The Venus SAGE Atmospheric Structure Investigation

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- Experiment Goals and Objectives -

- To accurately define the state properties as a function of altitude from below the $10^{-4}$ mb level (~150 km) to 92 bars (surface).
- To measure the stability of the atmosphere, and identify convective layers and stable layers, where they exist.
- To detect cloud levels from changes in the lapse rate at their boundaries.
- To provide state properties within the cloud levels, and thus provide supplementary information on cloud composition.
- To search for and characterize wave structure within the atmosphere.
- To search for and measure the intensity and scale of turbulence.
- To measure descent and surface wind speed and direction.
- To provide Lander altitude and attitude during decent for descent imaging analysis.
- To provide a back-up landing sensor.
### Measurement

- **Altitude**
  - \(dz \sim 250\,\text{m}\) (upper atm.)
  - \(dz \sim 20\,\text{m}\) (lower atm.)

- **Acceleration & Attitude**
  - \(a \sim 3\,\mu\text{g}\) (threshold)
  - \(a \sim 0.05\,\text{g}\) (peak)
  - \(\Theta_v \sim 0.5\,\text{mrad}\,s^{-1}\)

- **Pressure**
  - \(dP \sim 0.1\,\text{mb}\) (100 mb)
  - \(dP \sim 25\,\text{mb}\) (92 bars)

- **Temperature**
  - 1 K

- **Surface Wind**
  - \(w < 0.05\,\text{m/s}\)

### Performance

- **Example Venus Profile**
  - Altitude
  - Acceleration & Attitude
  - Pressure
  - Temperature
  - Surface Wind

- **Subsonic**
  - **Supersonic**

- **Clouds**

- **T (K)**
  - 100  200  300  400  500  600  700  800

- **z (km)**
  - 120
  - 110
  - 100
  - 90
  - 80
  - 70
  - 60
  - 50
  - 40
  - 30
  - 20
  - 10
  - 0
- Instrument Accommodation -

Pressure Vessel

IMU

Wind / Temperature Boom

Pressure / Temperature Boom
Measurement:
- Acceleration in 3 axis (x, y, z)
- Roll, pitch and yaw rates

Accelerometers:
- x, y and z axis low impact sensors
- +/- 20 g range
- < 1 micro g accuracy
- z axis, high impact sensor
- +/- 1000 g range
- < 0.1 g accuracy

Gyroscopes:
- +/- 300 degree/sec range
- < 0.03 degree/sec accuracy (< 0.5 mrad/sec)
Pressure / Temperature Boom
- Pressure Sensor Implementation -

- Pressure manifold holds pressure transducers with three ranges cover pressure range:
  - 0.01 to 1 bar
  - 0.1 to 10 bar
  - 1 to 100 bar

- Fully redundant system
  - Provides method to measure pressure offset and gain drifts

- Micromachined capacitive aneroid barometers used:
  - MVACS/HASI heritage
  - No new technology, but modifications needed for high temperature operation
Schematic of an atmospheric temperature TC sense junction and reference junction on the isothermal block

- Thin-wire thermocouple (TC) assemblies deployed on 2 fixed booms
- Reference junctions are located on an isothermal block inside probe body
  - temperature monitored by a precision platinum resistance thermometer (PRT)
- Accuracy: $\pm 1^\circ C$, $150 \leq T \leq 750^\circ C$  
  Precision: $\sim 0.01^\circ C$ (14-bit)
- Time Constant: $< 1$ sec
- Wind / Temperature Boom -
- Directional Pitostatic Anemometer -

- 1-cm diameter sphere with six pressure ports equally spaced around its equator and two additional pressure ports located at its fore and aft poles.

- Speed and direction can be derived from pressure differences measured at these eight ports.

- During decent the fall speed will be derived from the wind sensor and used to adjust pressure measurements for dynamic effects.

- Surface winds measured to < 0.05 m sec⁻¹
- SYSTEM ARCHITECTURE -

Motherboard

Control/Communications Interface

Z-Axis, Impact Accelerometer Interface

JPL Daughter Board

Pressure, Temperature, Wind Speed

Interface

+5V, +/-12V

I/O LINES, TTL

Main power

CMD/DATA TRANSFER

Temp. Thermal couples Interface

Magnetometers Interface

Payload Power/data link

Z-Axis, Accelerometer Interface

Y-Axis, Accelerometer Interface

X-Axis, Accelerometer Interface

X-Axis, Gyro Interface

Y-Axis, Gyro Interface

Z-Axis, Gyro Interface

- SYSTEM ARCHITECTURE -
High Pressure and Temperature, Miniaturized Sensors

- AlGaN/GaN-based microsensors (Kyung-ah Son, JPL)
  - Small: \(\sim 1\text{cm}^3\)
  - Low mass: <5g
  - Low power: < 10 mW

- Broad Operational range
  - Temperature: 4 K-1000 K (0.1 °C)
  - Pressure: 0-10 kbar (<5%)

Highly Integrated Systems

- Integrated power, com., C&DH, and structure