LONG-LIVED IN-SITU SOLAR SYSTEM EXPLORER (LLISSE)

LLISSE BASICS

- LLISSE is a small (~10kg) probe being developed to acquire and transmit simple but important science measurements for extended periods from the surface of Venus
  - Scale driven to fit Venus balloon payload expectations – could be larger / heavier for longer life or more capable science package

- Three key elements are being leveraged to enable this revolutionary capability
  - Recent developments in high temperature electronics
  - Focused, low data volume measurements
  - Novel operations scheme

FOCUSED SCIENCE GOALS

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

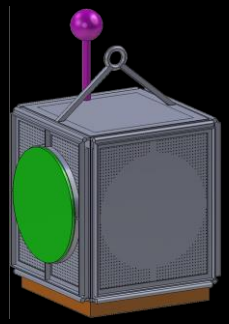
SCIENTIFIC MEASUREMENTS

- Surface wind speed
- Wind direction (relative to surface)
- Surface temperature and pressure
- Near-surface atmospheric chemical composition
- Incident radiance ?
- Measured over long time scales -

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

  - Take / transmit measurements periodically – timed for science need and to maximize transfer to orbiter / data relay

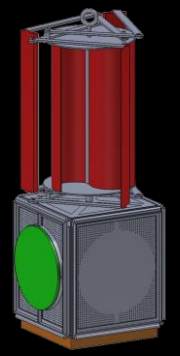
TWO VERSIONS IN WORK



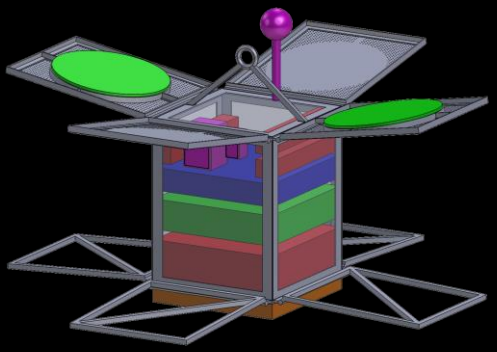
~ 20 cm cube

Basic Features

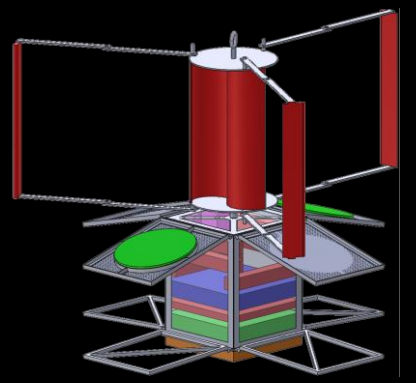
- Deployed from balloon, with lander, or via own entry shell
- Two approaches in work: battery & wind powered
- Battery version: 3000 hrs if data sent for 2 minutes every 8 hours
- Wind version: indefinite life, variable data transmission frequency possible



~ 20 cm cube



Battery Version –
3000 hours, ~ 10 kg



Wind powered version –
?? Hours, ~10 kg
transmission frequency is power dependent

ENABLING CAPABILITIES

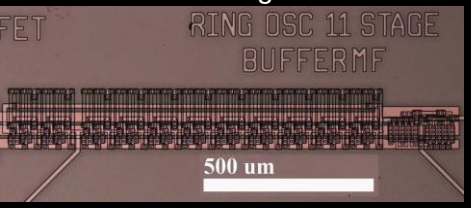
- High temperature:
  - Sensors
  - Electronics
  - Communication system
  - Power generation / storage system
- High fidelity test / validation capability
- Creative operations approach

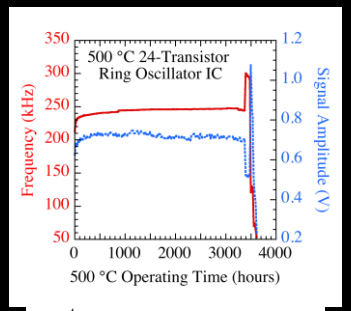
READINESS OF COMPONENTS

- High Temp electronics
  - World's First Microcircuits at moderate complexity fabricated with long-lived operation at 500˚C
  - SiC Integrated Circuits that function for thousands of hours at 500°C have been demonstrated
    - Amplifiers, converters, logic, and more
  - A tool-box of signal conditioning, processing, and communications circuits are being developed and demonstrated (presently 100+ transistor ICs)
  - Direct pathway to more complex circuits identified
  - Successful operation of SiC Integrated Circuits electronics for over 21 days achieved in the GEER chamber under Venus simulated surface environments (submitted to peer review journal)

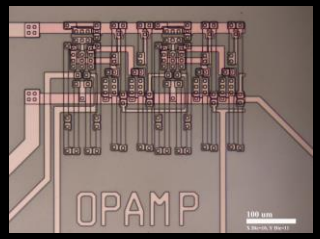
READINESS OF COMPONENTS

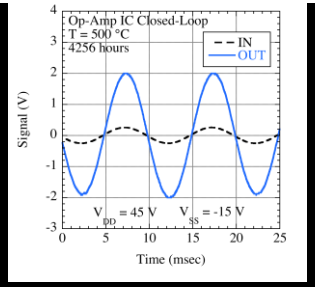
24-Transistor Ring Oscillator IC



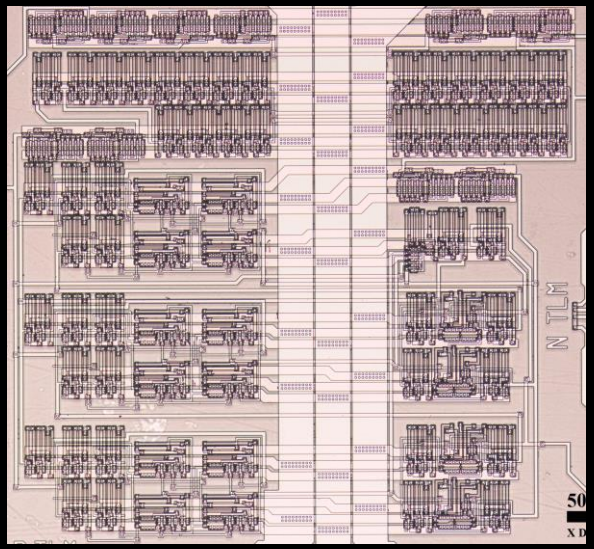


2-Stage Operational Amplifier IC





Long-Lived Electronics Operation



500°C Durable 100+ Transistor SiC IC

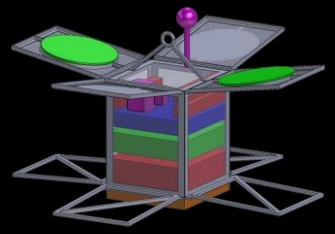
Multispecies Chemical Sensor Probe

High Temperature Pressure Sensor

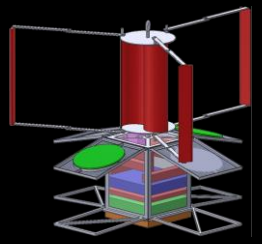
- Component level hardware exists and performance has been demonstrated at Venus temperatures
  - High temperature electronics
  - Multispecies chemical sensor array
  - High temperature pressure and temperature sensors

PROJECT OBJECTIVES

- Develop full/half scale prototype probes (one battery and one wind powered) and demonstrate performance in Venus conditions in GEER
  - Wind version would be tested with simulated winds in GEER
  - Take science measurements and transmit



Focus in FY17-19



Focus in FY20-21

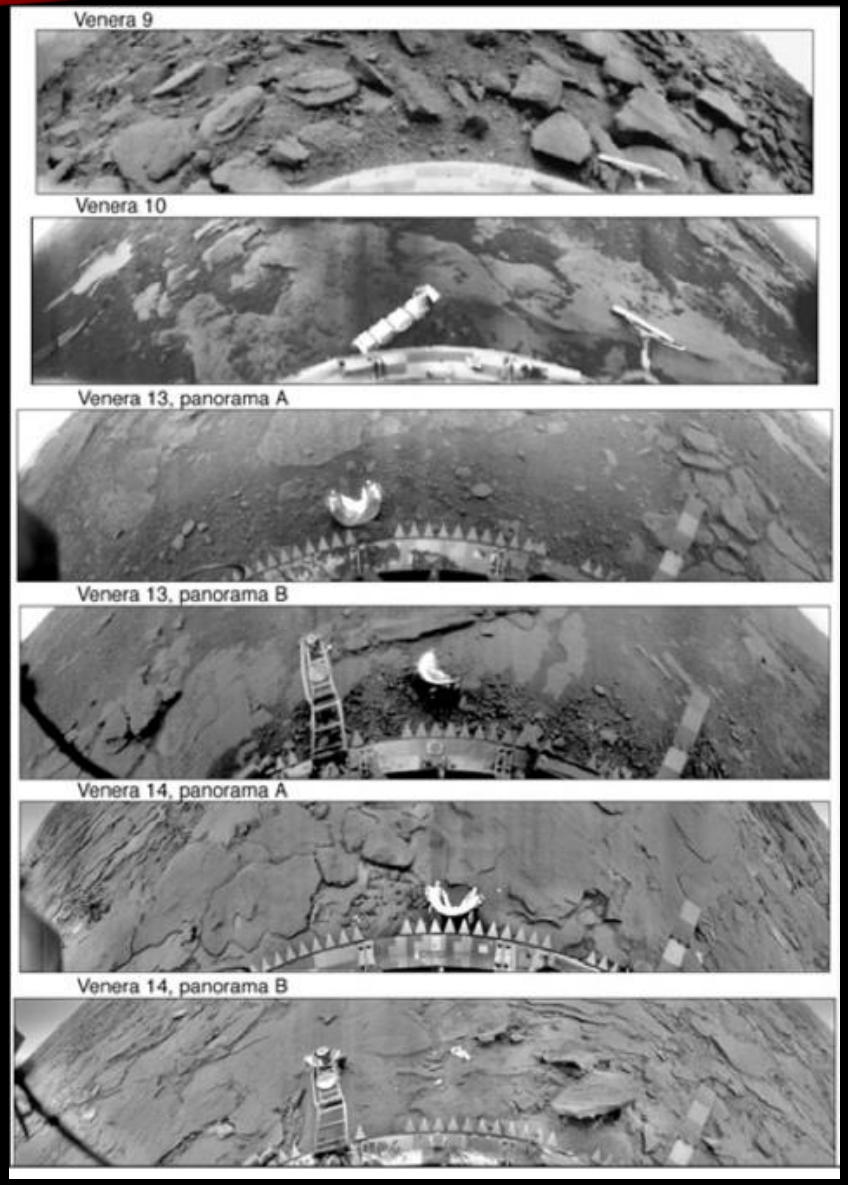
- Complete performance test of full scale prototype model running 10 MHz comm system within 3 years
- Complete turbine and test half scale version 18 - 24 months later

CONSIDERATIONS

- Data captured and transmitted in real time – not stored
- Battery version more mature – comm system driven
- Wind powered version maturity is turbine system driven
- Battery version is simple with long life – but not indefinite
- Wind powered version is higher risk and transmission could be variable (depends on surface wind speeds)
  - However a strong step toward future surface exploration

BACK-UP

KNOWN MEASUREMENTS OF VENUS SURFACE WINDS SPEEDS (FROM VENERAS)



- 9: 0.4-0.7 m/s
- 10: 0.8 m/s – 1.3 m/s
- 13 0.5 m/s
- 14 0.3-.35 m/s

WIND SPEED VS POWER GENERATED

Venus wind speed (m/s)	.35	.4	.5	.6	1	1.25	1.5	1.8
RPM	50	57	72	86	143	179	215	258
Power from generator (W)	.05	.06	.09	.13	.37	.57	.83	1.2
Time to charge battery (h)	13.8	8.1	4	2.5	.8	.5	.3	.2
Min coeff. of friction (for probe stability)	.02	.02	.04	.05	.14	.22	.32	.46