Preparing For Venus Surface Exploration

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Why Explore Venus?

Layers of Acid Clouds

Continuous tornado – like winds

Venus

Earth

Similar but Sooo… Different - Why?

Temps approaching 900°F

Crushing pressure

243 Days
NASA is Preparing to Explore the Venus Surface

1) Conducting experiments to better understand the environment when we get there
   - Know what to look for
   - Better interpret data from instruments

2) Developing high temperature systems
   - Electronics, sensors, batteries, and more

3) Built and supporting Venus simulation capabilities
   - E.g. Glenn Extreme Environment Rig (GEER) and other rigs

4) Studying surface systems and lander mission concepts
Ground Based Experiments

Ground based experiments will not replace much needed in-situ data but can help explore possibilities and better prepare missions that do go there.

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 to assess compatibility of potential spacecraft materials with the near surface atmosphere.
- Potential stratification and implications for the deep Venus atmosphere.
- Tests and experiments also conducted to verify instrument measurement capabilities in the unique Venus conditions.
Developing High Temperature Systems

NASA is investing in Venus specific hardware development

Some of the recent investments include:

- **Venus specific instruments**
  - (E.g. High temperature seismometer (GRC), Heat flux (JPL)
  - Laser Induced Breakdown Spectroscopy (LIBS) - New Frontiers technology support

- **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

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LLISSE
Changing the Paradigm 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

Science Focus Areas:
• Estimate momentum exchange
• Near-surface atmospheric chemistry
• Temporal weather data
• Technology demonstration

Battery Version: Expecting ~ 3000 hours life for 10 kg

Conceptual Wind Powered Version

Fully demonstrated at Venus surface conditions in GEER

High Temp Mems Chem Sensors – SBIR with Makel Engineering

500°C Durable 100+ Transistor SiC IC

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## HOTTech Projects Summary

### Developing the Building Blocks of a System

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<td>Ratnakumar Bugga / JPL</td>
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<td>Michael Paul / JHUAPL</td>
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<td>Leora Peltz/ Boeing Corp.</td>
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<td>Debbie Senesky / Stanford Univ.</td>
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<td>Kris Zacny / Honeybee Robotics Corp.</td>
<td>Development of a TRL6 Electric Motor and Position Sensor for Venus</td>
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<td>Yuji Zhao / Univ. of Arizona</td>
<td>High Temperature GaN Microprocessor for Space Applications</td>
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Venus Simulation

Several Venus Chambers Exist – Varying Capabilities and Purposes

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

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

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

JPL Venus vessel focused on weathering. Full temp and pressure

These are just examples. Various other chambers exist as well:
https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140013390.pdf

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Large Concepts:

- Initiated Venus flagship mission study - expected to include lander(s)
- Venera-D
  - NASA is supporting a joint study with ROSCOSMOS / IKI on a mission concept that includes a large lander and one or more LLISSE’s
- New Frontiers and Discovery missions proposed
  - Also partnership opportunities with other Agencies on their Venus missions
- Small landers / Concepts
- Surface Focused Studies

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Science Objectives:
1) Determine if Venus is seismically active and characterize the rate and style of activity
2) Determine the thickness and composition of the crust
3) Acquire temporal near surface meteorological data to guide global circulation models
4) Estimate moment exchange between the planet and its atmosphere
5) Measure atmospheric chemistry variability
6) Determine current rate of heat loss from the Venus interior
7) Examine rock and soil distribution and morphology

Mission Overview:
Two landers delivered to Venus via ride along
- Landers enter Venus atmosphere via Genesis like entry capsules
- Landers descend through the thickening atmosphere
- Turn themselves on and begin transmitting science data at pre-determined intervals
- Operate for 120 days, 3 orders magnitude > than current record

Team Members/Institutions

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Walter Kiefer  Lunar and Planetary Institute
Sanjay Limaye  University of Wisconsin
Michael Pauken  Jet Propulsion Laboratory
Colin Wilson  University of Oxford

SAEVe revolutionizes our paradigm for exploring the deep atmosphere, surface, and geophysical activity of Venus via enabling new technologies

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VEXAG is a great source for learning about upcoming and past Venus-related activities.

https://www.lpi.usra.edu/vexag/

Contributors: Gary Hunter, Carol Tolbert, Leah Nakley, Dan Vento, Jeff Balcerski
LLISSE Back-Up
LLISSE Science

**Science Goals**
- Estimate moment exchange between planet and atmosphere
- Quantify near surface atmospheric chemistry variability
- Quantify incident and reflected solar radiance
- Acquire temporal weather data to update global circulation models
- Technology demonstration for more capable future lander missions

**Measurements**
- Surface wind speed
- Wind direction (relative to surface)
- Surface temperature and pressure
- Near-surface chemical composition
- Incident and reflected solar radiance

**Operations Goals:**
- Operate for one Venus “daylight period” and day/night transition (~60 Earth days)