm)

Mitigate the effects of variations in surface physical properties (not too large a thermal contrast)

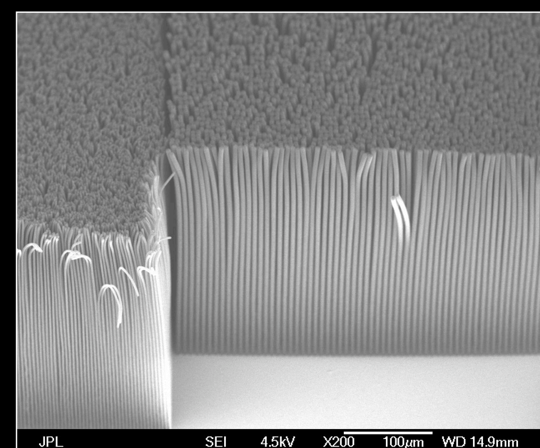
  Approach: match surface conductivity and emissivity to the extent possible

Operation in the Venus environment

  Approach: No exterior electronics other than temperature sensors



Heat Flow Flux Plate



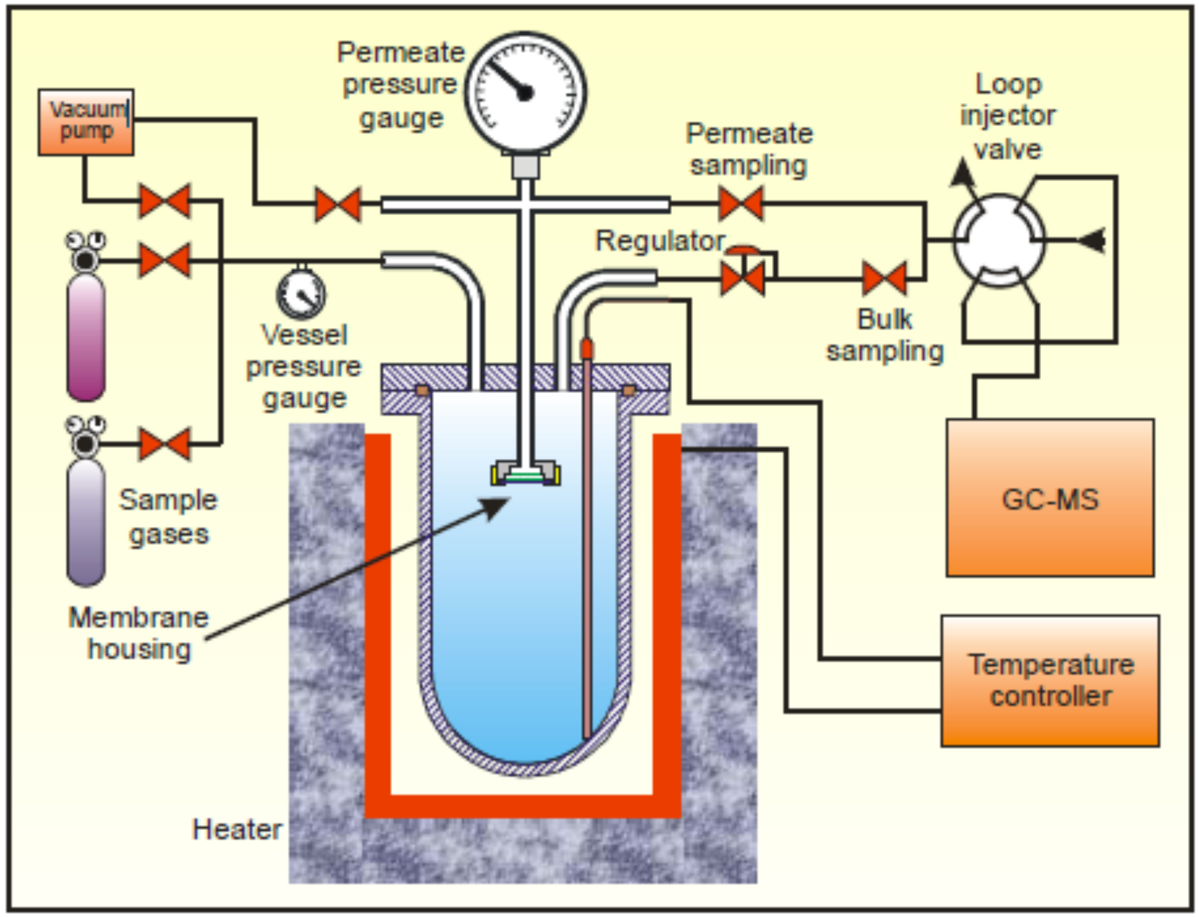
Carbon Nanotube array bundles are approximately 320 μm tall.

Development of a Membrane Inlet System for Use in Harsh Environments

PI: Tim Brockwell/ Southwest Research Institute

Science Objective

Mass spectrometers will play a major role in the investigation of planetary atmospheres. The use of membrane inlet is applicable wherever the ambient pressure would overwhelm the pumping system of a spectrometer and is advantageous in dusty or condensing environments that would block conventional inlets.



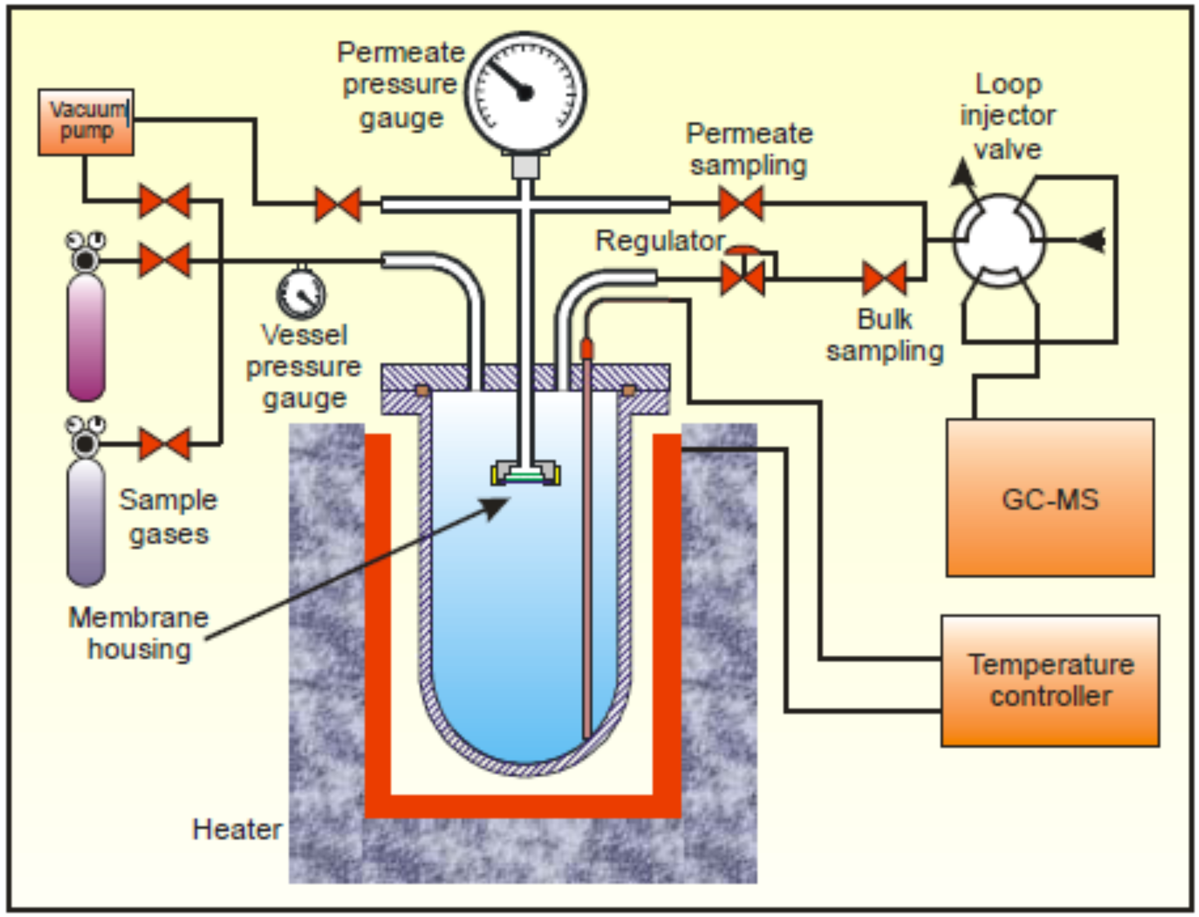
Schematic of the Membrane Testing Apparatus

Development of a Membrane Inlet System for Use in Harsh Environments

PI: Tim Brockwell/ Southwest Research Institute

Technical Objective

To determine the suitability of membrane inlets for future missions to Mars, Venus and Saturn by the creation of an environment simulator to reproduce the mission conditions and to determine the corresponding characteristics of the candidate membranes.



Schematic of the Membrane Testing Apparatus

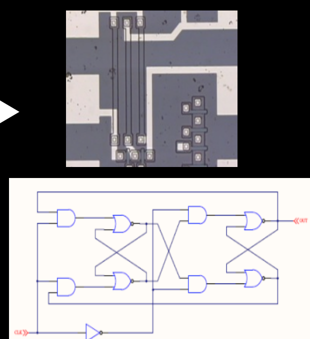
High Temperature Seismometer For Venus Applications

PI: Gary W. Hunter/NASA Glenn Research Center

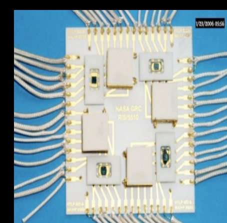
Overview of High Temperature Seismometer For Venus Applications

Sensor and Seismic Measuring Instrument Relevant to Venus

High Temperature Electronics and Communication Design and Fabrication



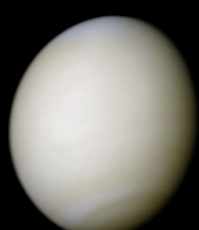
Integration of Instrument and Electronics to form a Seismometer



Extended Testing at Venus Temperatures

Proof-of Concept Demonstration of Venus Seismometry

Venus Seismometer Roadmap



Science Objective

Seismometry on Venus has been identified as a fundamental measurement with revolutionary scientific implications. However, there is a fundamental question as to whether such measurements can be performed given the high temperature, harsh environments of Venus.

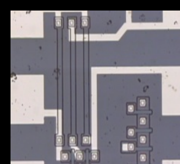
High Temperature Seismometer For Venus Applications

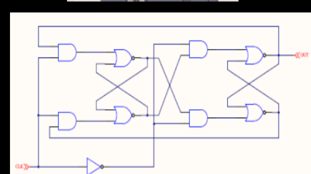
PI: Gary W. Hunter/NASA Glenn Research Center

Overview of High Temperature Seismometer For Venus Applications

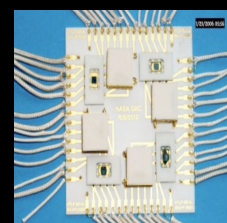
Sensor and Seismic Measuring Instrument Relevant to Venus

High Temperature Electronics and Communication Design and Fabrication





Integration of Instrument and Electronics to form a Seismometer



Extended Testing at Venus Temperatures

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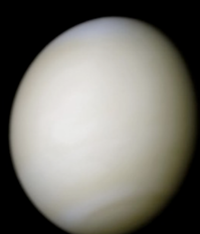


Venus Seismometer Roadmap

Technical Objective

- This project will design, fabricate, and demonstrate a high temperature proof-of-concept seismometer operating at 500˚C.
- Bring together the leading technology developer for high temperature electronics and sensors, a leading planetary researcher, and company at the forefront of high temperature sensor development.
- Approximate TRL: TRL_{in} ~ 2; TRL_{out} ~ 3-4

Extreme Temperature Nanotube Electronics (ETNa)

PI: Andrew Monica/Johns Hopkins University Applied Physics Laboratory

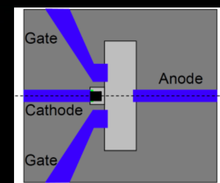
Program Goal

The ETNA program outlines a 2-year effort to develop harsh environment integrated microelectronics based on field emission from carbon nanotubes (CNTs) for use in space and planetary missions.

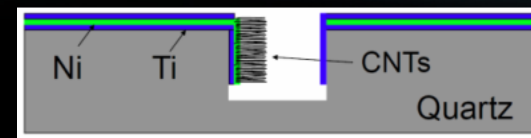
These CNT-triodes are immune to ionizing radiation and are capable of operating over a wide temperature range (~20K to ~900K). Our goal is to demonstrate both analog and digital integrated circuit building blocks using this CNT-triode electronics paradigm.

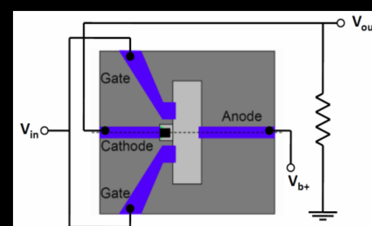
This project addresses the NASA goal of solar system exploration, specifically of Venus, volcanic vents on Io, the lower atmospheres of the Jovian planets, Jupiter’s moons, asteroids, etc.

CNT Triode: Top-down

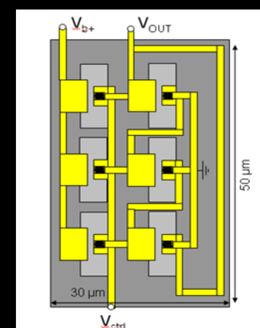


CNT Triode: Cross-section

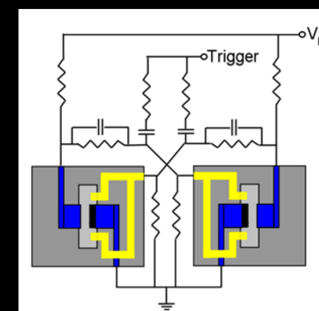




Voltage amplifier



Voltage-controlled oscillator

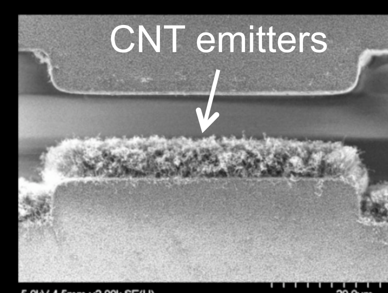


Flip-flop

Increasing Complexity

- High-T CNT Triode development
- High-T amplifier development
- Flip-Flop development
- Ring Oscillator development

TRL 4 to TRL 6

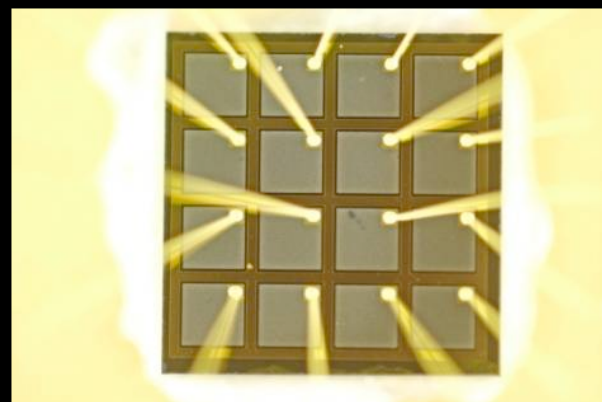


SiC-based Robust Uncooled X-ray Detectors for Extreme Planetary Environments

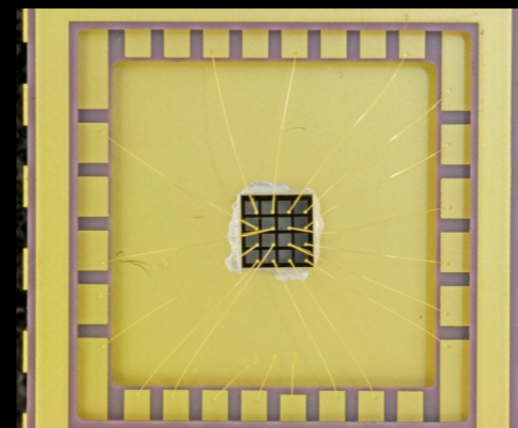
PI: Kyung-ah Son/JPL

Fabrication of new generation SiC Schottky diode detectors

SiC X-ray detectors



4x4 Detector Array



Detector Housing

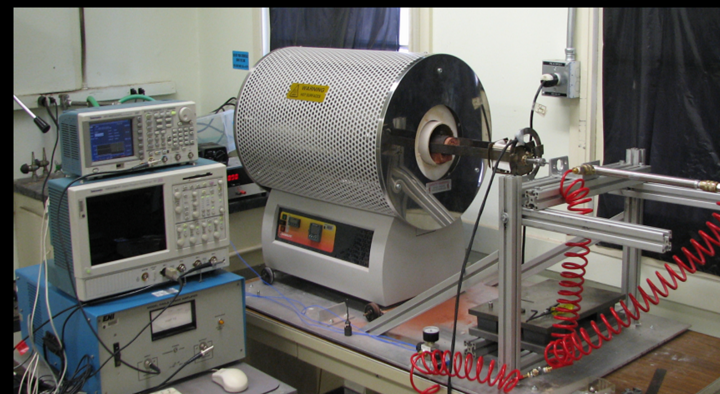
Developing SiC-based X-ray detectors that will enable an uncooled, chemically and thermally stable, radiation-hard, high resolution X-ray detector capable of operating over wide ranges of temperature and pressure and in caustic and strong radiation environments, which are expected in the future Venus and outer planet missions.

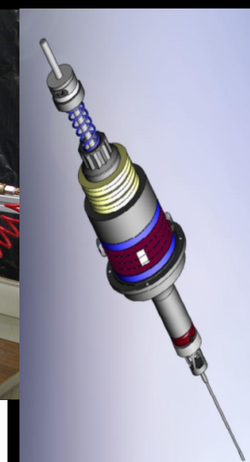
High Temperature Piezoelectric Actuated Sampler for Operation on Venus

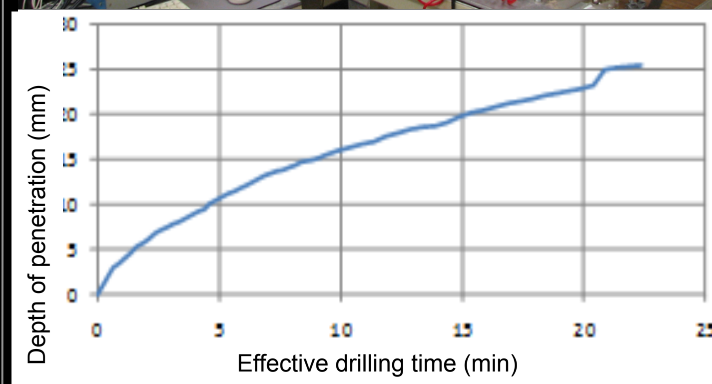
PI: Yoseph Bar-Cohen, JPL

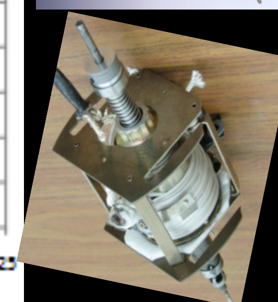
Technical Objectives:

To establish sampling capability for missions to Venus by advancing the development of a ultrasonic/sonic driller and corer that can operated at temperatures as high as 500°C.









Technology Development Partners PI: Yoseph Bar-Cohen, JPL, yosi@jpl.nasa.gov, 818-354-2610
JPL: CoI: Mircea Badescu, Xiaoqi Bao, and Stewart Sherrit
Penn State University: Lead CoI: Tom Shrout, CoI: Shujun Zhang and Beth Jones
Education outreach (Space Grant students): Scott Widholm and Patrick Ostlund, JPL

High Temperature Piezoelectric Actuated Sampler for Operation on Venus

PI: Yoseph Bar-Cohen, JPL

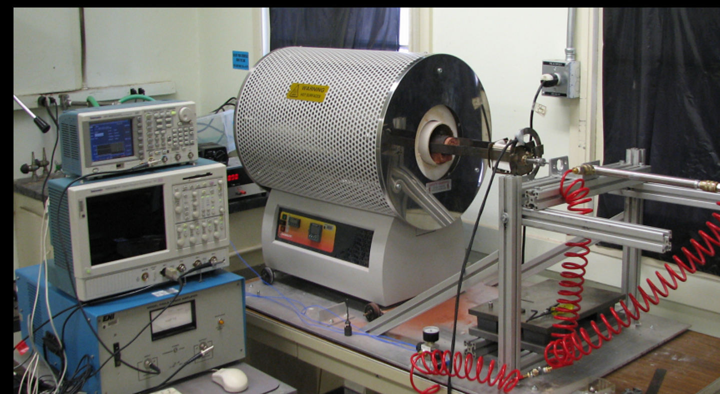
Recent Accomplishments:

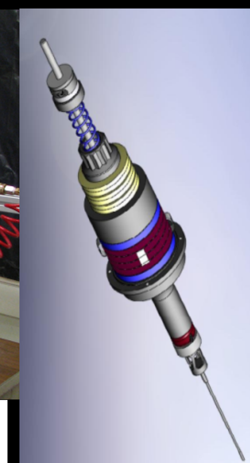
✓Developed novel design that makes the drill a rotary-hammer - the rotation is generated by the vibration of the piezoelectric actuator.

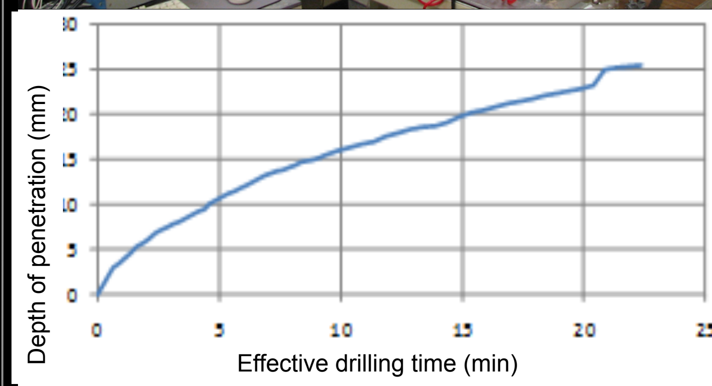
✓ Completed isothermal tests of $LiNbO_3$ piezoelectric discs at 500°C for 1000 hours which yielded no change in properties

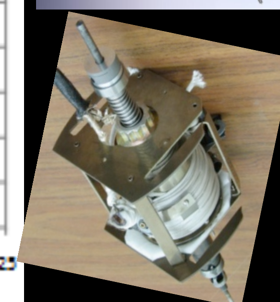
✓Successfully drilled at 460°C thru a 25 mm thick brick sample in 21 minutes accumulated time

✓Submitted several New Technology Reports









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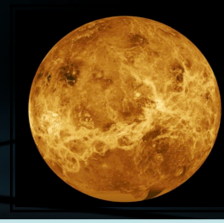
Venus Pressure Test Chamber

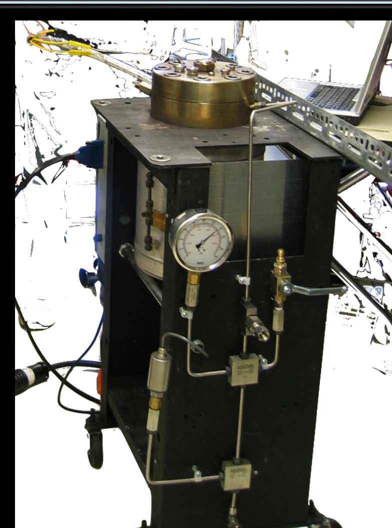


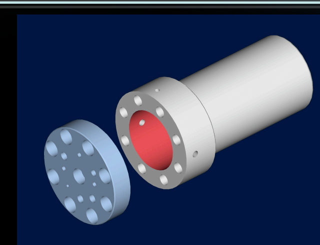
Natasha M Johnson/PI, GSFC

Description – What is it?:

A small, high temperature, high pressure chamber to simulate environmental conditions on Venus' surface. (*e.g., 740 K and 95.6 bar*)

Small size allows for quick turn-around testing of components and experiments. Conditions are monitored in real-time.





The Basics:

- Internal dimensions: diameter 12.7 cm (5 in)
  depth 30.5 cm (12 in)

- Monitored via NI LabView
- Operating parameters:
  Max pressure 96 bar
  Temp range 298K – 740K
  Gases: CO_2, N_2, SO_2 *(ppm)* or mixture

Objectives:

- Test instruments and/or components to be proposed for Venus missions (*i.e.*, Discovery/New Frontiers)
- Conduct Venus appropriate experiments (*e.g.*, surface-atmosphere reactions)
- Explore different chamber configurations for a range of experimental options

Key PIDDP Information

Proposals Due Date: August 26, 2011

Expected Budget for 1st Year of Awards : $3M

Number of Selected Awards : 10-15

Max duration of Awards : 3-Years

Thank You for Your Attention

Janice L. Buckner

Technology Program Officer

Planetary Science Division

NASA Headquarters

janice.l.buckner@nasa.gov