Mars Acoustic Anemometer

D. Banfield (Cornell)

R. Dissly (Ball Aerospace)

Why are Mars Winds Important?

- Safe Delivery of S/C to/from Martian surface
  - Wind shears in Boundary Layer
- Hazards due to Aeolian Processes
  - Dust storms, Dust Devils
- Better Prediction of Global/Regional Weather
  - Validate models
  - Data for Boundary Conditions
- Fluxes between surface/atmosphere
  - Water fluxes
  - Heat, momentum fluxes
  - Biotracer effluent fluxes (e.g., CH_4)

These are backed up by specific callouts in MEPAG goals (2 & 4), and Strategic Knowledge Gaps for Human Exploration

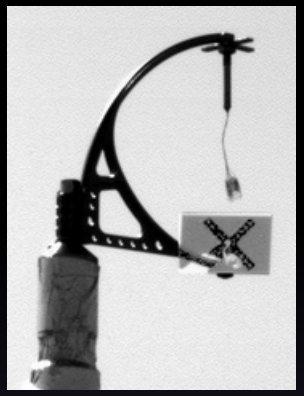
History of Wind Measurements on Mars

Viking 1 & 2
Hot-Wire/Film

- 2-D only
- Insensitive
- Slow
- Radiative errors

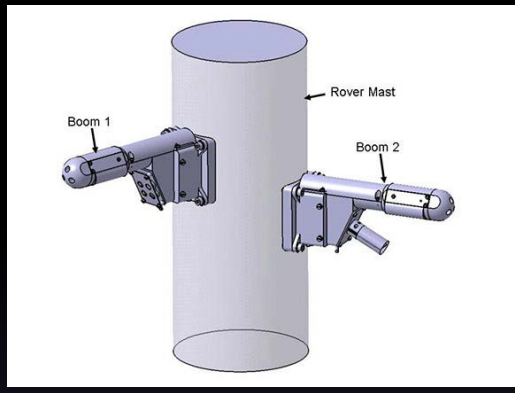
Pathfinder
Hot-Wire & Wind Socks

- Calibration problems with hot-wire
- Sensitivity issues with wind socks



Phoenix
Telltale

- Very Slow!



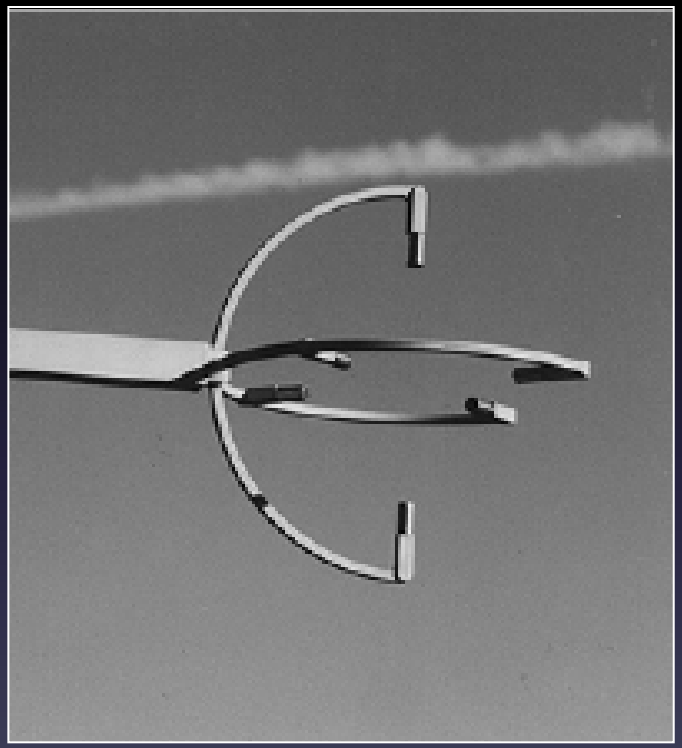
MSL
Hot-Film

- Delicate
- Mast Interference
- Slow

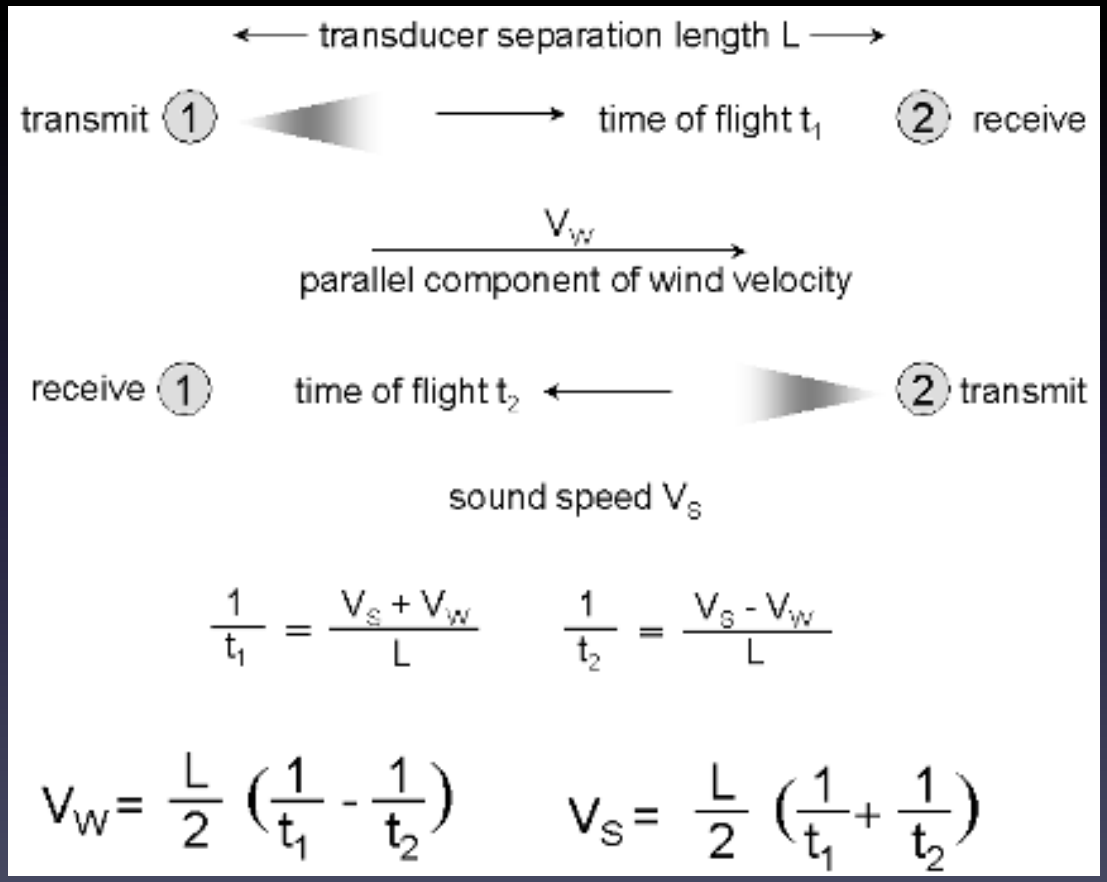
Prior attempts have been slow, limited in capability and difficult to calibrate

How to Improve Measurements?

Adapt premier terrestrial technique for Mars:
Sonic Anemometry



Terrestrial Sonic Anemometer



Measures wind speed via sound pulse travel-time differences.
Temperature is inferred from sound speed.

Sonic Anemometry Advantages

- 3-D capable (open sensing volume)
- Also yields temperature! (~ ±0.2K)
- Higher sensitivity (~5 cm/s)
- Higher time resolution (<~100 Hz!)
- Improved accuracy (fewer biases)
- Insensitivity to radiative heating
- Resolve eddies, measure fluxes

Why Are These Capabilities Important?

- Allows new, important questions to be asked in atmospheric science
  - Directly measure turbulent eddies => surface-atmosphere fluxes
    - Heat flux for surface energy balance
    - Momentum flux for aeolian processes
    - Water vapor flux for water stability/climate
- Provide more robust measures for model validation
  - U, V, T, P are not enough to validate mesoscale models fully
  - Fluxes give more dimensions to compare models to data
  - Improved models mean safer S/C delivery
- Find sources of bio-tracer effluents? Use Plume Tracing.

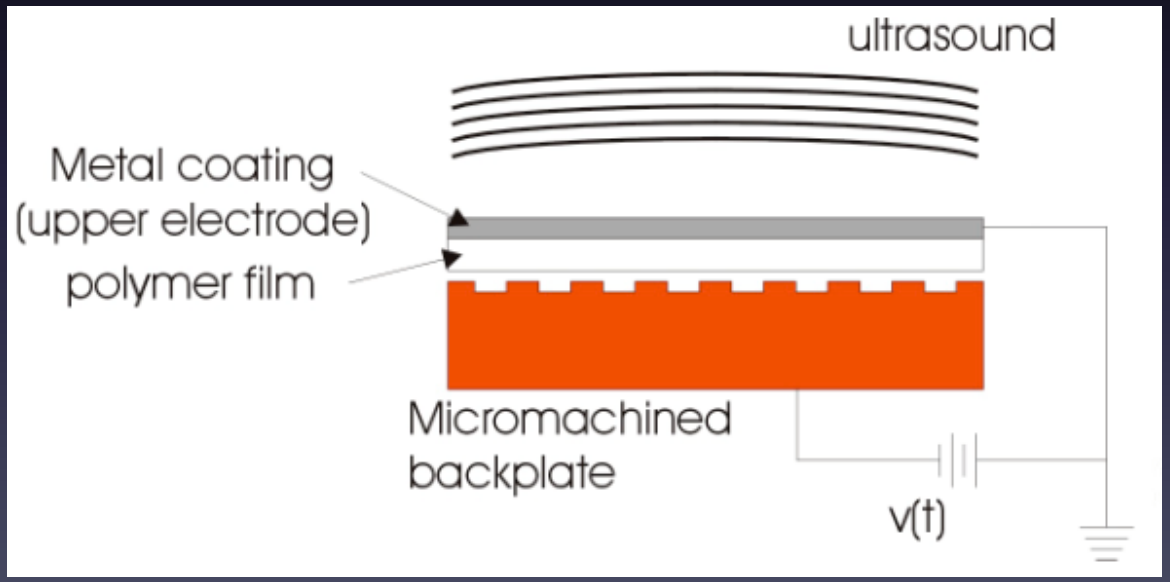
Challenges at Mars

Difficult to make sound on Mars

- Air density ~1%. Acoustic impedance mismatch
- Use very special transducers (broadband & low acoustic impedance)

Much lower signal strengths

- Use Radar technique: Pulse Compression



Martian Sonic Anemometer Progress

Funding History:

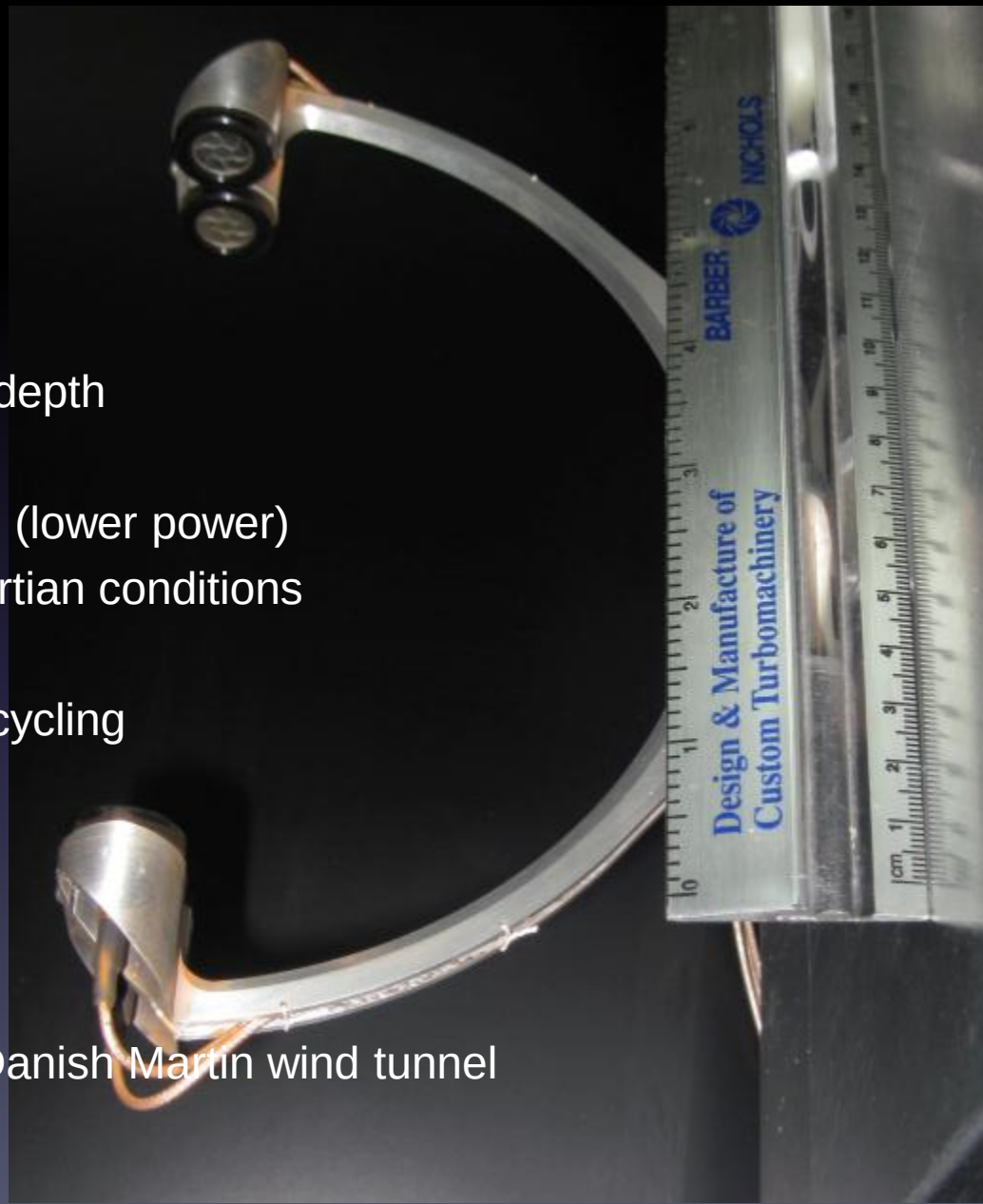
- PIDDP (2002-2005)
- PIDDP (2008-present)

Miniaturized Transducers:

- Now 1.7cm diameter X 0.7cm depth
- 6 grams each
- Reduced voltage requirements (lower power)
- Increased sensitivity under Martian conditions
- Miniaturized amplifiers
- Simulated 90 sols -60C to 0C cycling
- 3 cycles to <-120C

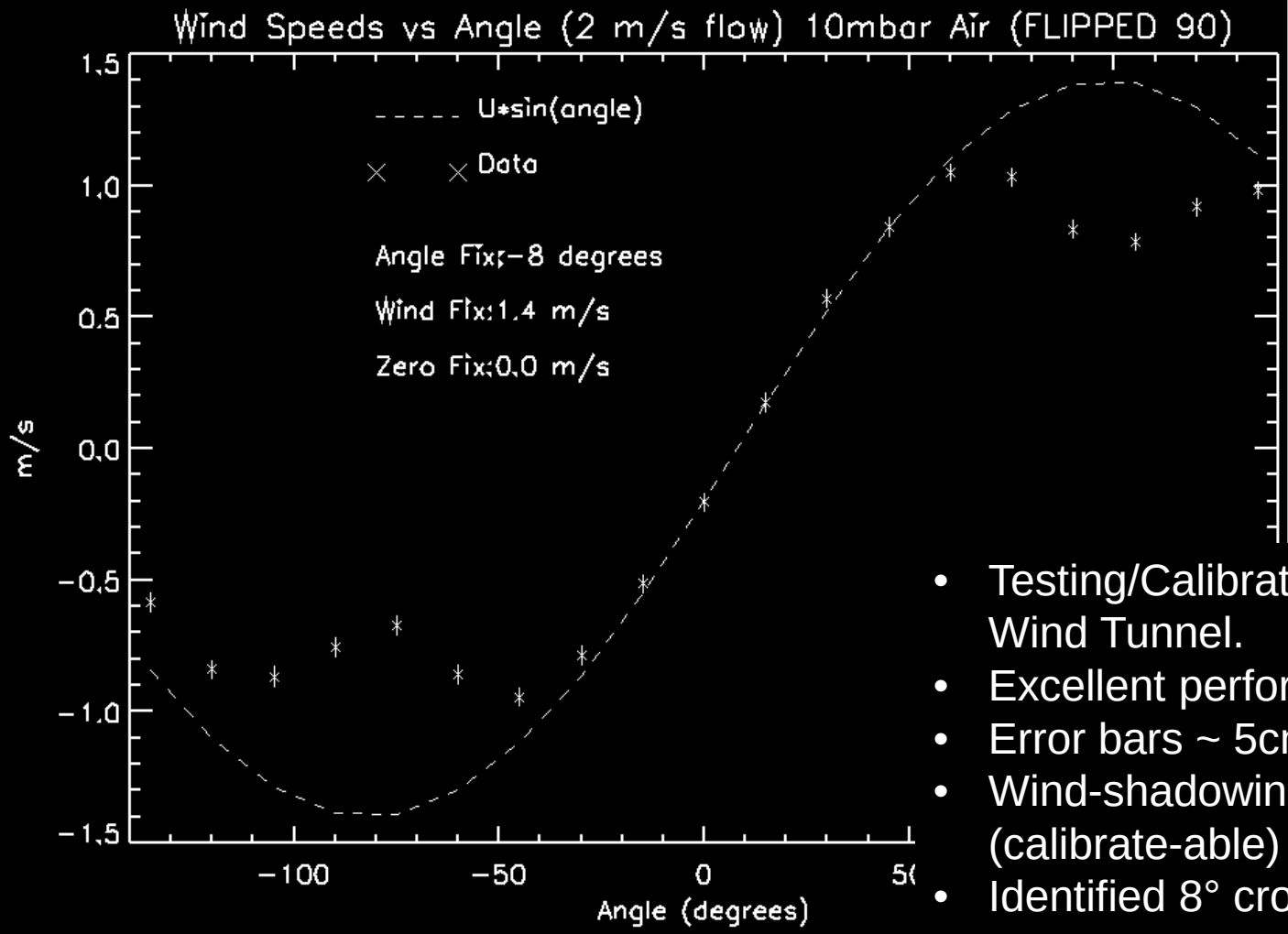
Current Maturity:

- 1-D breadboard instrument
- Demonstrated & calibrated at Danish Martin wind tunnel
- TRL 5 (Transducers 6)



Martian Wind Tunnel Validation/Calibration

Mars Wind Tunnel
Denmark, June 2012

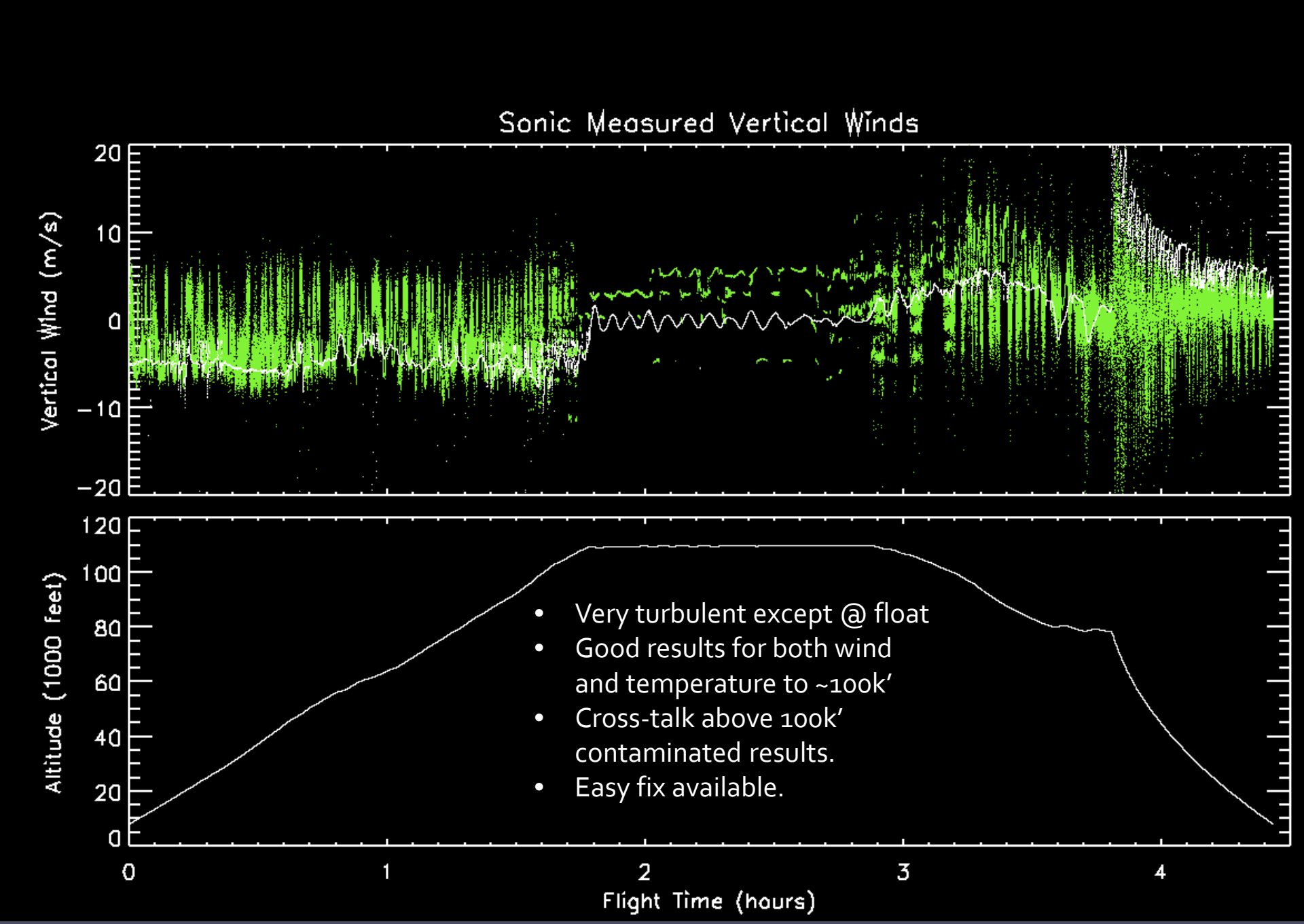


- Testing/Calibration in Danish Martian Wind Tunnel.
- Excellent performance at 10 mbar.
- Error bars ~ 5cm/s
- Wind-shadowing effect evident (calibrate-able)
- Identified 8° cross-flow in wind tunnel

Stratospheric Balloon Validation

- JPL ASTRA PHAETON Project (Stratospheric Balloon Mars Simulator)
- Flew both sonic anemometer (1-D) and Hot Wire Anemometer

At 110,000’ (7 mbar)


Sonic Measured Vertical Winds
Vertical Wind (m/s)
20
10
0
−10
−20
Altitude (1000 feet)
120
100
80
60
40
20
0
0
1
2
3
4
Flight Time (hours)
• Very turbulent except @ float
• Good results for both wind and temperature to ~100k'
• Cross-talk above 100k' contaminated results.
• Easy fix available.

Martian Sonic Anemometer

- Technical Characteristics:
  - Mass: ~1.5 kg
  - Volume: Total: ~1500 cm^3
    - electronics: ~1000 cm^3
    - Sensor Head: D=20 cm sphere deployed
      D=20 cm X 3 cm deep cylinder stowed
  - Power: ~5 W active, 0 W quiescent
  - Maximum Data Rate: 1200 Byte/s
  - Typical Data Rate: 80 Byte/s

- Key Performance Characteristics:
  - Measurement Rate: >20 Hz
  - Wind Speed Accuracy, Sensitivity: ~5 cm/s
  - Temperature Accuracy: ~0.2 K
  - Fluxes (horizontal and vertical; heat, momentum)