Long-Duration Venus Lander Development

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Approved for public release

Why Explore Venus?

Venus Earth

Layers of Acid Clouds

Continuous tornado – like winds

Mysteries to Solve - Similar but Sooo… Different

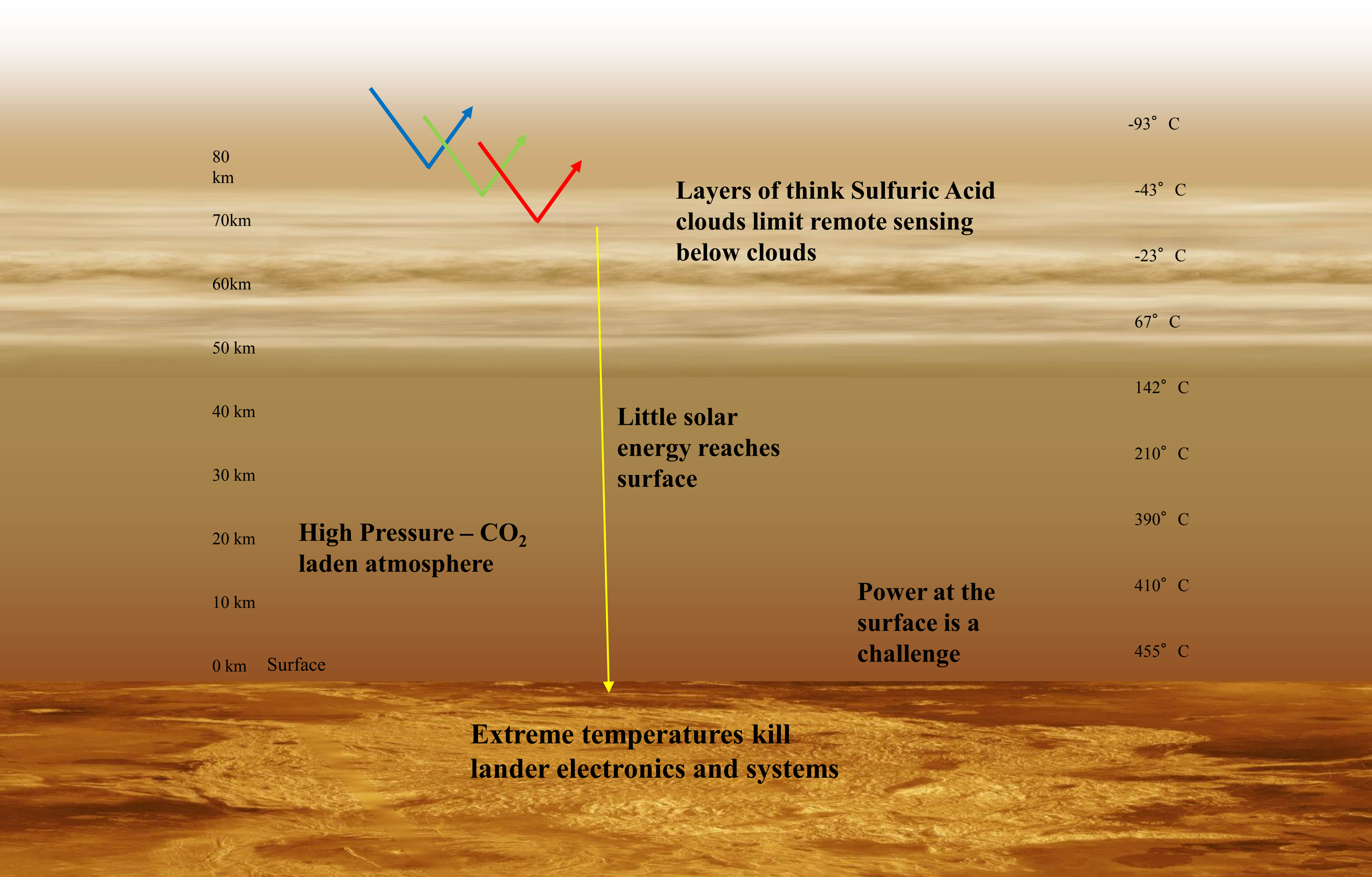
Temps approaching 900°F

Crushing pressure

No Magnetic field

Backward and super slow rotation

The Unique Challenges of Venus



Preparing to Explore the Venus Surface

Provide Venus simulation capabilities

- Support experiments, technology development, flight qualification, and mission support
  - E.g. Glenn Extreme Environment Rig (GEER) and other rigs

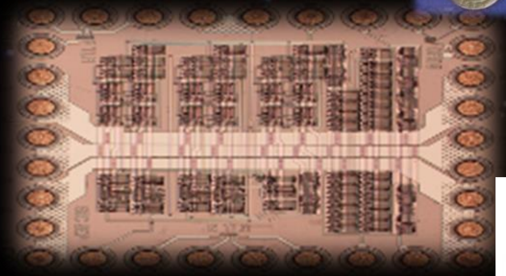
Conduct experiments to better understand the environment when we get there

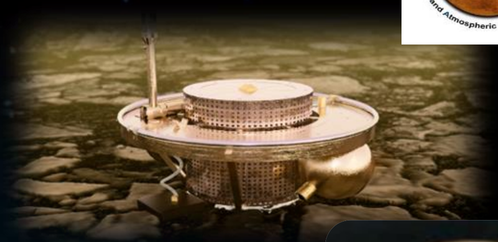
  - Know what to look for and interpret data we capture

Develop and mature exploration approaches

  - Better thermal management and more durable components for “conventional” landers
  - High temperature systems for long duration missions
    - Electronics, sensors, batteries, and more

Studies for innovative concepts and operations

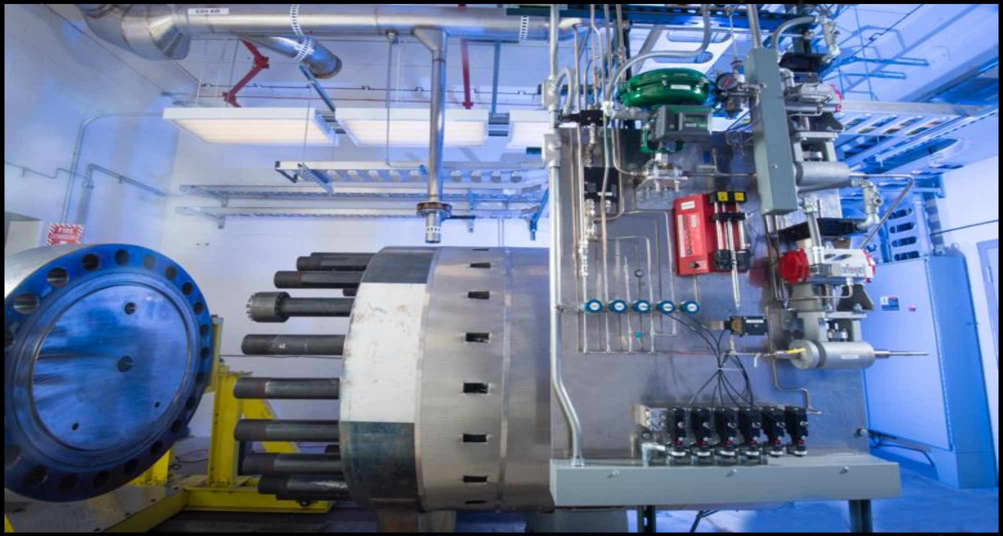




Venus Simulation

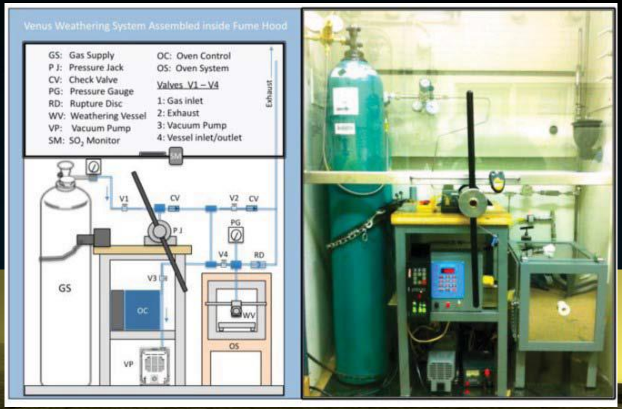
Venus Chambers of Varying Capabilities and Purposes

GEER (GRC): Large volume, full temp and pressure, complete and precise chemistry for extended periods



Los Alamos vessel: Long axis, full temp and pressure for remote sensing

VICI (GSFC) : Full temp and pressure, quick sample exposures



JPL Venus vessel focused on weathering. Full temp and pressure

Various other chambers exist as well (E.g. APL)– contact respective organization for potential access

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140013390.pdf

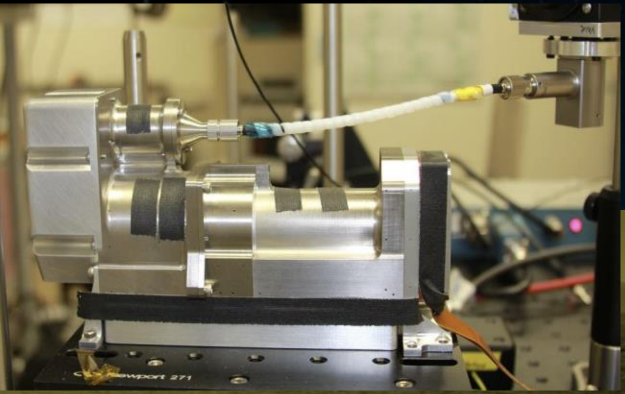
Ground Based Experiments

Ground based experiments will better prepare missions and mission concepts

Some recent experiments have included:

- Exposure tests to understand nature and time scales of chemical weathering, and in a broader sense, explore the potential surface / atmosphere interactions
- Experiments on compatibility of spacecraft materials with the atmosphere
  - Near surface atmosphere is reactive
- Tests and experiments to verify instrument measurement capabilities in the unique Venus conditions

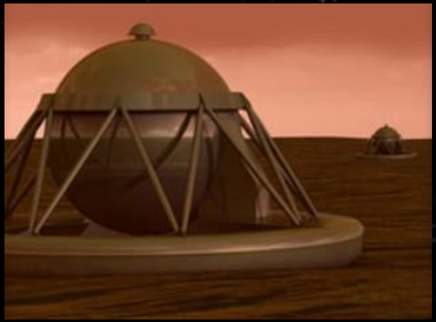
VEMCAM testing (Courtesy Sam Clegg) LANL



Mineral testing in NASA Glenn's GEER facility

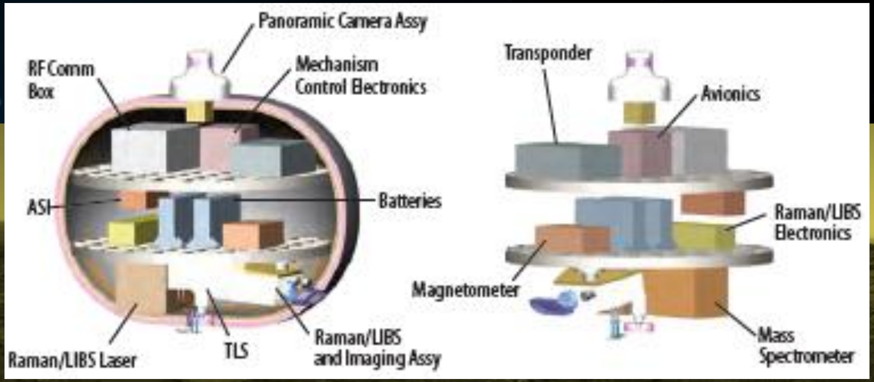
Develop / Mature Conventional Approaches

- Leverage latest instrumentation, thermal management, robust electronics
  - Leverage improvements in instrumentation since last Venus surface mission – greater science with similar surface life (2-3 hours)
  - Use a combination of medium temperature electronics (150-250 C) and thermal management techniques to extend life – few more hours
  - Many short duration measurements can be achieved
    - One time composition determination, surface or shallow sample testing, local morphology, measurements during descent
  - Does not implement temporal science
    - Energy balance, weather, surface / interior activity, atmospheric chemistry variability / outgas



Venus Flagship Mission Lander Concept (2009) from Flagship Mission Report

VITaL Mission Concept – 2010 NASA Study Report



Develop High Temperature Systems for Extended Operations

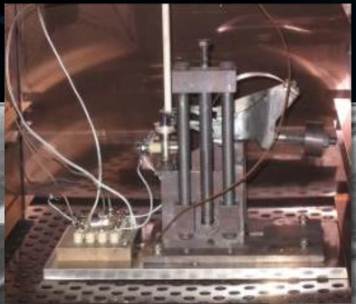
NASA is investing in Venus surface hardware development

Some of the recent investments include:

- Development of small probe / lander for long duration surface operations – Long Lived In-Situ Solar System Explorer (LLISSE)
- Focused effort on high temperature electronics / sensors - High Operating Temperature Technologies (HOTTech)
    - Awarded 12 tasks and funding a variety of efforts across the US
- Venus specific instruments
    - (E.g. High temperature seismometer (GRC), Heat flux (JPL)
    - Laser Induced Breakdown Spectroscopy (LIBS) - New Frontiers technology support

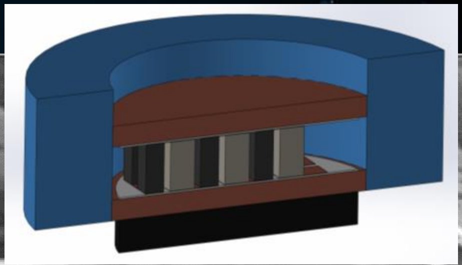

Early LLISSE concept – wind powered

Early Venus seismometer. Courtesy NASA GRC



Venera-10 surface image

Heat Flux sensor - Courtesy: Mike Pauken / JPL



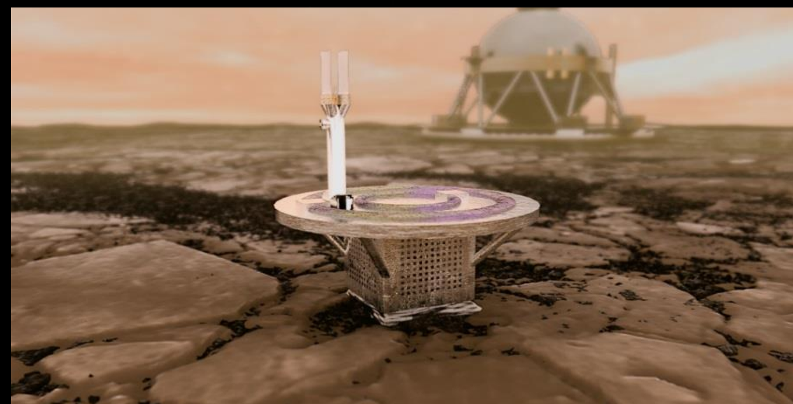
LLISSE

Another Approach for Venus Surface Exploration

LLISSE leverages high-temp electronics, sensors, power, communications and an innovative operations model to enable long life on the surface of Venus

Simple but important science from the Venus surface - for months

Potential Technology Demonstration version - Up to 10 days surface ops

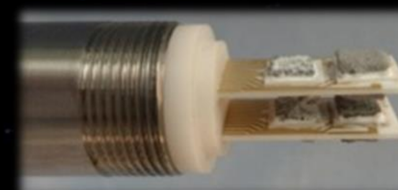


Version of LLISSE in development ~10 kg and ~3000 hrs life

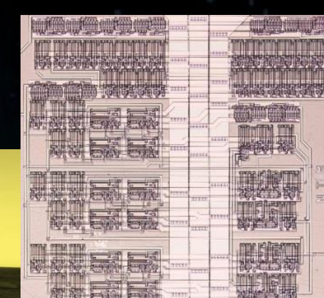
All LLISSE's will be demonstrated at Venus surface conditions for intended life in GEER

<u>LLISSE Science</u>

- Next slide



High Temp Mems Chem Sensors – SBIR with Makel Engineering



500°C Durable 1000+ Transistor SiC IC

LLISSE Science Objectives and Traceability

Decadal Survey Goals	LLISSE Science Objectives	Measurements	Instrument Requirements
A) Define the current climate on the terrestrial planets	1) Acquire temporal meteorological data	Measurement of p, T, u, v and light	3-axis wind sensor measurements, radiance
	2) Estimate momentum exchange between the surface and the atmosphere	Same as above	Same as above
B) Understand chemistry of the middle, upper and lower atmosphere	3) Determine the key atmospheric species at the surface over time	Measure the abundance of gases H_2O, SO_2, CO, HF, HCl, HCN, OCS, NO, O_2	Chemical sensor measurements
C) Determine how solar energy drives atmospheric circulation and chemical cycles	4) Determine the rate of solar energy deposition at the Venus surface	Measure incident and reflected solar energy	Measurements of radiance

- Operations Goals:
  - Operate for a minimum ½ Venus solar day – capture one day/night transition (~60 Earth days)
  - Take / transmit measurements periodically – timed for science need and to maximize transfer to orbiter / data relay
- LLISSE will be a demonstrator to open up this difficult environment for more sophisticated future exploration

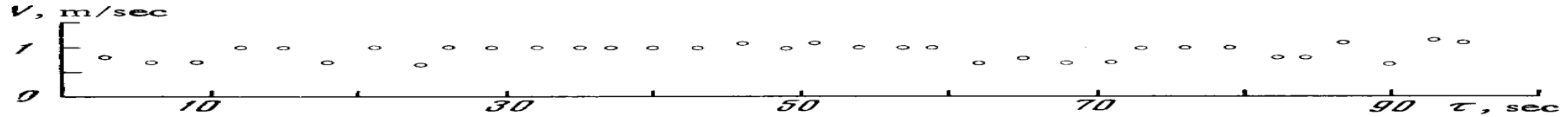


Fig. 5. Measured velocities at the landing site of automatic interplanetary station Venera 10.

Ref: V.S. Avduevskii et al, Measurement of Wind Velocity on the Surface of Venus During the Operations of Stations Venera-9 and Venera-10, Cosmic Research , 1977

HOTTech Projects Summary

Developing the Building Blocks of a System

P.I.	Title	Project Duration	TRL Start/Finish
Simon Ang, / Univ. of Arkansas	500°C Capable, Weather-Resistant Electronics Packaging for Extreme Environment Exploration	2	2,5
Ratnakumar Bugga / JPL	High Temperature-resilient and Long Life (HiTALL) Primary Batteries for Venus and Mercury Surface Missions	2	3,4
Jonathan Grandidier /JPL	Low Intensity High Temperature (LIHT) Solar Cells for Venus Exploration Mission	2	2,4
Jitendra Kumar / Univ. of Dayton	Higher Energy, Long Cycle Life, and Extreme Temperature Lithium Sulfur Battery for Venus Missions	3	3,5
Michael Paul / JHUAPL	Hot Operating Temperature Lithium combustion IN situ Energy and Power System (HOTLINE Power System)	3	2,5
Darby Makel / Makel Engr. Inc.	SiC Electronics To Enable Long-Lived Chemical Sensor Measurements at the Venus Surface	3	3-4, 6
Robert Nemanich/ Arizona State Univ.	High Temperature Diamond Electronics for Actuators and Sensors	3	3,5
Phil Neudeck / NASA GRC	High Temperature Memory Electronics for Long-Lived Venus Missions	3	3-4, 6
Leora Peltz/ Boeing Corp.	Field Emission Vacuum Electronic Devices for Operation above 500 degrees Celsius	3	3,5
Debbie Senesky / Stanford Univ.	Passively Compensated Low-Power Chip-Scale Clocks for Wireless Communication in Harsh Environments	2	2,4
Kris Zacny / Honeybee Robotics Corp.	Development of a TRL6 Electric Motor and Position Sensor for Venus	2	5,6
Yuji Zhao / Univ. of Arizona	High Temperature GaN Microprocessor for Space Applications	3	

Studies and Concepts

Large Missions/Concepts:

- Venera-D
  - NASA is supporting a joint study with ROSCOSMOS / IKI on a mission concept that includes a large lander, orbiter and a LLISSE. Other potential augmentations exist as well such as SAEVe, aerial platform and sub-satellite

Venera-D

- New Frontiers and Discovery missions routinely proposed

DAVINCI

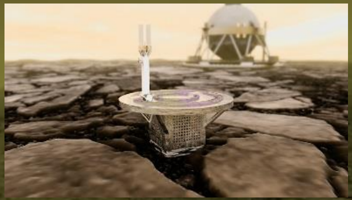
- Surface missions can complement potential future orbiters

Small landers / concepts:

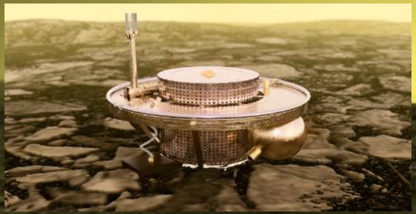
- LLISSE, SAEVe, VBOSS

VITAL

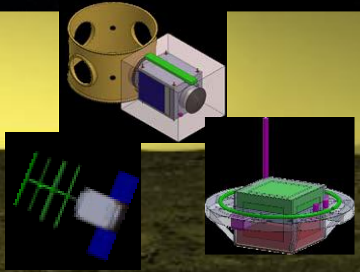
VERITAS



LLISSE



SAEVe



VBOSS

Questions?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