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.
Example Venus Profile

**Measurement**

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

- Acceleration & Attitude
  - \( a \sim 3 \mu g \) (threshold)
  - \( a \sim 0.05 g \) (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
  - \( 1 \text{ K} \)

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

**Performance**

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

- Acceleration & Attitude
  - \( a \sim 3 \mu g \) (threshold)
  - \( a \sim 0.05 g \) (peak)
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- Pressure
  - \( dP \sim 0.1 \text{ mb (100 mb)} \)
  - \( dP \sim 25 \text{ mb (92 bars)} \)

- Temperature
  - \( 1 \text{ K} \)

- Surface Wind
  - \( w < 0.05 \text{ m/s} \)
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 Sensor Implementation -

- Pressure manifold holds pressure transducers with three ranges covering 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: ±1 °C, 150 ≤T≤ 750 °C        Precision: ~0.01 °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
  - Z-Axis, Impact Accelerometer Interface
  - Z-Axis, Accelerometer Interface
  - Y-Axis, Accelerometer Interface
  - X-Axis, Accelerometer Interface
  - X-Axis, Gyro Interface
  - Y-Axis, Gyro Interface
  - Z-Axis, Gyro Interface
  - Magnetometers Interface
  - Payload Power/data link

- JPL Daughter Board
  - +5V, +/-12V
  - I/O Lines, TTL
  - Pressure
  - Temperature
  - Wind Speed

- Temp. Thermal couples Interface
- Main power
- CMD/DATA TRANSFER
- Future ASI Development -

High Pressure and Temperature, Miniaturized Sensors

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

- 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