DISCUSSION OF VENUS SEISMOMETRY AND A METEOROLOGY STATION

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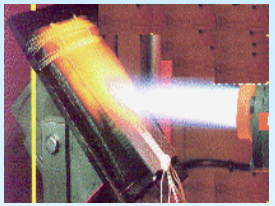
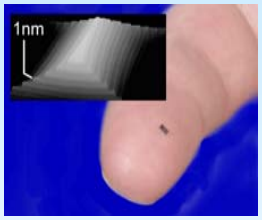
HARSH ENVIRONMENT ELECTRONICS AND SENSORS APPLICATIONS

- **NEEDS:**
  - **OPERATION IN HARSH ENVIRONMENTS**
  - **RANGE OF PHYSICAL AND CHEMICAL MEASUREMENTS**
  - **INCREASE DURABILITY, DECREASE THERMAL SHIELDING, IMPROVE IN-SITU OPERATION**

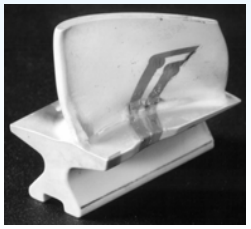


1998 R&D 100 Award



2004 R&D 100 Award

- **RESPONSE: UNIQUE RANGE OF HARSH ENVIRONMENT TECHNOLOGY AND CAPABILITIES**
  - **STANDARD 500˚C OPERATION BY MULTIPLE SYSTEMS**
  - **TEMPERATURE, PRESSURE, CHEMICAL SPECIES, WIND AVAILABLE**
  - **HIGH TEMPERATURE ELECTRONICS TO MAKE SMART SYSTEMS**

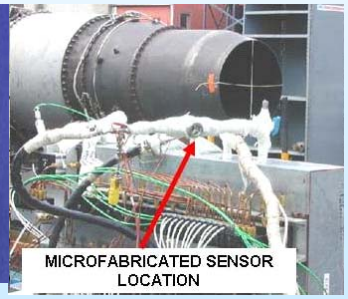


1995 R&D 100 Award

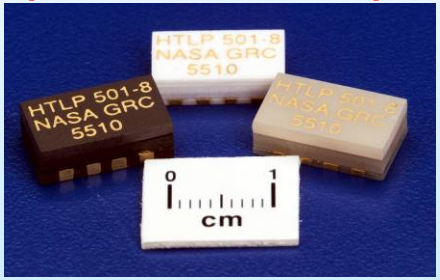
1991 R&D 100 Award

- **ALL-IN-ONE SHOP FOR HARSH ENVIRONMENT SYSTEM APPLICATIONS**
- **ENABLE EXPANDED MISSION PARAMETERS/IN-SITU MEASUREMENTS**

Range of Physical and Chemical Sensors for Harsh Environments

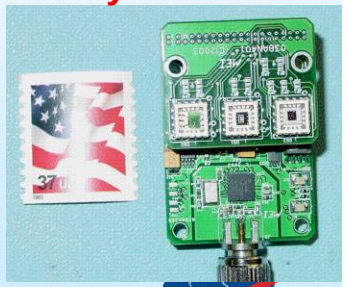


Harsh Environment Packaging (2000 hours at 500C)



High Temperature Signal Processing and Wireless

Long Term: High Temperature "Lick and Stick" Systems



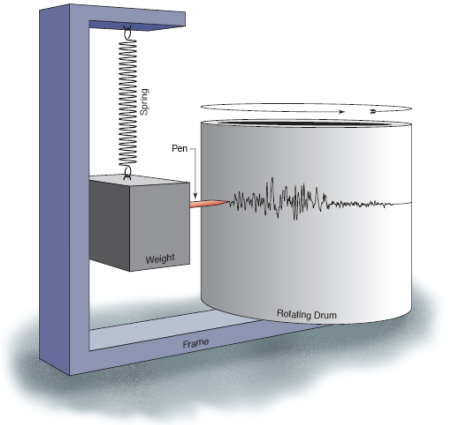
BACKGROUND

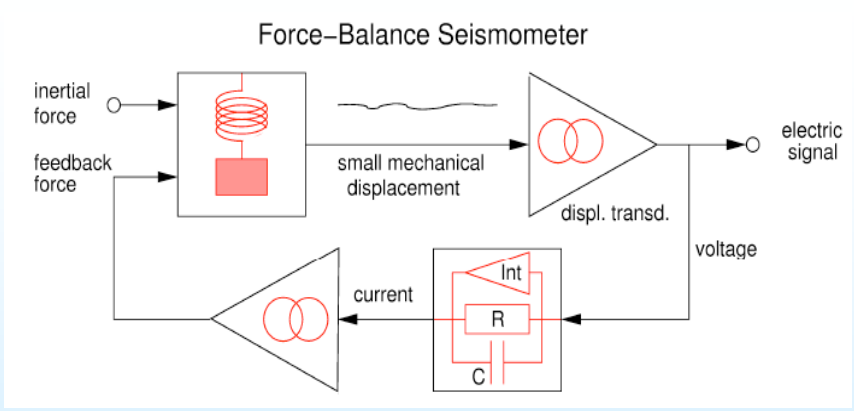
- **SEISMIC MEASUREMENTS CAN HAVE REVOLUTIONARY IMPLICATIONS IN THE UNDERSTANDING OF VENUS PLANETARY SCIENCE**
  - **VEXAG HIGH-PRIORITY TECHNOLOGY DEVELOPMENT NEED : *"SEISMOMETERS CAPABLE OF OPERATION UNDER VENUS-SURFACE CONDITIONS"***
- **ONE OF THE FUNDAMENTAL QUESTIONS IN VENUS STDT DISCUSSIONS INVOLVED WHETHER VENUS SEISMOMETRY WAS VIABLE**
- **MAJOR TECHNICAL HURDLE IS THAT IN ORDER FOR A SEISMOMETER TO BE EFFECTIVE IT MUST BE COUPLED IN SITU TO THE PLANET**
  - **THIS IMPLIES HIGH TEMPERATURE OPERATION OF AT LEAST SOME SYSTEM COMPONENTS**
  - **EXTENDED OPERATION OF AT LEAST 117 DAYS DESIRED**
- **SEVERAL POSSIBLE DIFFERENT ARCHITECTURES WERE DISCUSSED**
  - **STAND-ALONE SYSTEM**
  - **SEISMOMETER SYSTEM COUPLED WITH LANDER POWER**
  - **SEISMOMETER SYSTEM COUPLED WITH LANDER POWER AND COOLED SUPPORT SYSTEM**
- **IN RESPONSE TO THESE QUESTIONS AND TO MEET A SCIENTIFIC NEED, A PROPOSAL FOR A VENUS SEISMOMETER WAS DEVELOPED**

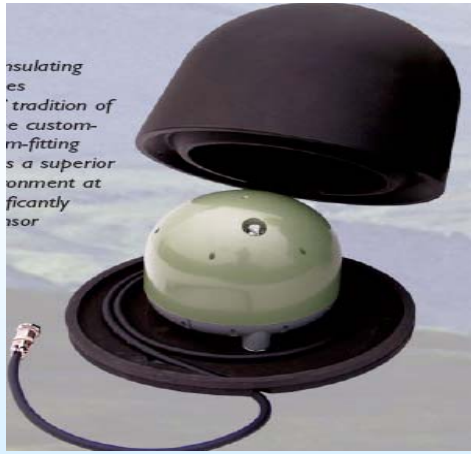
WHAT IS A SEISMOMETER

Instruments that measure and record motions of the ground

- **Vibrations affect an inertial mass or sensor attached to an instrument by a mechanical system (involving e.g. springs). The mechanical system as well as the sensor needs to be specially designed for frequency range**
- **Modern instruments using electronics so that the mass is held nearly motionless relative to the frame by an electronic negative feedback loop**
- **The feedback loop applies a magnetic or electrostatic force to keep the mass nearly motionless. The voltage needed to produce this force is the output of the seismometer**
- **Sensors and electronics not viable for Venus missions as-is.**





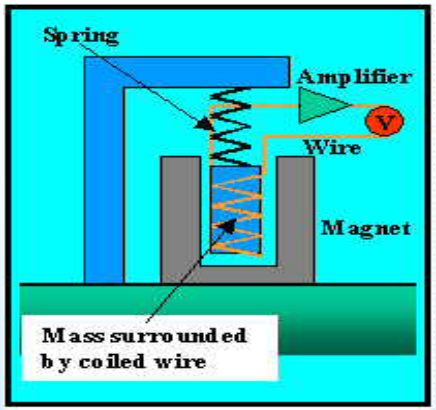


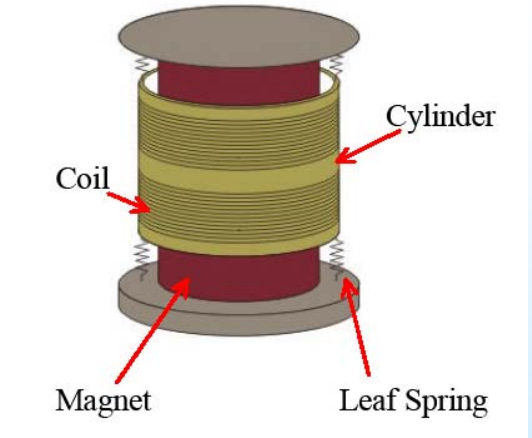
http://www.iris.edu/stations/seisWorkshop04/PDF/Wielandt-Design3.pdf
http://www.nanometrics.ca/index.php?option=com_content&task=blogcategory&id=18&Itemid=82&gclid=CPzD8o_PuZUCFRQEIwodg3YrRQ;http://en.wikipedia.org/wiki/Seismometer#Basic_principles;http://www.iris.washington.edu/edu/onepagers/Hi-Res/OnePager7.pdf

WHAT IS A GEOPHONE

Generally, a simpler instrument that measures and record motions of the ground usually for higher frequencies

- **A long history of operation of measuring seismic events before the more recent introduction of electronic circuits into seismic instruments**
- **Standard instruments include a coil generating a field which is affected by motion of a magnet**
- **Viable for high frequency ranges e.g. 1-30 Hz but with demonstrated range of sensitivity relevant to seismic events**
- **Use of magnetic materials make standard Geophones questionable for Venus missions**



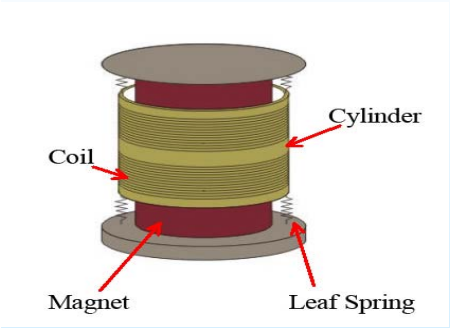


http://micromachine.stanford.edu/smssl/projects/Geophones/DefenseBarzilaiFinalCopyWeb/DefenseBarzilaiFinalCopy.pdf
http://www.earthsci.unimelb.edu.au/ES304/MODULES/SEIS/NOTES/geophone.html

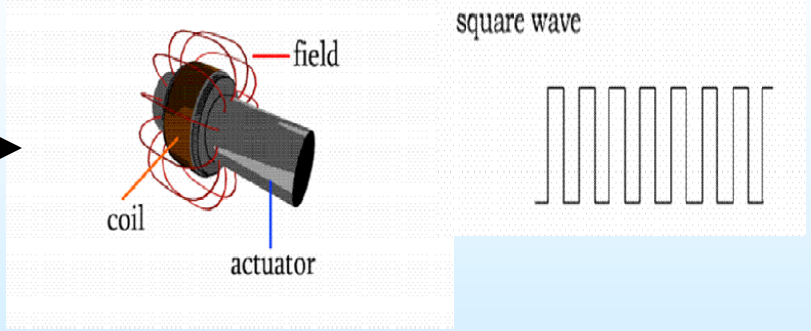
SENSOR/SEISMIC MEASURING INSTRUMENTS RELEVANT TO VENUS

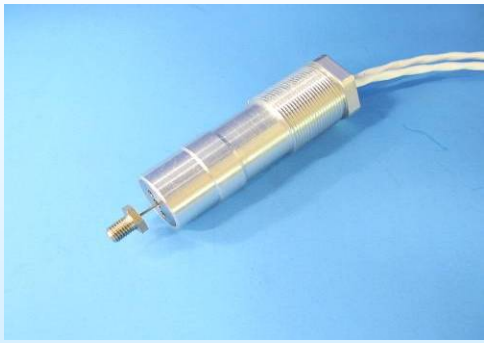
INPROX TECHNOLOGIES

- HIGH TEMPERATURE VARIABLE INDUCTOR IS PRESENTLY A SPECIALIZED COMMERCIAL PRODUCT-AEROSPACE POSITION SENSOR
  - ➢DEMONSTRATED OPERATION TEMPERATURE UP TO 650˚C; NO MAGNETIC MATERIALS
  - ➢SINGLE COIL SYSTEM WITH HIGH SENSITIVITY
- A RANGE OF AEROSPACE AND INDUSTRIAL APPLICATIONS
  - ➢NAMED TOP TEN GLOBAL SENSORS LIST
  - ➢SAME OR BETTER RESOLUTION, PERFORMANCE AND ACCURACIES AS TRADITIONAL TECHNOLOGIES (LVDT); WIDE FREQUENCY RANGE CAPABILITIES (DC TO MORE THAN 100 Hz)
- NASA GRC AND INPROX PRESENTLY HAVE A SPACE ACT AGREEMENT TO DEVELOP A HIGH TEMPERATURE LINEAR POSITION SENSOR WITH SiC ELECTRONICS OPERATIONAL TO AT LEAST 500˚C
- MATERIALS ISSUES ARE ADDRESSED FOR 500˚C OPERATION OF THESE SENSORS



Geophone Design

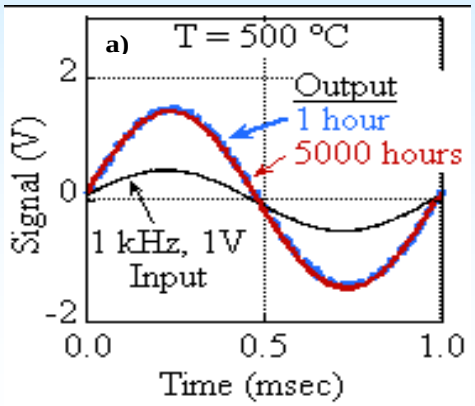


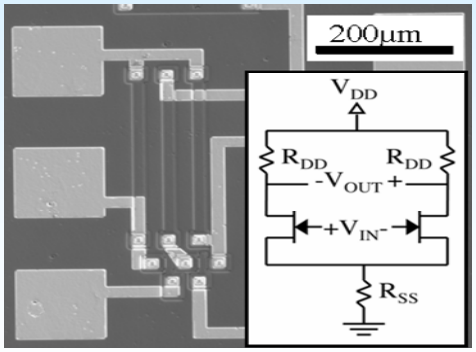


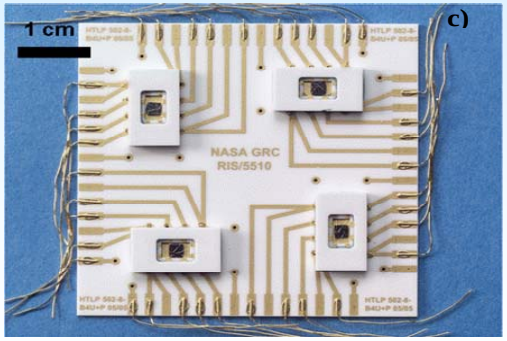
ITC Captive Field Linear Direct (CFLD4) transducer operational to 650°C and core of the project's seismometer.

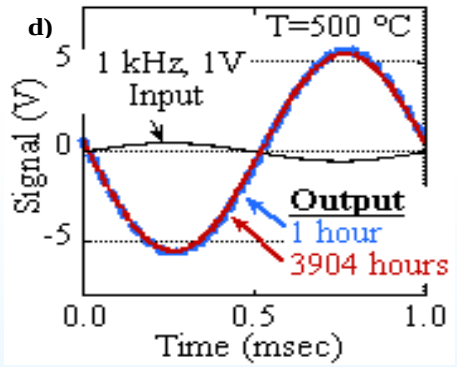
BASIC ELECTRONIC COMPONENTS

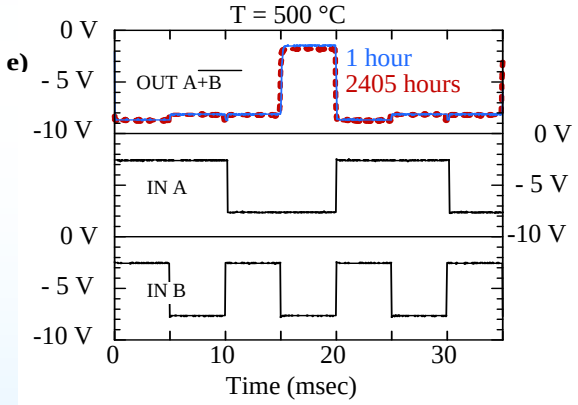
All components including packaging have demonstrated long-term operation at 500˚C

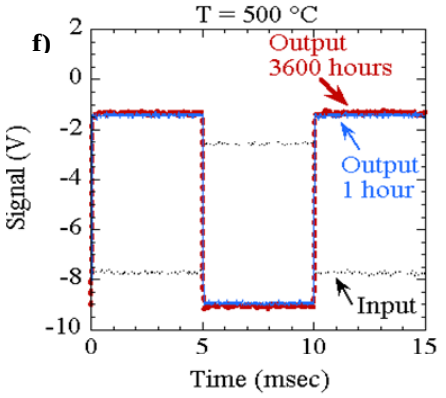












a) Differential Amplifier IC output at 5000 hours and 500˚C,
b) Picture of Differential Amplifier IC and schematic,
c) High temperature packaging for SiC electronics,
d) Inverting Amplifier IC output,
e) NOR logic gate output,
f) NOT logic gate output.

OBJECTIVE : WIRELESS TRANSMISSION AND HARSH ENVIRONMENT SMART SENSOR SYSTEMS

HIGH TEMPERATURE WIRELESS TECHNOLOGY:

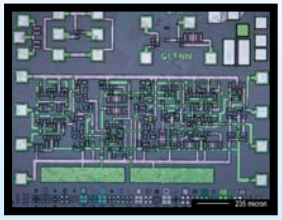
- **CASE WESTERN RESERVE UNIVERSITY: WIRELESS TRANSMISSION OF SENSOR DATA AT 400˚C AT 31.5 MHZ USING COMMERCIAL TECHNOLOGY FOR LIMITED TIMES**
- **WE WILL USE OUR OWN SPECIALLY DESIGNED LONG-LIVED CIRCUITS**
- **FREQUENCY TRANSMISSION IN THE MHz TRANSMISSION RANGE PLANNED.**

MILESTONE: DEMONSTRATE HIGH TEMPERATURE SENSING, WIRELESS COMMUNICATION, AND POWER SCAVENGING FOR PROPULSION HEALTH MANAGEMENT: 8/30/2011

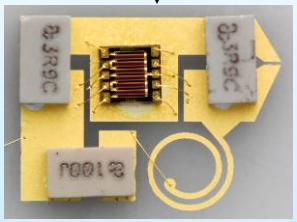
METRIC: DEMONSTRATE INTEGRATED SELF POWERED WIRELESS SENSOR SYSTEM AT 500˚C WITH DATA TRANSMISSION WITH OPERATIONAL LIFE OF AT LEAST 1 HR

Significant wiring exists with present sensor systems

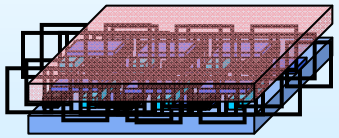
Allow Sensor Implementation by Eliminating Wires



World Record High Temperature Electronics Device Operation



High Temperature RF Components

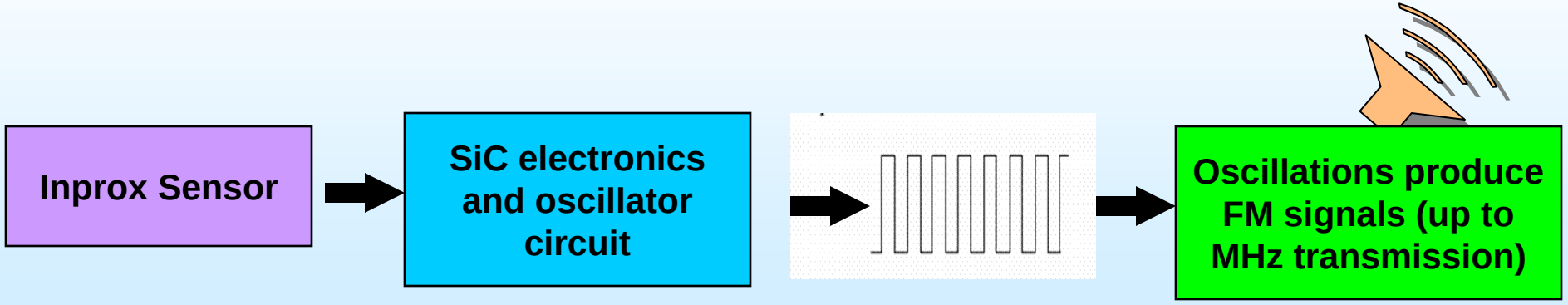


Energy Harvesting Thin Film Thermoelectrics

HIGH TEMPERATURE ELECTRONICS DESIGN AND COMMUNICATIONS

TECHNICAL APPROACH

- **PROCESS AND DIGITIZE AT THE SOURCE:**
  - **NEED COMPONENTS SUCH AS CAPACITORS, RESISTORS, AMPLIFIERS, LOGIC GATES**
  - **NEED APPROPRIATE SIGNAL COMING FROM SEISMIC INSTRUMENT**
- **YEAR 1: FABRICATE AND DEMONSTRATE A SIC BASED ELECTRONICS SYSTEM TO CONVERT THE 1-30 HZ SEISMOMETER SIGNAL.**
- **YEAR 2: FABRICATE AND DEMONSTRATE A SIC BASED ELECTRONICS SYSTEM TO CONVERT THE 1-30 HZ SEISMOMETER SIGNAL AND WIRELESSLY TRANSMIT THE FREQUENCY MODULATED SIGNAL.**
- **YEAR 3: FABRICATE AND DEMONSTRATE A SIC BASED ELECTRONICS SYSTEM TO CONVERT THE 1-30 HZ SEISMOMETER SIGNAL AND WIRELESSLY TRANSMIT THE DATA, EXTENDING THE FREQUENCY RANGE EVEN INTO THE MHZ FREQUENCY RANGE.**



VENUS METEOROLOGY

EXAMPLE POSSIBLE MISSION: Venus Integrated Weather Sensor (VIWS) System

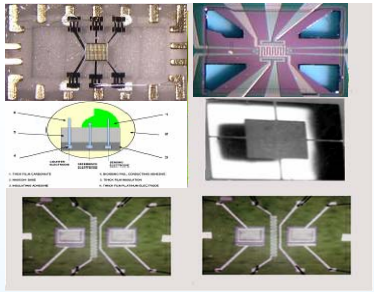
Sensor Suite to Monitor Venus Weather Conditions including:

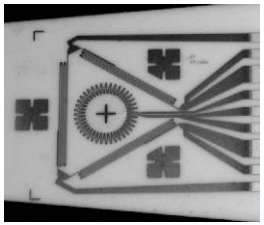
Wind Flow, Pressure/Temperature/Heat Flux,

Chemical Environment, Data Processing

- **AERONAUTICS DEVELOPMENT CAN ENABLE OTHER IN-SITU VENUS SYSTEMS**
  - **SIGNAL PROCESSING AND DATA COMMUNICATION**
  - **HIGH TEMPERATURE PACKAGING AND SENSOR SYSTEMS**
- **ALL OF THE TECHNOLOGIES BELOW HAVE BEEN DEMONSTRATED AT 500˚C AND OFTEN SIGNIFICANTLY ABOVE**
- **SUGGEST IN-SITU VENUS WEATHER SYSTEM ACHIEVABLE**

HIGH TEMPERATURE ELECTRONIC NOSE (Chemical Species)

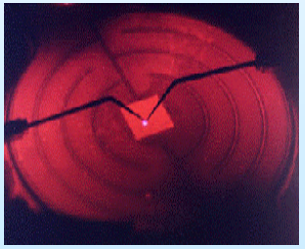




MULTIFUNCTIONAL PHYSICAL SENSOR ARRAY (Temperature, Heat Flux, Flow)

HOTProbe (Wind flow, Pressure, Temperature)

PRESSURE SENSOR (Pressure)



SiC ELECTRONICS (Data Processing)

OVERVIEW

- BASIC MESSAGE: SEISMOMETRY WAS DONE BEFORE THE PENTIUM AND CAN BE DONE AGAIN ON VENUS
- WORK WITH CORE TECHNOLOGY AND CIRCUIT DESIGN APPROACHES PREVIOUSLY USED BEFORE MORE COMPLICATED TECHNOLOGIES WERE AVAILABLE
- BY YEAR 3, THE SEISMOMETER WILL OPERATE IN THE 1-30 HZ RANGE WITH SIGNAL CONDITIONING, DATA TRANSMISSION, AND SIMULATED DETECTION OF AN EVENT.
- ALSO DEMONSTRATED WILL BE THE OPERATION OF A MULTISENSOR APPROACH COVERING THE mHZ RANGE TO 30 HZ COUPLED WITH SIGNAL CONDITIONING ELECTRONICS AT TEMPERATURE.
- HAVE RESPONDED TO THE BASIC QUESTION OF WHETHER VENUS SEISMOMETRY CAN BE DONE. SUGGEST THAT THE PROBLEM OF BASIC VENUS SEISMIC MEASUREMENTS AND DATA PROCESSING IS A MATTER OF ENGINEERING
- WE DO NOT SUGGEST THIS SOLVES ALL THE PROBLEMS WITH IMPLEMENTATION OF VENUS SEISMOMETRY
  - ➢ NOT FULLY OPTIMIZED IN POWER CONSUMPTION, PACKAGING, DATA PROCESSING, OR COMMUNICATION
  - ➢ MECHANICAL SYSTEMS FOR OPERATION ON THE VENUS SURFACE
  - ➢ SEISMOMETER FOR LOWER FREQUENCY RANGES NOT DEMONSTRATED
    - CORRECT MASS RATIOS, LEVER ARMS, ETC.
    - INTERACT WITH SEISMOMETER PRODUCERS
- EXPLORED IMPLEMENTATION SCENERIOS
- TRANSMISSION TO ORBIT IS THE PRESENT MAJOR TECHNICAL CHALLENGE