



Long Lived InSitu Solar System Explorer (LLISSE): Development Status

What LLISSE IS?

- LLISSE is a project to mature capability and develop engineering model hardware for a small long lived Venus lander
- LLISSE will be an independent platform with all the needed subsystems
 - < 10 kg, < 20 cm/side, base diameter
- Focuses on and returns simple but important temporal science (i.e. temp, pressure, atmospheric specie abundances, etc.)
- Key elements leveraged for Venus application
 - Focused, low data volume measurements
 - Novel operations scheme
 - Recent developments in high temperature electronics



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 ₂ O, 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

Top Level Status

- Great progress to date
 - Battery cell level testing using expected discharge profile : > 50 days life
 - Since project start: complexity of IC circuits increased by ~2 orders magnitude
 - Operation of most sensors and core electronics in Venus environment demonstrated several times
 - Strong interest among mission planners – Venera-D, Venus flagship, and other potential applications like Discovery, New Frontiers, and more

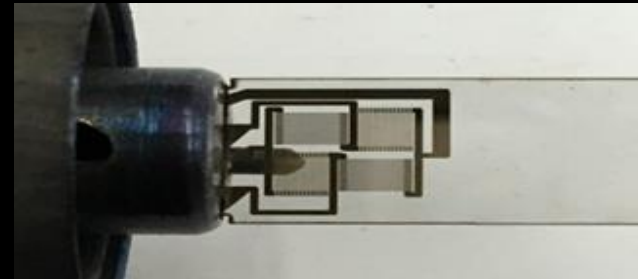
**Makel Chemical Sensor
Testing in GEER**



LLISSE Concept



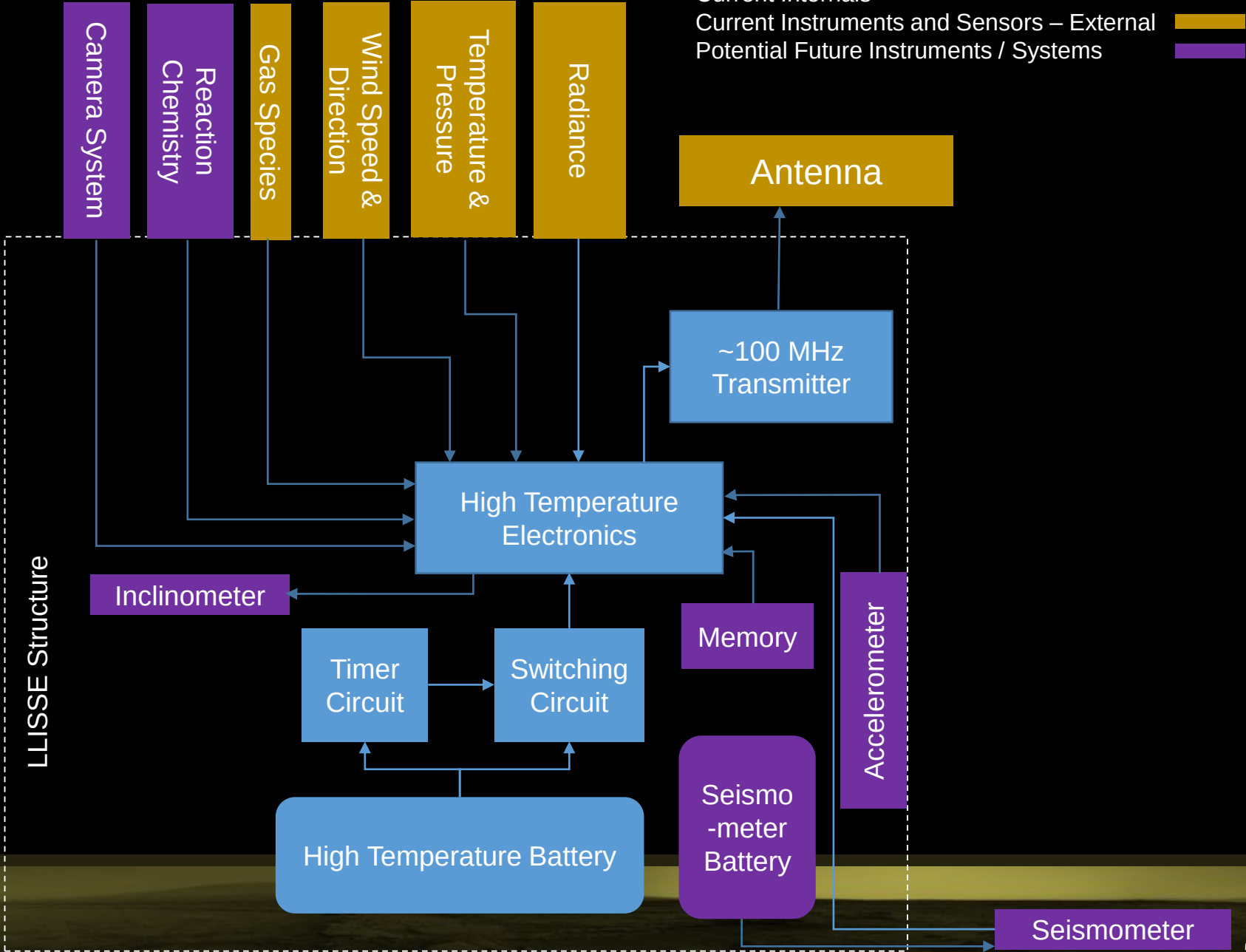
**Wind Sensor for
Testing in GEER**



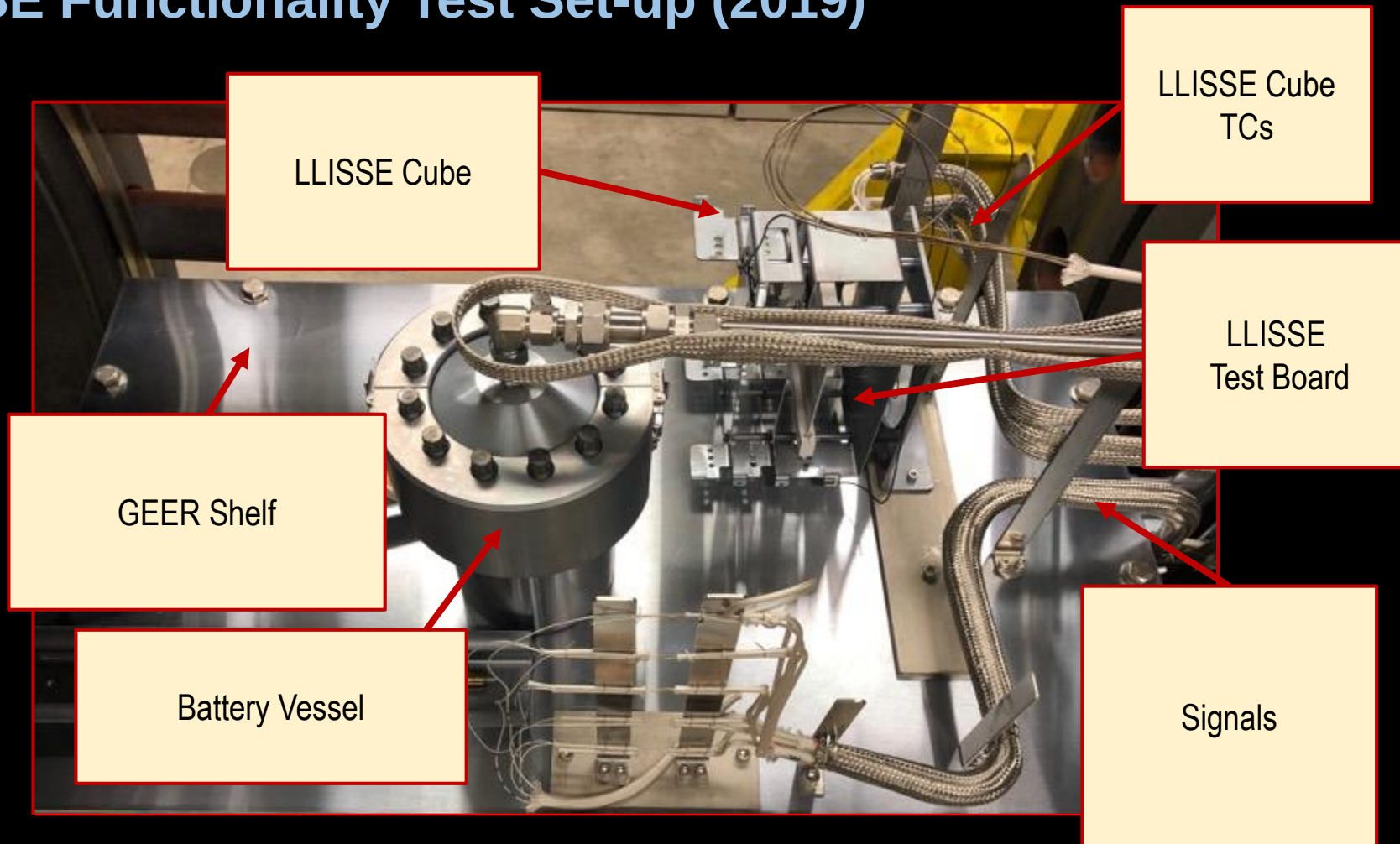
LLISSE Block Diagram

Legend

- Current Internals
- Current Instruments and Sensors – External
- Potential Future Instruments / Systems



LLISSE Functionality Test Set-up (2019)



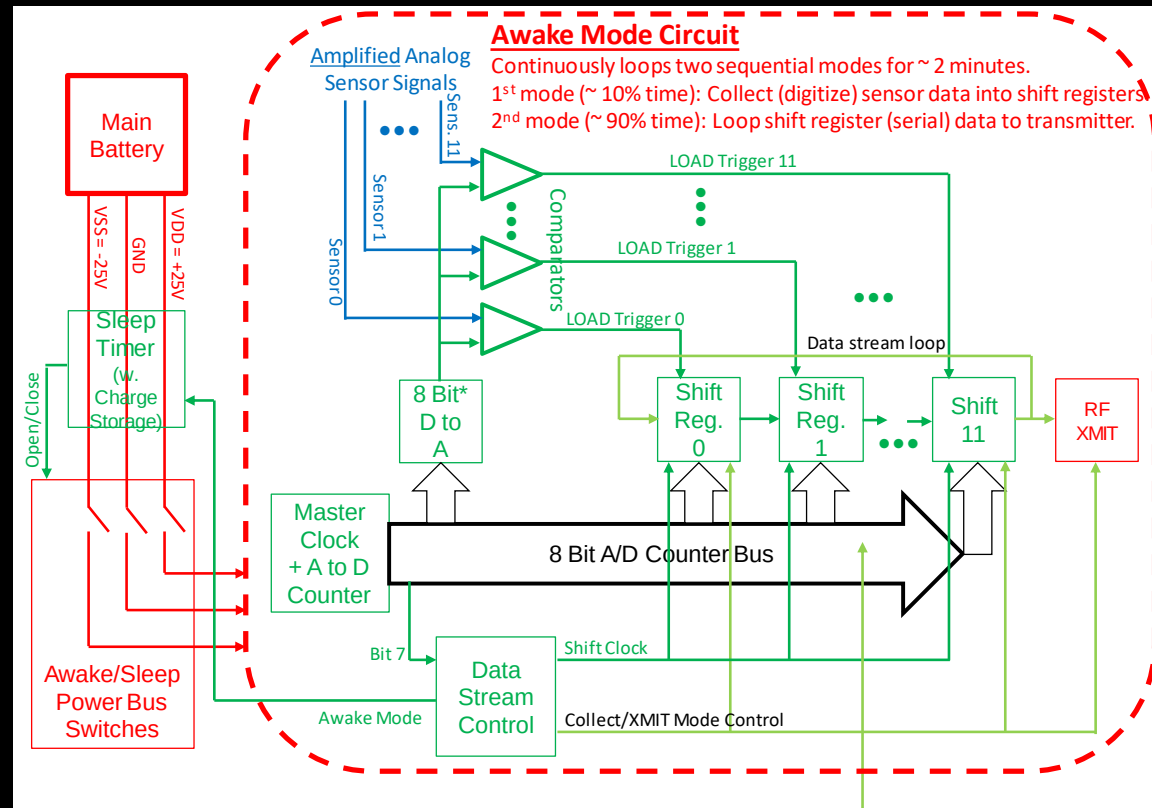
LLISSE Electronics Status

- Several generations worked: generation “11” (2019) met many LLISSE functionality goals

Simplified LLISSE Electronics Block Diagram
(Design driven by emphasis on conservation/minimization of battery power.)

Enables:

- Amplification of the Analog Sensor Signals
- Sequential Sampling of Data from Multiple Analog Sensors
- Digitization of The Analog Inputs
- Processing of Digitized Data from Each Sensor for Transmission to an Orbiter



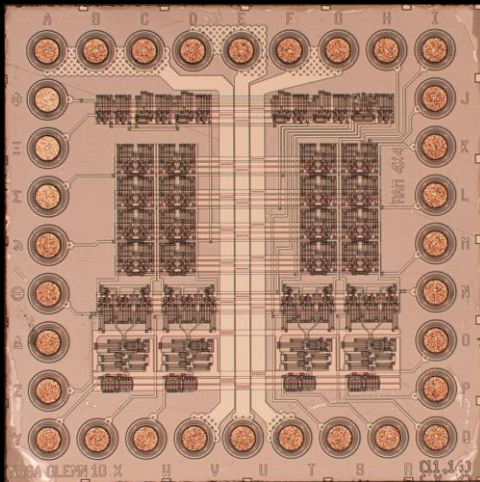
LLISSE Electronics Status

- On-going efforts to increase complexity and capability.

Example: comparison of version 10 vs version 11 JFET IC prototype chips

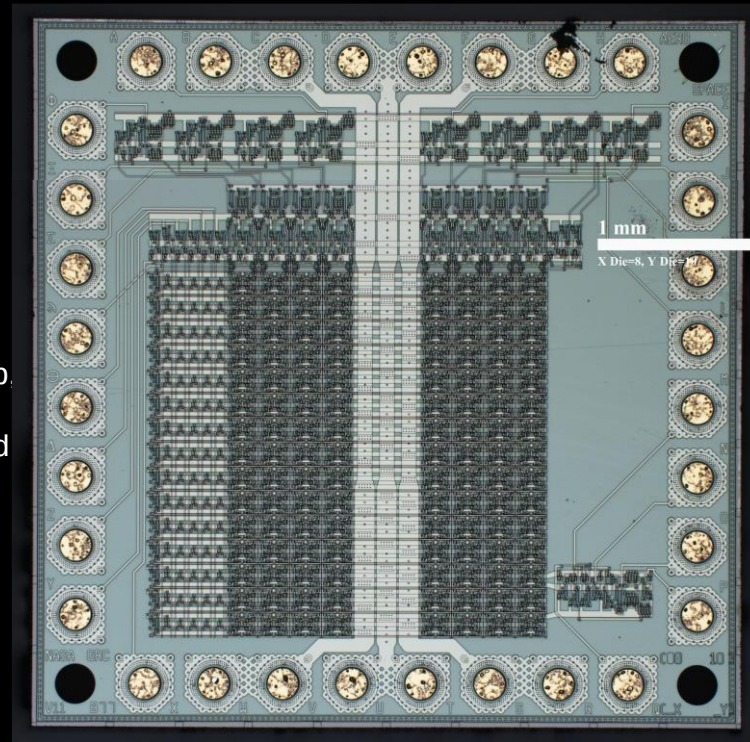
IC Version 10

4x4 (16) bit RAM
195 JFETs
3 mm x 3 mm
Chip, 32 I/O Bond
Pads Separated
Read & Write
Data Busses



IC Version 11

15x8 (120) bit RAM ~
1000 JFETs
4.65mm x 4.65 mm Chip
32 I/O Bond Pads
Shared (Tri-State) Read
& Write Data Bus



LLISSE Electronics Future Plans

Electronics complexity has increased ~ 2 orders of magnitude over the course of this project. Another factor of ~ 3 is planned

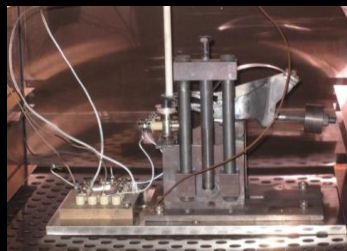
- Circuits have now been designed to meet the needs of the LLISSE lander, ready for fabrication and intended to:
 - demonstrate both LLISSE functionality and power requirements
 - significantly broaden the range of tools available for mission operations
- Complete the SiC circuits to enable 100 MHz communication
- Develop passive components specifically to enable, e.g., the LLISSE timer circuit

LLISSE Communications Background

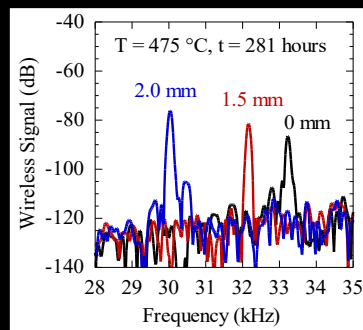
History of High Temperature Wireless: Foundation for Future Development

Venus Seismometer Operation at High Temperatures (2012)

- Integration of NASA GRC SiC electronics, capacitors, and circuit design with high temperature seismometer mechanism
- Operation of combined system at 500°C for 20 days
- Wireless signal spectra for sensor displacements at 475° C
- Antenna distance ~ 2 meters



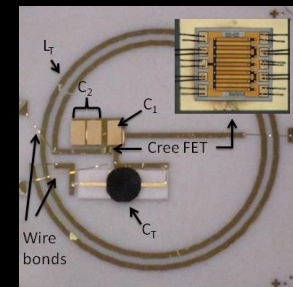
Wireless seismometer and circuit in an oven



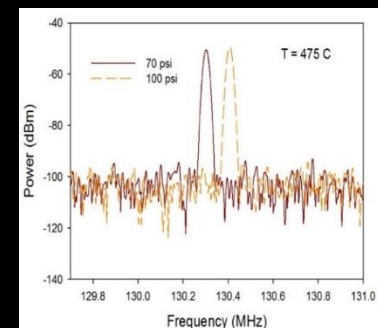
Inductive sensor element and oscillator circuit oven at 475°C

Wireless Demonstration at 475°C (2013)

- Demonstrated wireless pressure sensor at 475°C multiple high temperature technologies
- Pressure sensor, SiC circuitry and wireless circuit
- Limited power scavenging
- Operation at 475°C for 1 hour and telemetry over 1 meter
- Responsive to pressure variations



Wireless sensing circuit

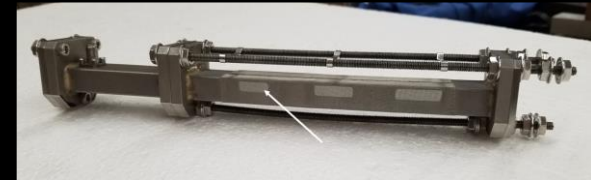


Spectrum response at 475°C of wireless pressure sensor at 70 and 100 psi

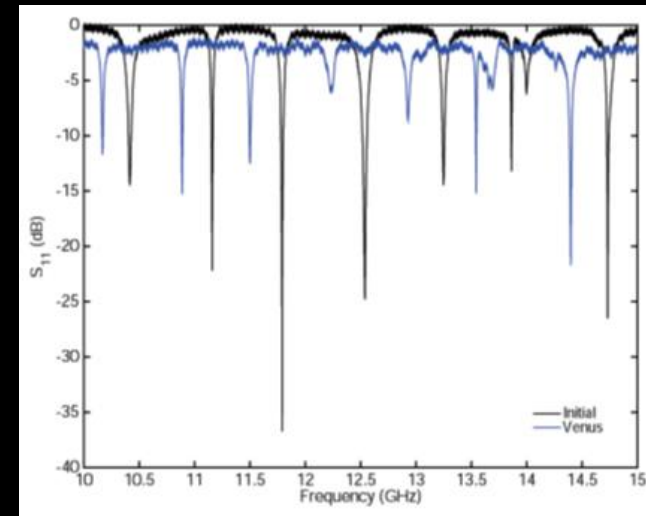
LLISSE Communications Status

GEER communications signal propagation testing

- Propagation studies have been conducted in GEER
 - Measurement of RF parameters to yield indication of scattering
- Comparison of properties from Earth to Venus
 - Wireless transmission and reception achieved
 - Shift in resonant frequency due to changes in dielectric
 - Generally stable signal over test period
- Waveguide and RF connections continued operation throughout duration of test



Rectangular waveguide cavity resonator and frequency response in GEER

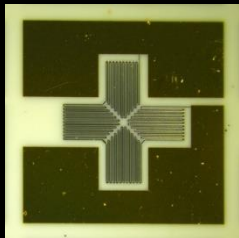


LLISSE Sensors Background

Development approach

- Miniaturized sensor systems produced by microfabrication techniques and high temperature compatible materials
- Parallel development of multiple sensor types – Each has targeted specs and electronics
- Several sensors have reached high levels of maturity for this application
- Integration of multiple sensor types with SiC electronics demonstrated

LLISSE Measurement Targets



Microbolometer



Pressure sensor

	Description	Number	Sensor Input	Sensor Output	Requirements			
					Target Min	Target Max	Target Accuracy (+/-)	Target resolution
Wind Sensor	Strain gage based	3	voltage	voltage	0.25 m/s	2.5 m/s	0.1 m/s	0.05 m/s
Solar Radiance	broad solar radiance	2	Radiance	Voltage				
Temperature Sensor	RTD in electronics	2	current	voltage	450 C	492 C	0.2 C	0.15 C
Pressure	Resistive	1	voltage	voltage	80 bar	92 bar	1 % full scale	0.6% full scale
	Capacitive		capacitance	voltage				
Chemical Species	SOx	1	voltage	voltage	0	400 ppm	0.3 ppm	10 ppb
	H2O	1	voltage	voltage	0	100 ppm	1 ppm	50 ppb
	OCS	1	voltage	resistance	0	50 ppm	1 ppm	10 ppb
	CO	1	voltage	resistance	0	50 ppm	1 ppm	10 ppb
	HCl	1	voltage	voltage	0	5 ppm	0.5 ppm	10 ppb
	HF	1	voltage	voltage	0	5 ppm	0.5 ppm	0.5 ppb



Chemical Sensor Probe
Courtesy Makel Engineering, Inc.



Wind Sensor Cantilever