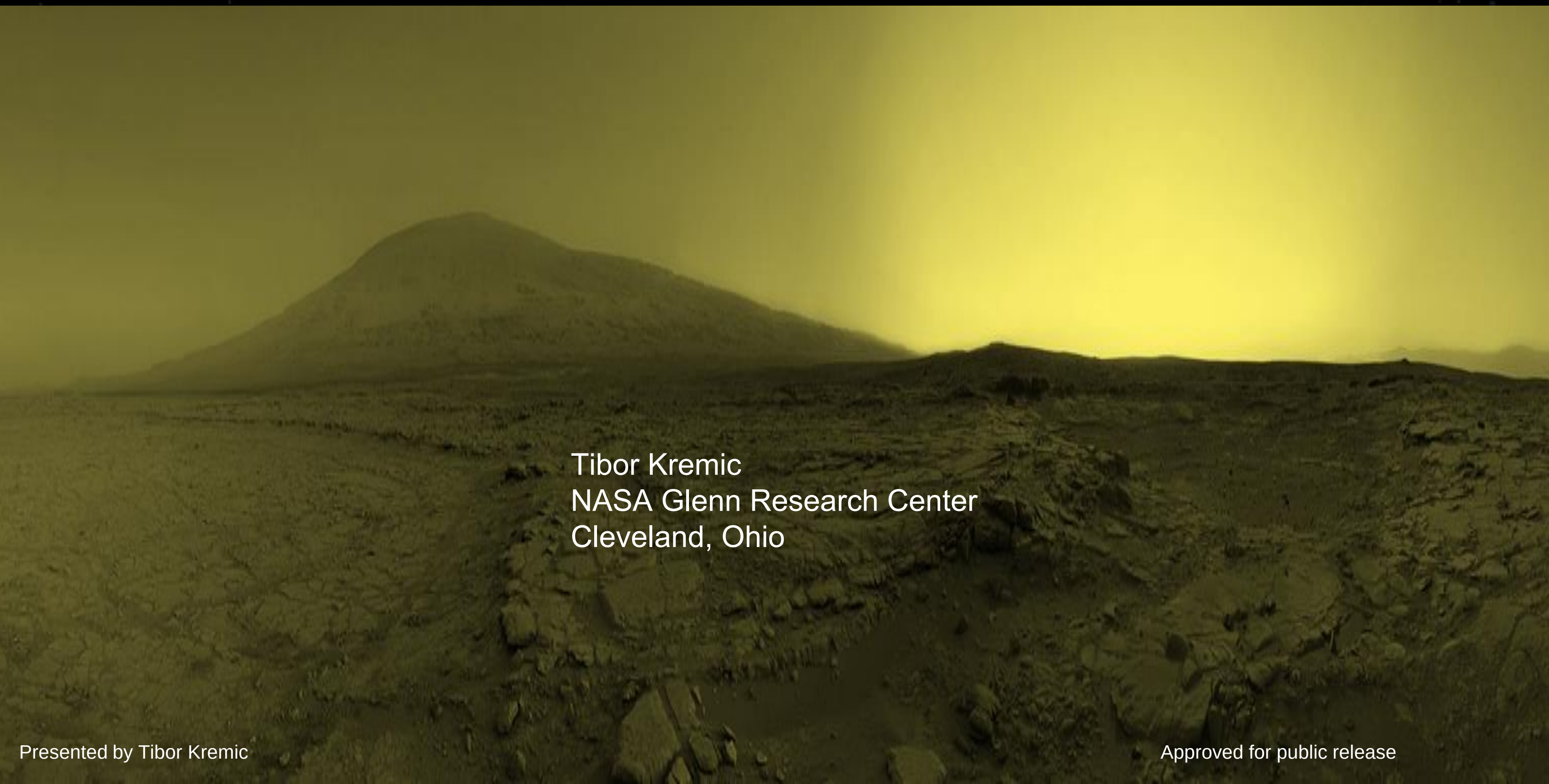
Preparing For Venus Surface Exploration

September 2018



Tibor Kremic
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Why Explore Venus?

Venus

Layers of Acid Clouds

Continuous tornado – like winds

Earth

Similar but Sooo… Different - Why?

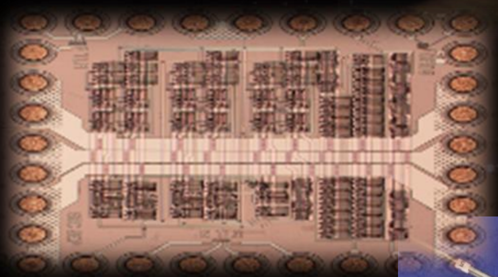
Temps approaching 900°F

Crushing pressure

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

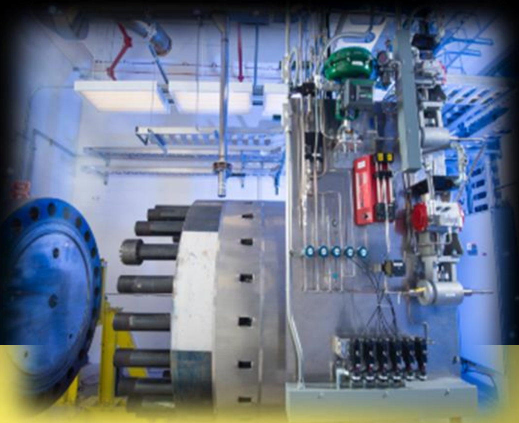


2) Developing high temperature systems

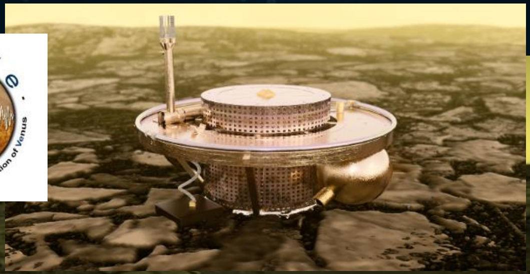
- Electronics, sensors, batteries, and more

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



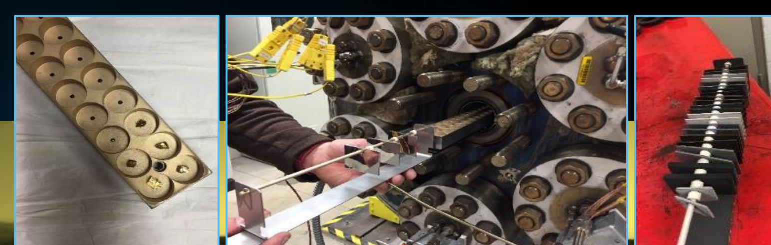
Ground Based Experiments

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

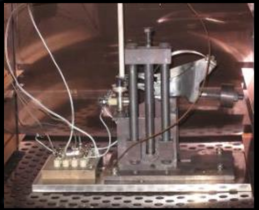
- Tests and experiments also conducted to verify instrument measurement capabilities in the unique Venus conditions



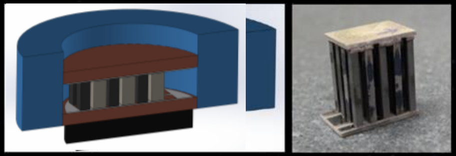
Developing High Temperature Systems

NASA is investing in Venus specific hardware development

Some of the recent investments include:



Prototype pendulum seismometer



Heat Flux sensor - Courtesy: Mike Pauken

- 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

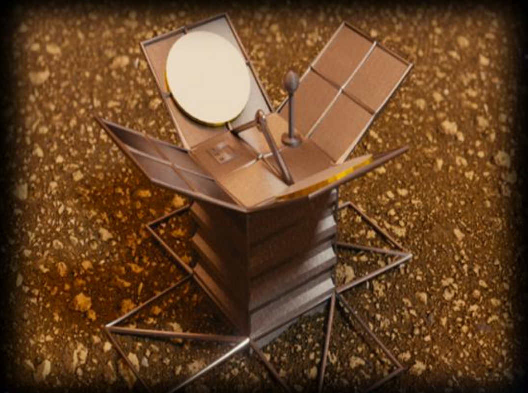
Early LLISSE concept – wind powered

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

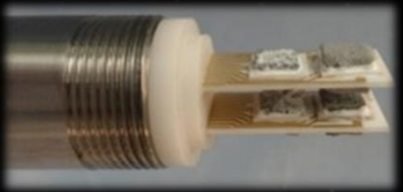
Simple but important science from the Venus surface - for months



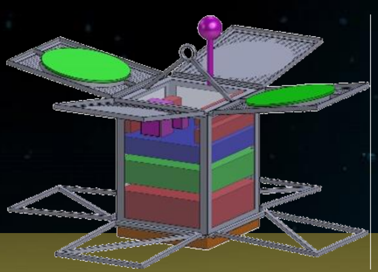
Science Focus Areas:

- Estimate momentum exchange
- Near-surface atmospheric chemistry
- Temporal weather data
- Technology demonstration

Conceptual Wind Powered Version

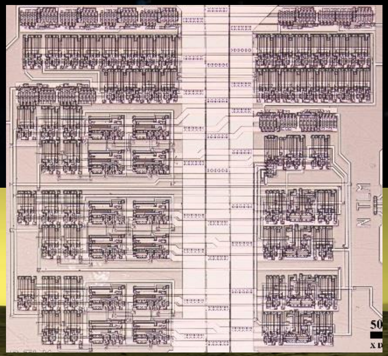


High Temp Mems Chem Sensors – SBIR with Makel Engineering



Battery Version: Expecting ~ 3000 hours life for 10 kg

Fully demonstrated at Venus surface conditions in GEER



500°C Durable 100+ Transistor SiC IC

HOTTech Projects Summary

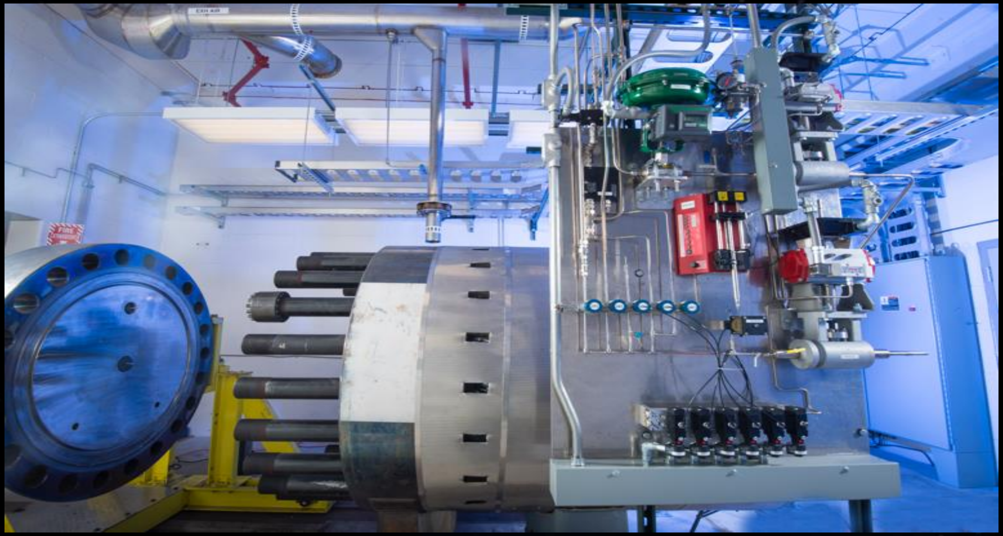
Developing the Building Blocks of a System

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	

Venus Simulation

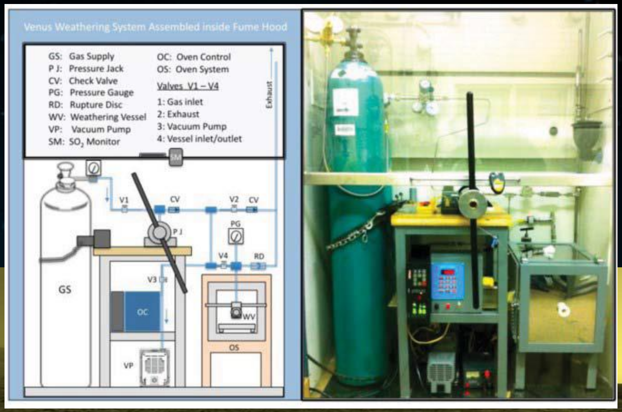
Several Venus Chambers Exist – Varying Capabilities and Purposes

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



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

These are just examples. Various other chambers exist as well:

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

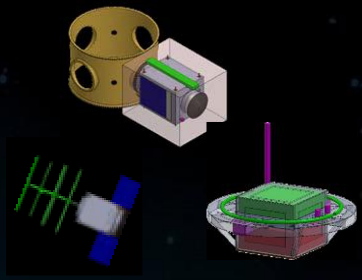
Studies and Concepts

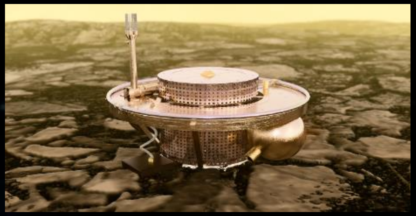
Large Concepts:

- Initiated Venus flagship mission study - expected to include lander(s)
- Venera-D
  - NASA is supporting a joint study with ROSCOSMOS / IKI on a missic 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

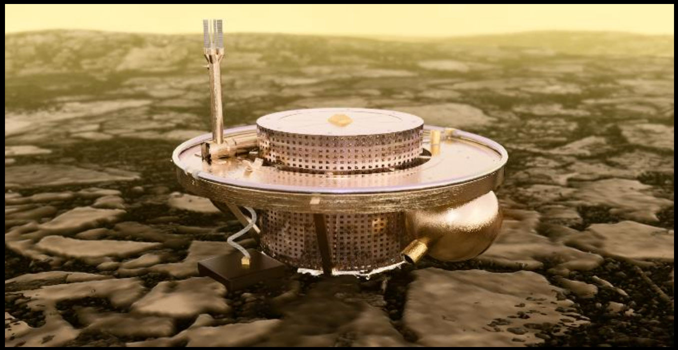

Venera-D


LLISSE


VBOSS


SAEVe

SAEVe Overview



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Team Members/Institutions

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**

Landers will:

Measure seismic activity, heat flux, wind speed and direction, incident and reflected solar radiation, abundance of selected atmospheric species and ambient temperature and pressure — **over a period of 120 days!**
Transmit the data to an orbiting spacecraft/comm relay, at preset intervals *(orbiter by others)*
Validate high-temperature and pressure technologies paving the way for larger, more complex Venus lander missions in the future

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

Approved for public release

Be Engaged

VEXAG is great source for learning about up coming and past Venus related activities

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

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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)