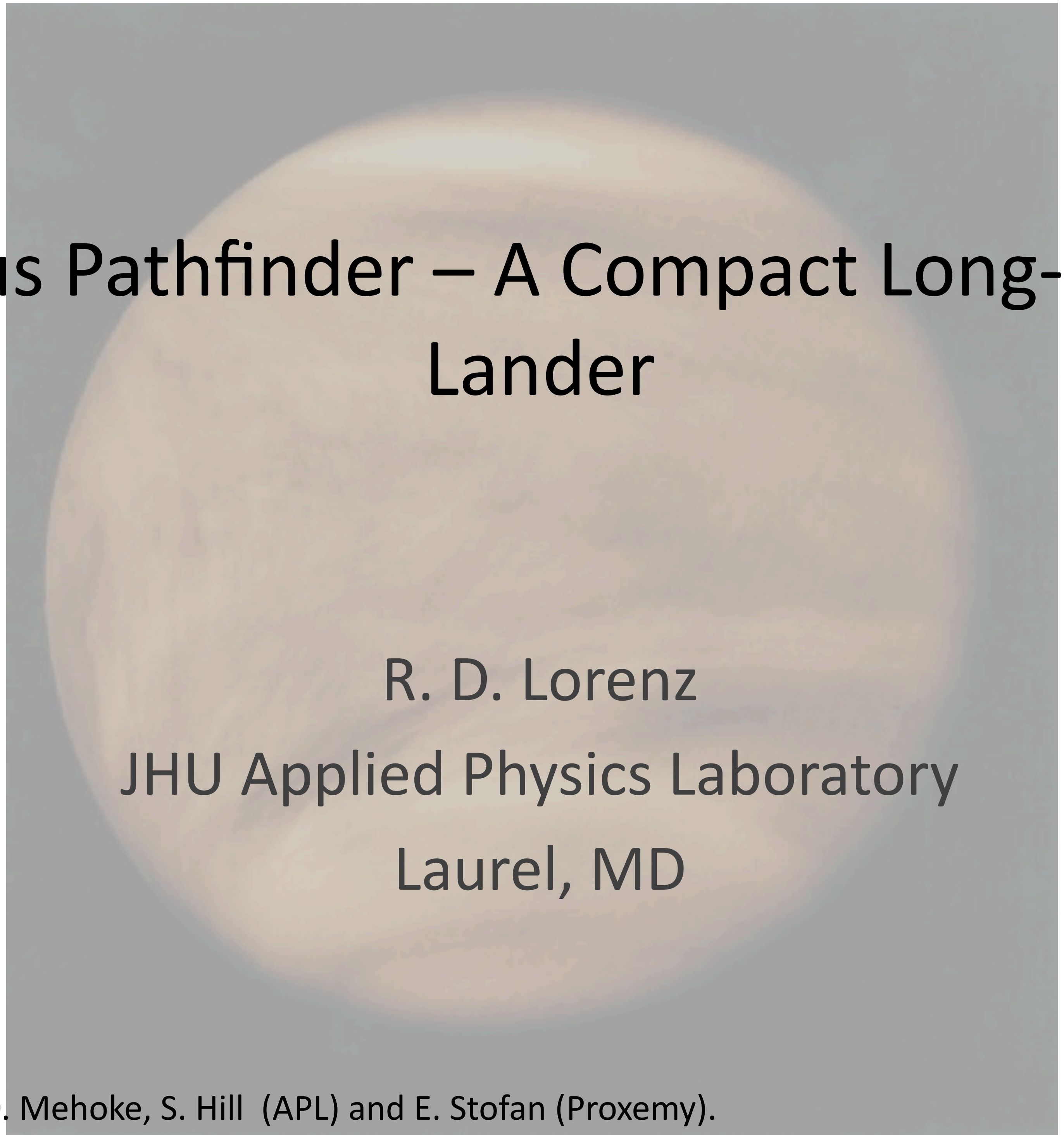


Venus Pathfinder – A Compact Long-Lived Lander

R. D. Lorenz

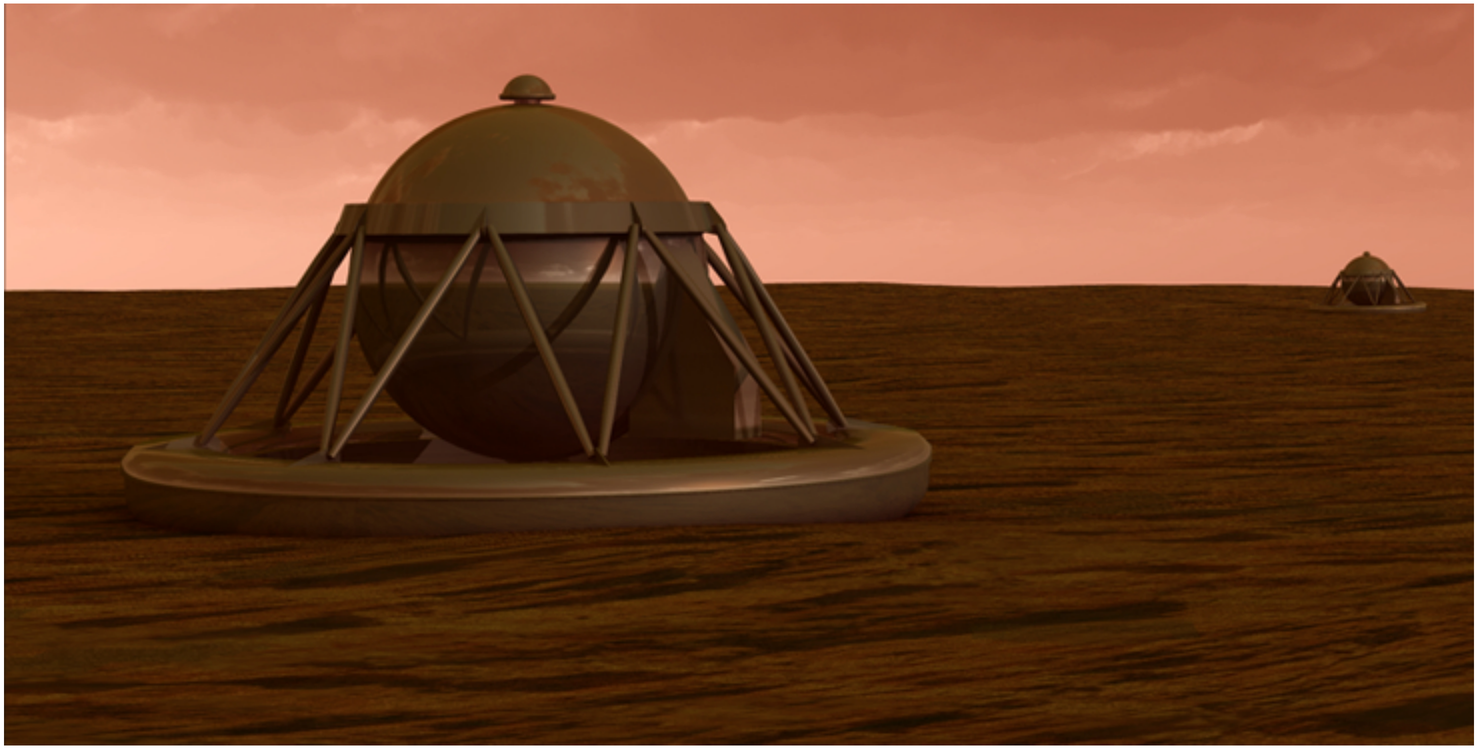
JHU Applied Physics Laboratory

Laurel, MD

With D. Mehoke, S. Hill (APL) and E. Stofan (Proxemy).

Venus Flagship Mission Study

April 17, 2009



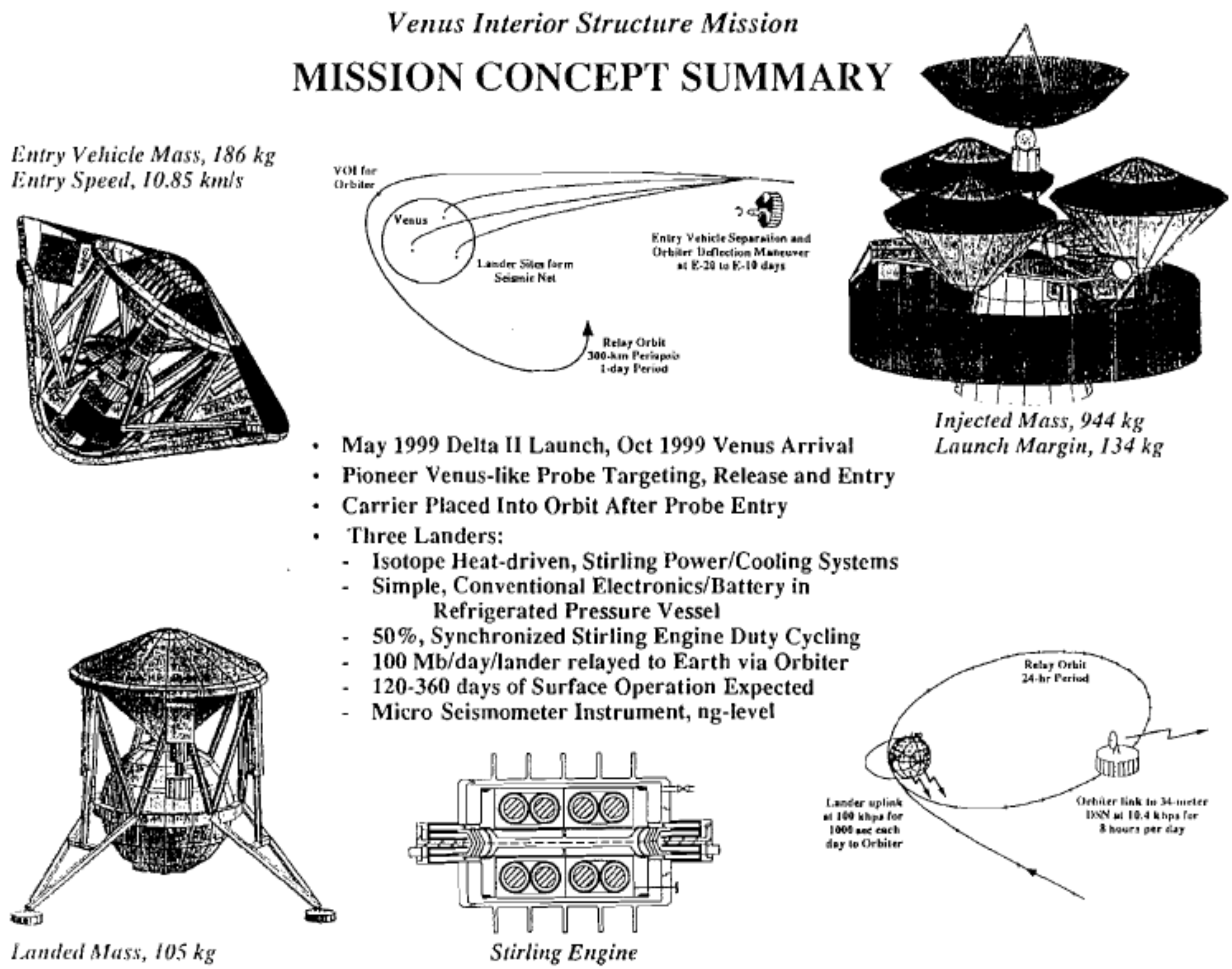
Bulletin of the Seismological Society of America. Vol. 61, No. 6, pp. 1731–1737. December, 1971

A VENUS SEISMIC EXPERIMENT FOR THE LATE 1970'S

JOHN S. DERR

ABSTRACT

NASA is planning a series of small-payload Venus missions, with launches beginning in 1976, some of which may be suited to small active and passive seismic experiments. Because the Earth and Venus are nearly the same size, one may theorize many parallels in seismic and tectonic activity, and any differences will provide information about the development of the Earth, as well as of Venus. A combined

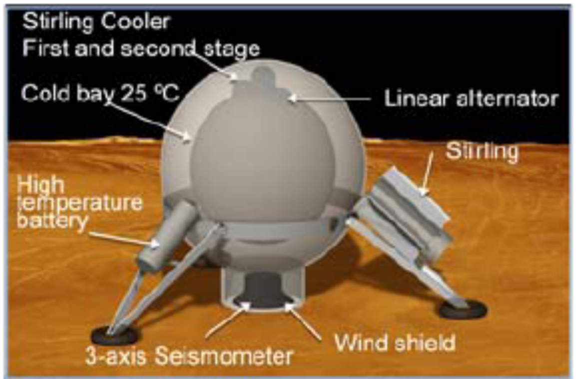


VISM Mission Concept Presentation, 1993. Courtesy of Ellen Stofan.

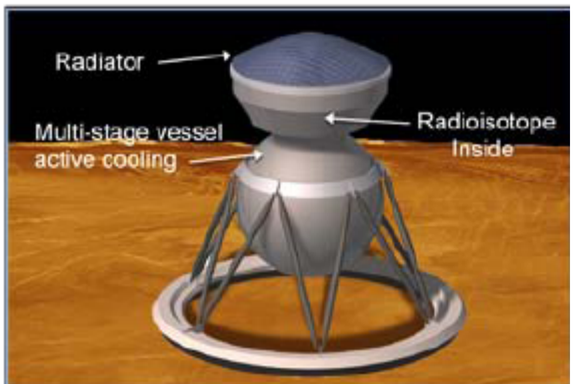
Progress Towards the Development of a Long-Lived Venus Lander Duplex System

AIAA 2010-6917

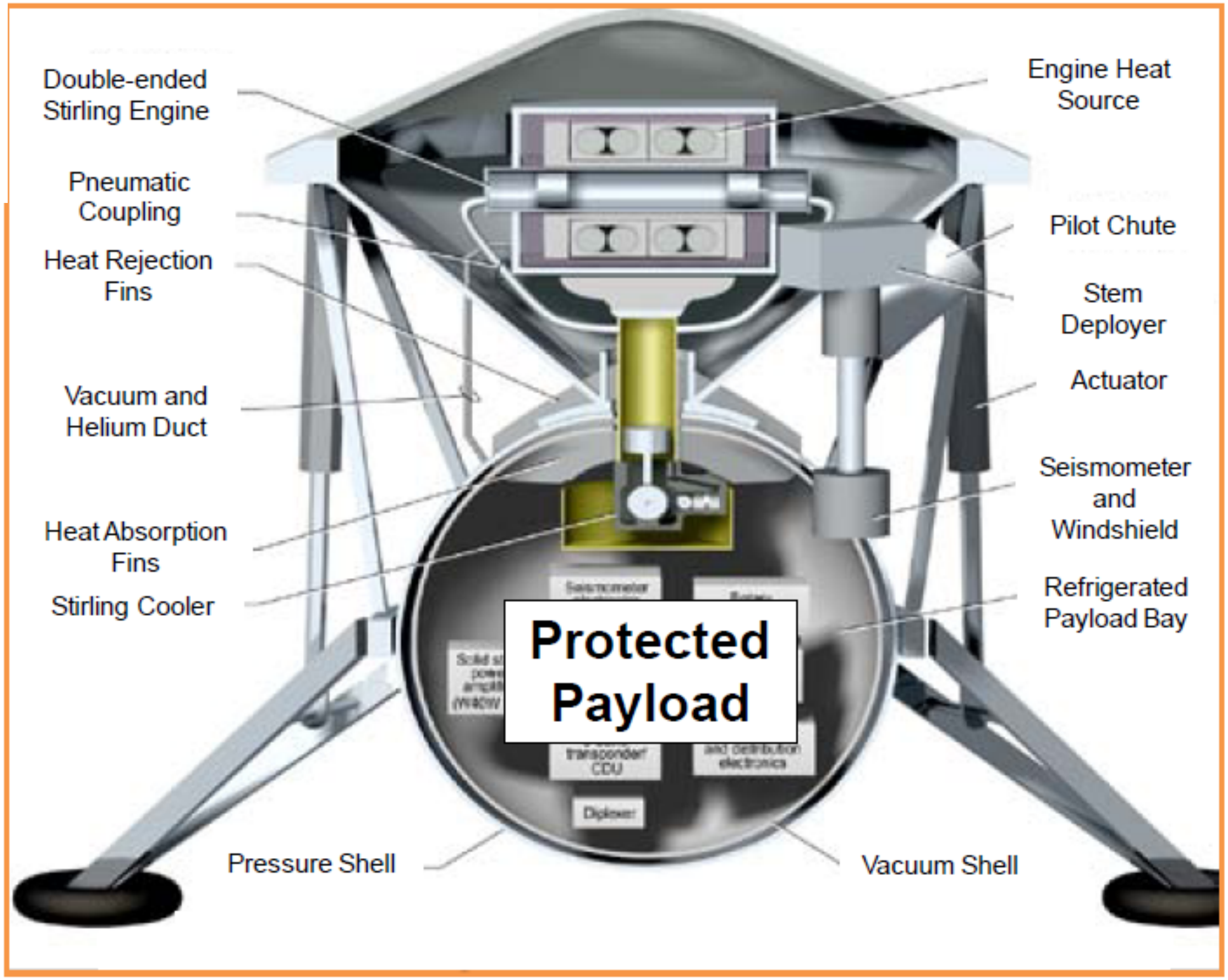
Rodger W. Dyson[1] and Geoffrey A. Bruder[2]
NASA Glenn Research Center, Cleveland, OH, 44135

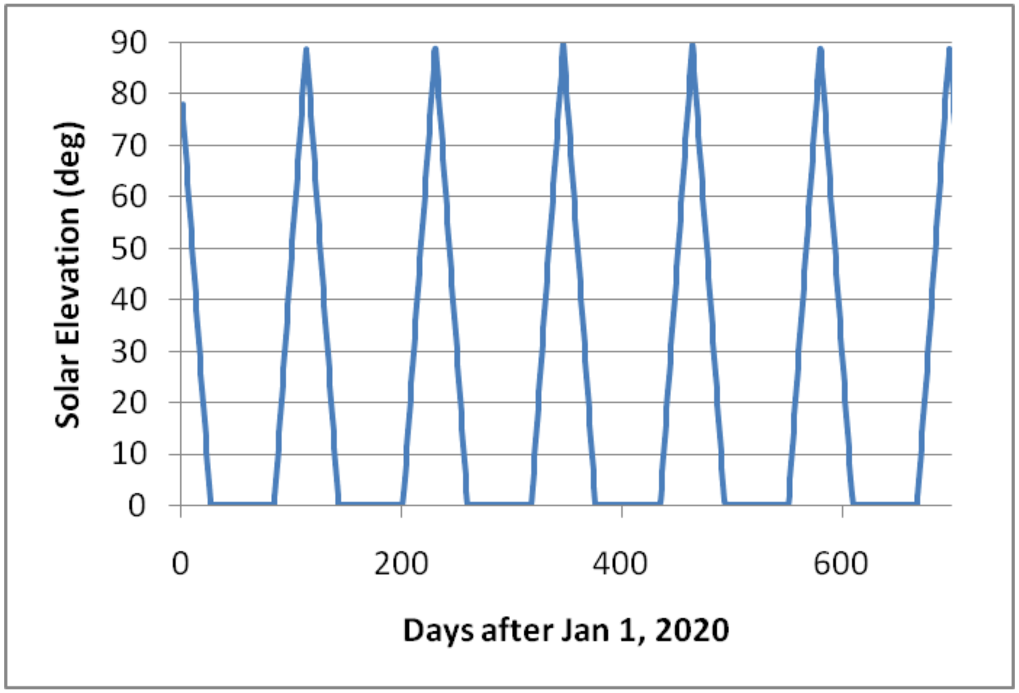


Venus Interior Surface Mission, 1993



Glenn's Advanced Stirling Duplex, 2010

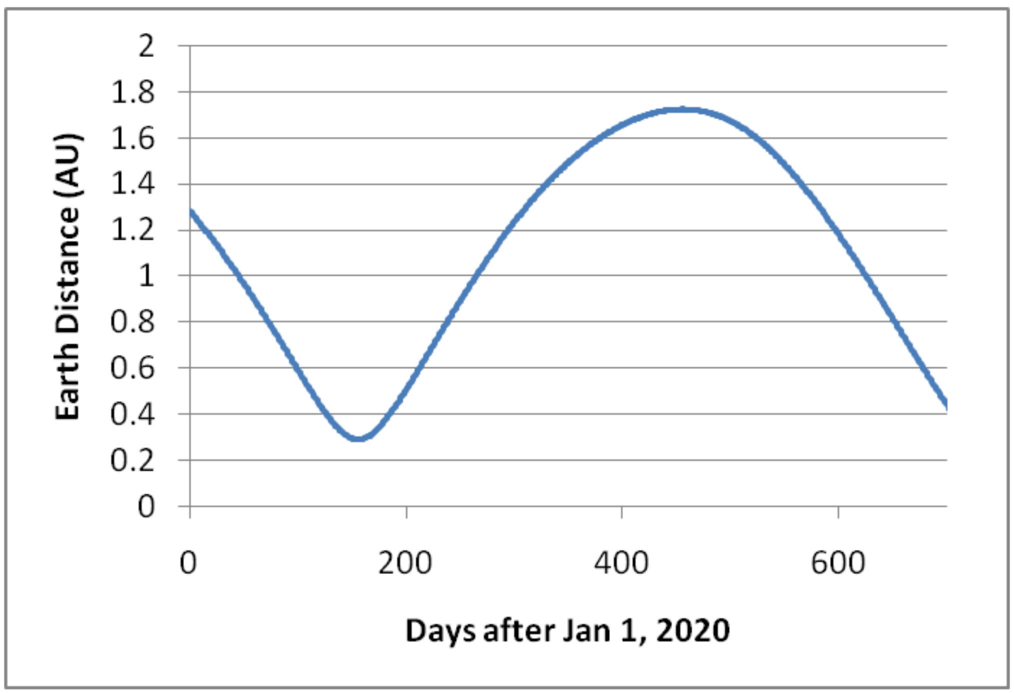




Venus solar day ~117 Earth days.

Visibility of Earth from equatorial location ~80 days long, ~50 with terrain mask.

200 day mission sees 2 communications windows (albeit of different quality, owing to changing range)



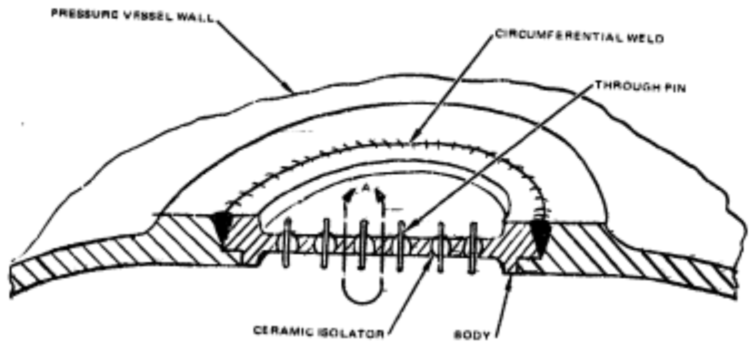
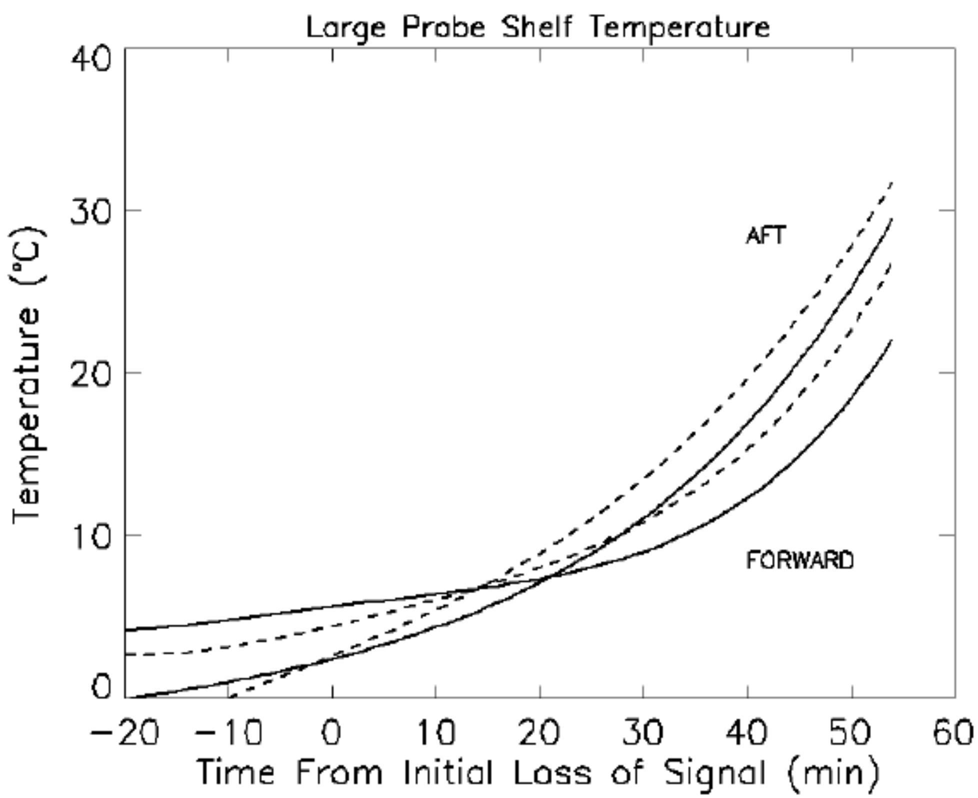


FIGURE 4.5-28. HERMETIC ELECTRICAL FEEDTHROUGH

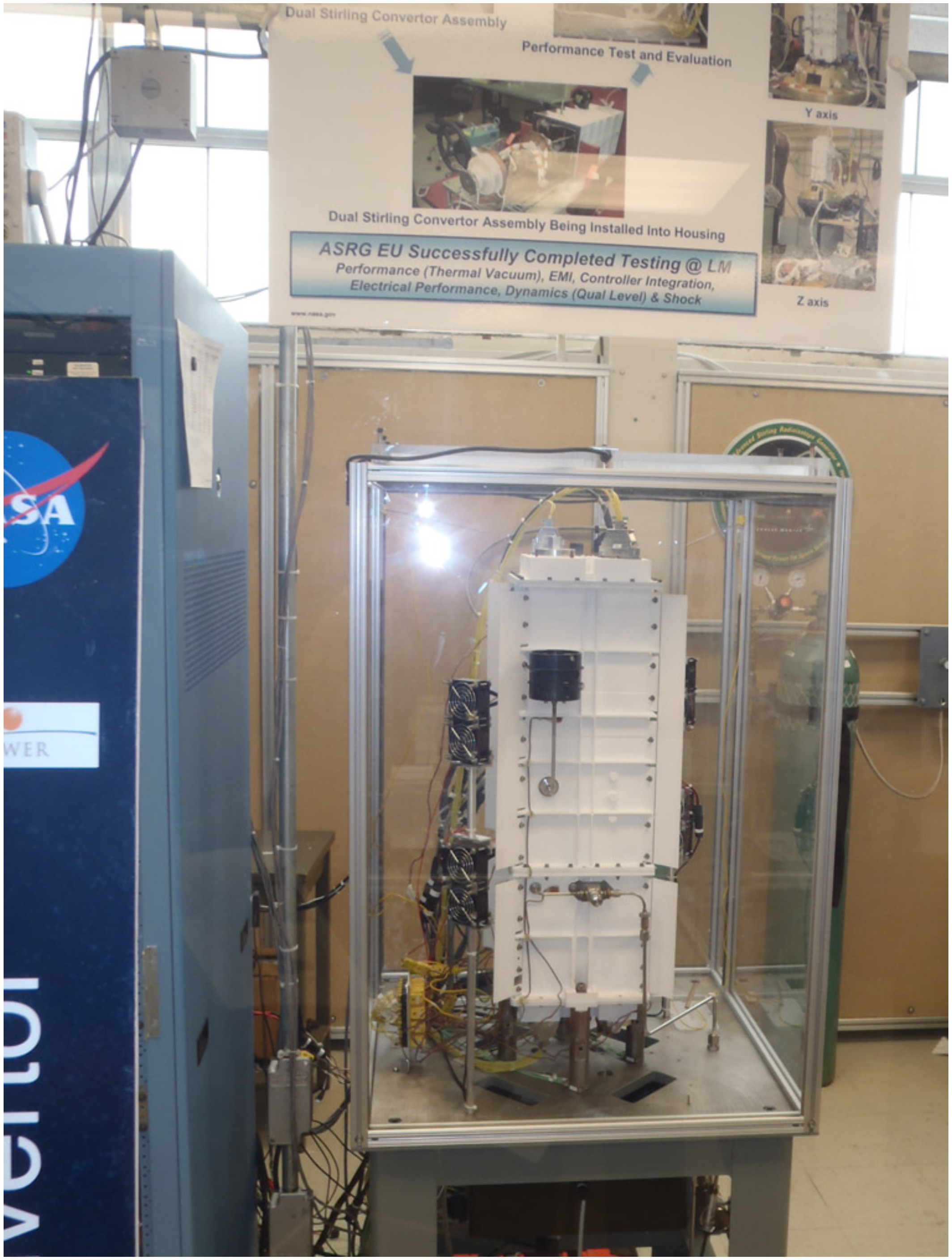


As-flown Pioneer Venus temperature evolution (Lorenz, IPPW5)

Multiplying terminal temperature rate ~1.2 K/min by heat capacity estimated from subsystem masses (~1.2E5 J/K) suggests total heat gain of ~2.5 kW !

This is ~500W internal dissipation, ~1.7kW through insulation and >300W through penetrations.

Can scale by pressure vessel size, estimated number of penetrations. Still seems hard to avoid expecting 100-200W cooling requirement.



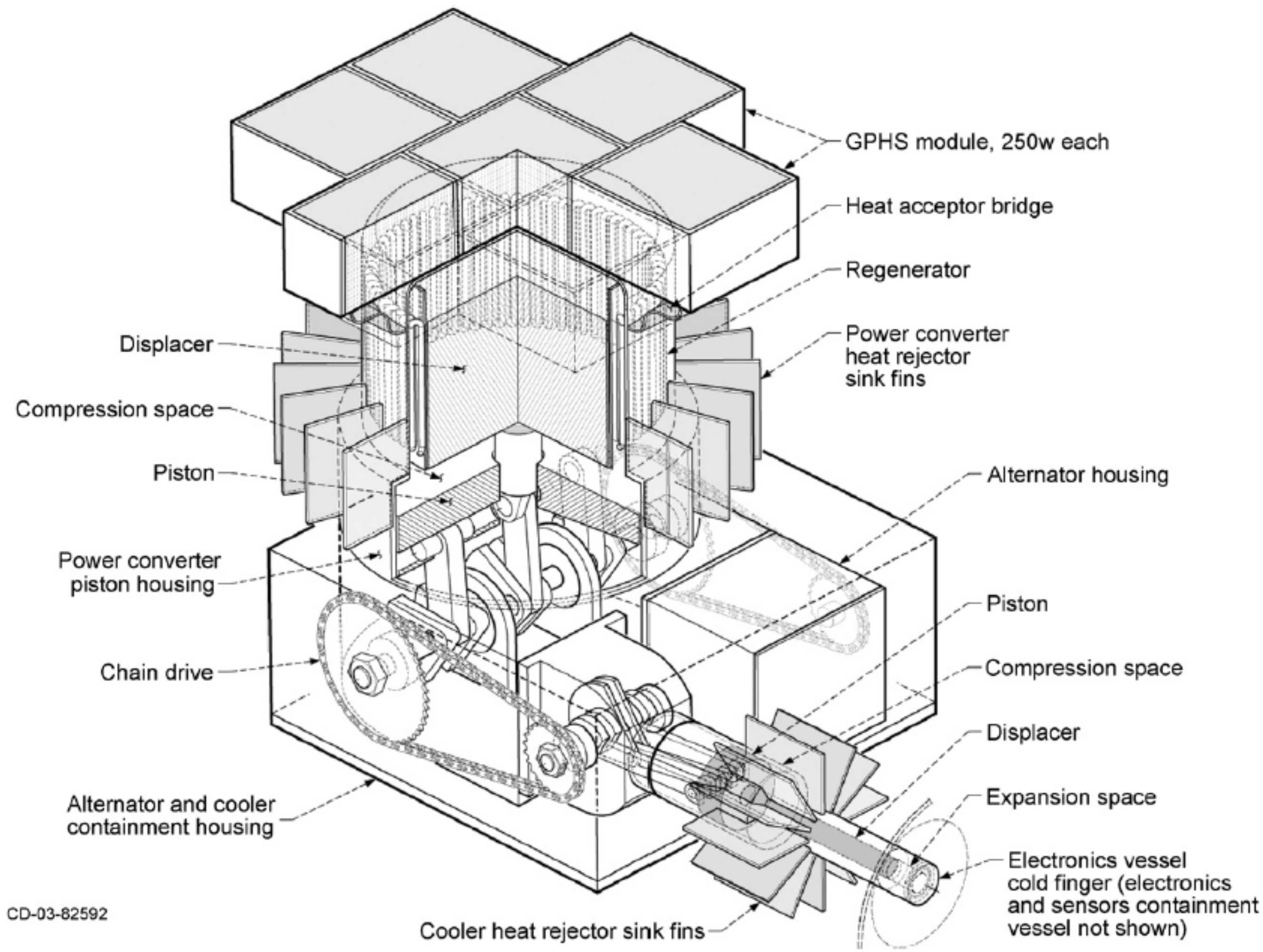
ASRG unit under test at NASA Glenn, March 2010

Discovery AO incentivized use of ASRGs. Two ASRG missions commencing Phase A study (Chopper and TiME).

Venus surface power and cooling systems☆

Geoffrey A. Landis*, Kenneth C. Mellott[1]

Acta Astronautica 61 (2007) 995–1001

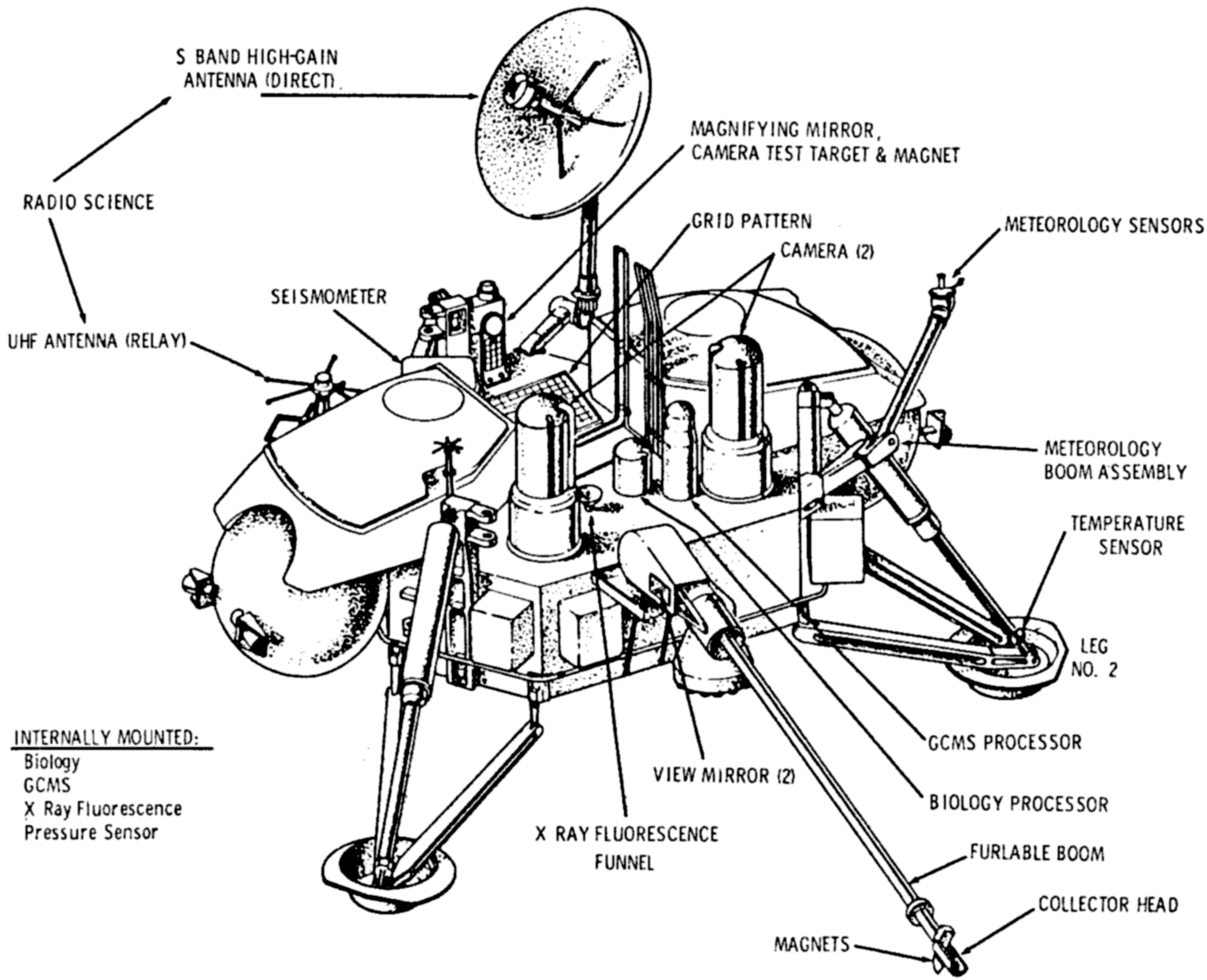


1750W Thermal Power (=7 GPHS)

478W mechanical output, 100 W thermal cooling power.

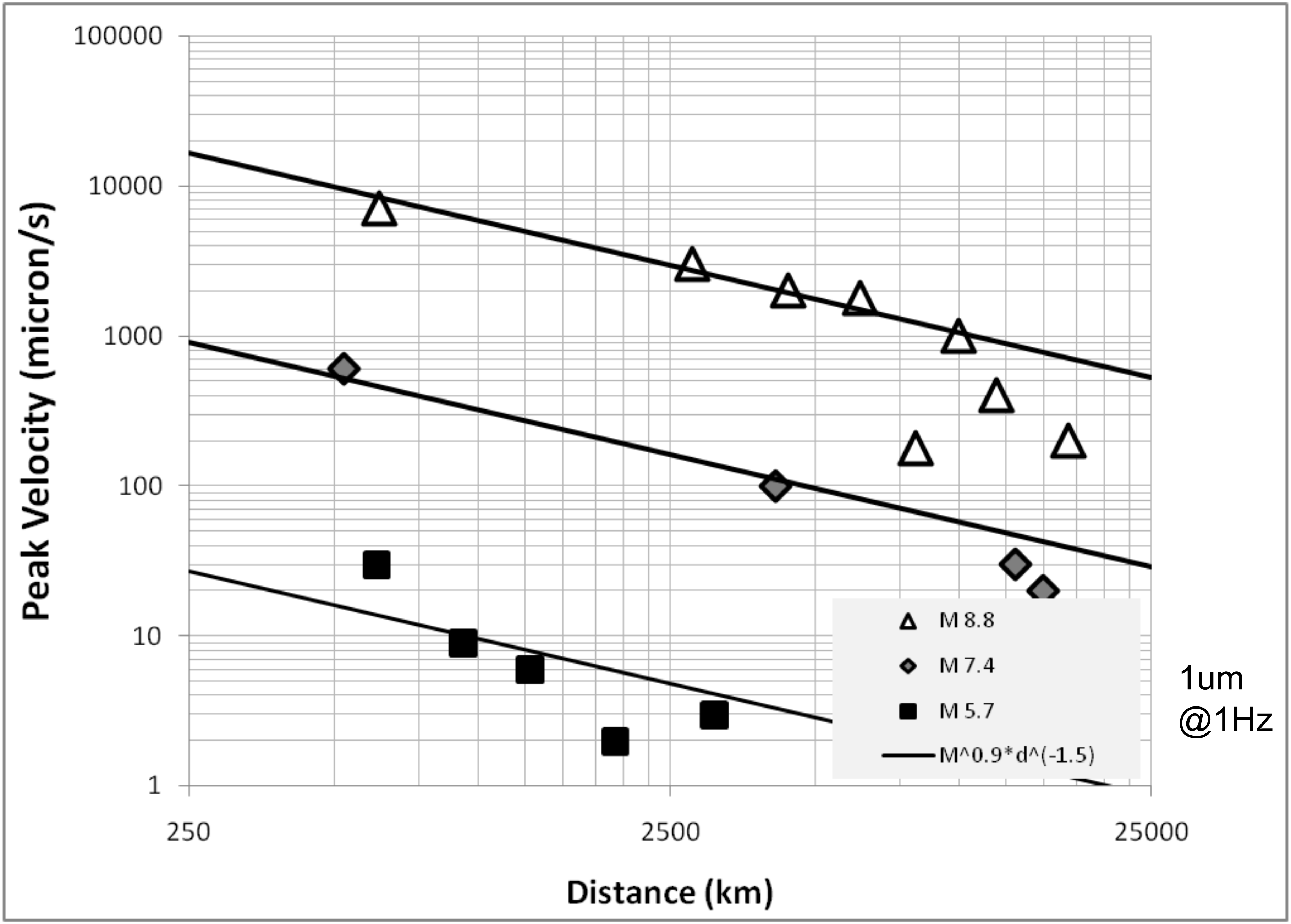
T_h~1200C, T_c~500C

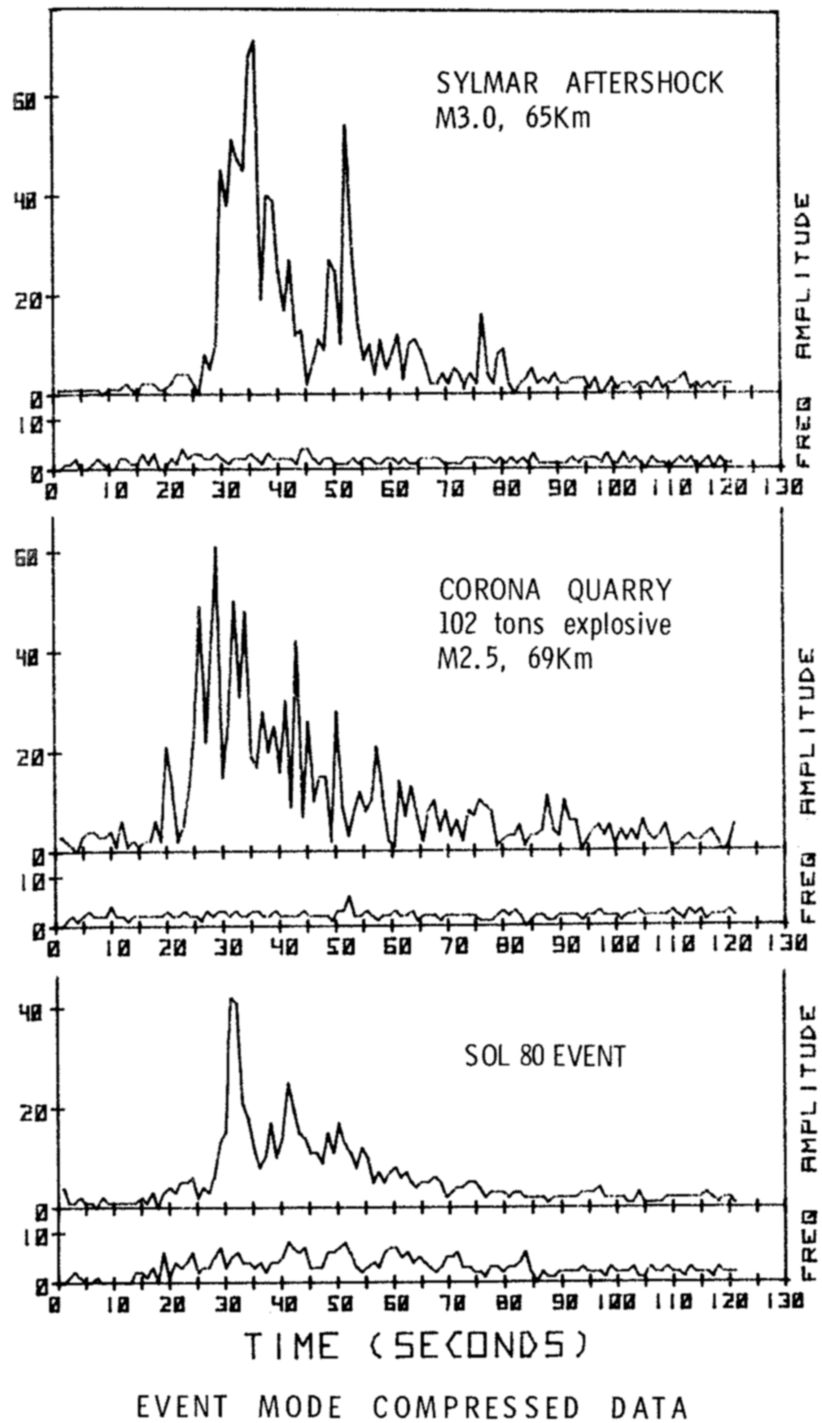
Magnets ?
Lifetime



INTERNALLY MOUNTED:

Biology
GCMS
X Ray Fluorescence
Pressure Sensor


100000
10000
1000
100
10
1
Peak Velocity (micron/s)
250
2500
25000
Distance (km)
M 8.8
M 7.4
M 5.7
M^0.9*d^(-1.5)
1um
@1Hz



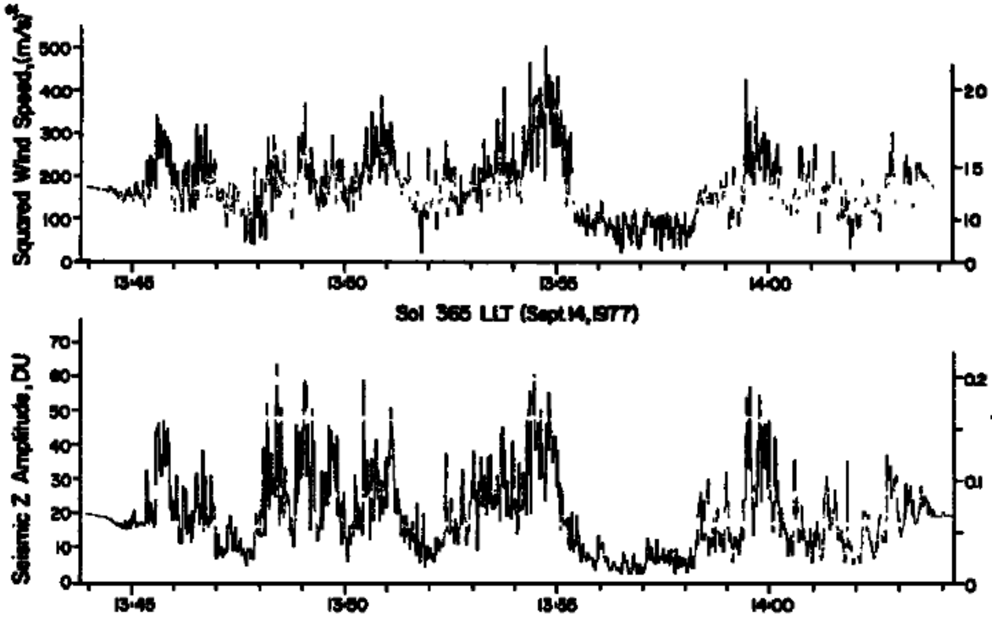
A Martian Earthquake ?

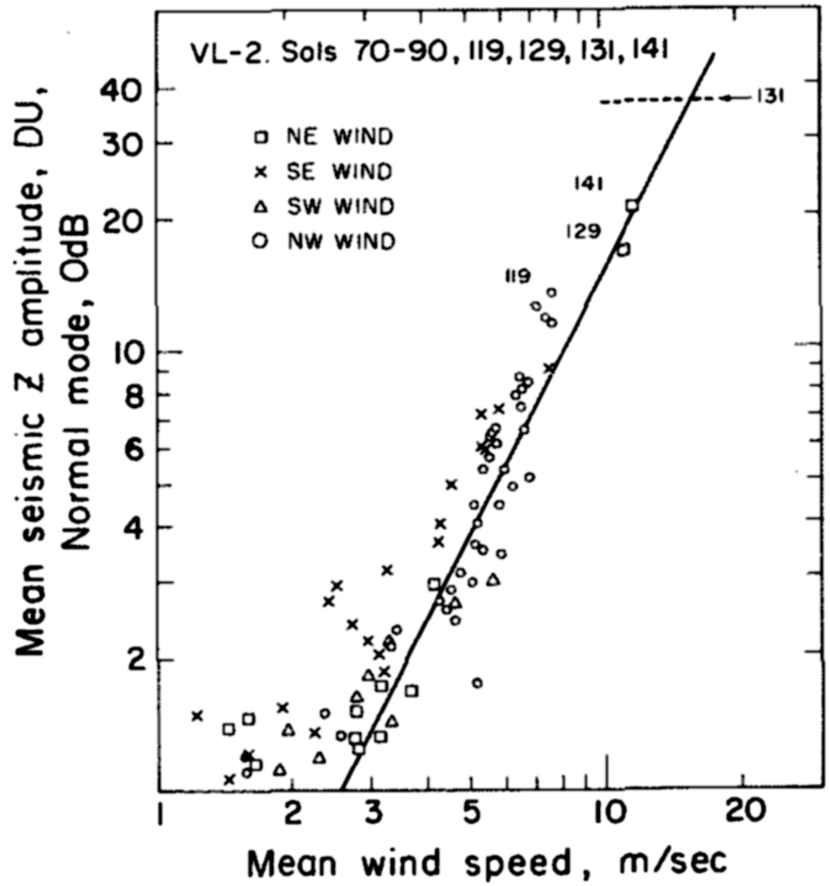
A single event was identified as a possible Marsquake, on Viking lander 2 Sol 80. Time history appears consistent with a small, nearby seismic event.

Statistical significance of a single event is very high (if it is real),

However, no contemporaneous wind data was acquired, so cannot eliminate wind gust loading on lander as a possible cause of this event. (And Viking 1 seismometer did not uncage, so cannot be used for confirmation).

D. Anderson et al., Seismology on Mars, JGR, 1977





Seismometer signals are coherent with wind speed measurements, and show the expected ~V^2 dependence.

Indicate a lander compliance of 1E7 N/m. (1 DU~2nm)

System considered 'quiet' for winds below 3 m/s.

Nakamura & Anderson, GRL, 1979

D. Anderson et al., Seismology on Mars, JGR, 1977

MEASUREMENT OF WIND VELOCITY ON THE SURFACE
OF VENUS DURING THE OPERATION OF STATIONS
VENERA 9 AND VENERA 10

Translated from Kosmicheskie Issledovaniya, Vol. 14, No. 5, pp. 710-713, September-October, 1976.
Original article submitted June 7, 1976.

V. S. Avduevskii, S. L. Vishnevetskii,
I. A. Golov, Yu. Ya. Karpeiskii,

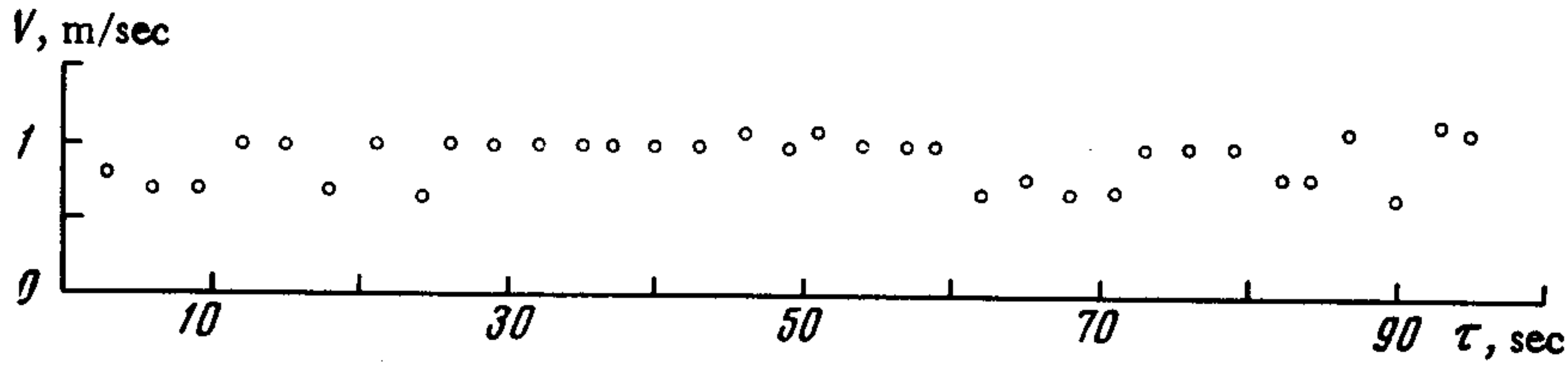
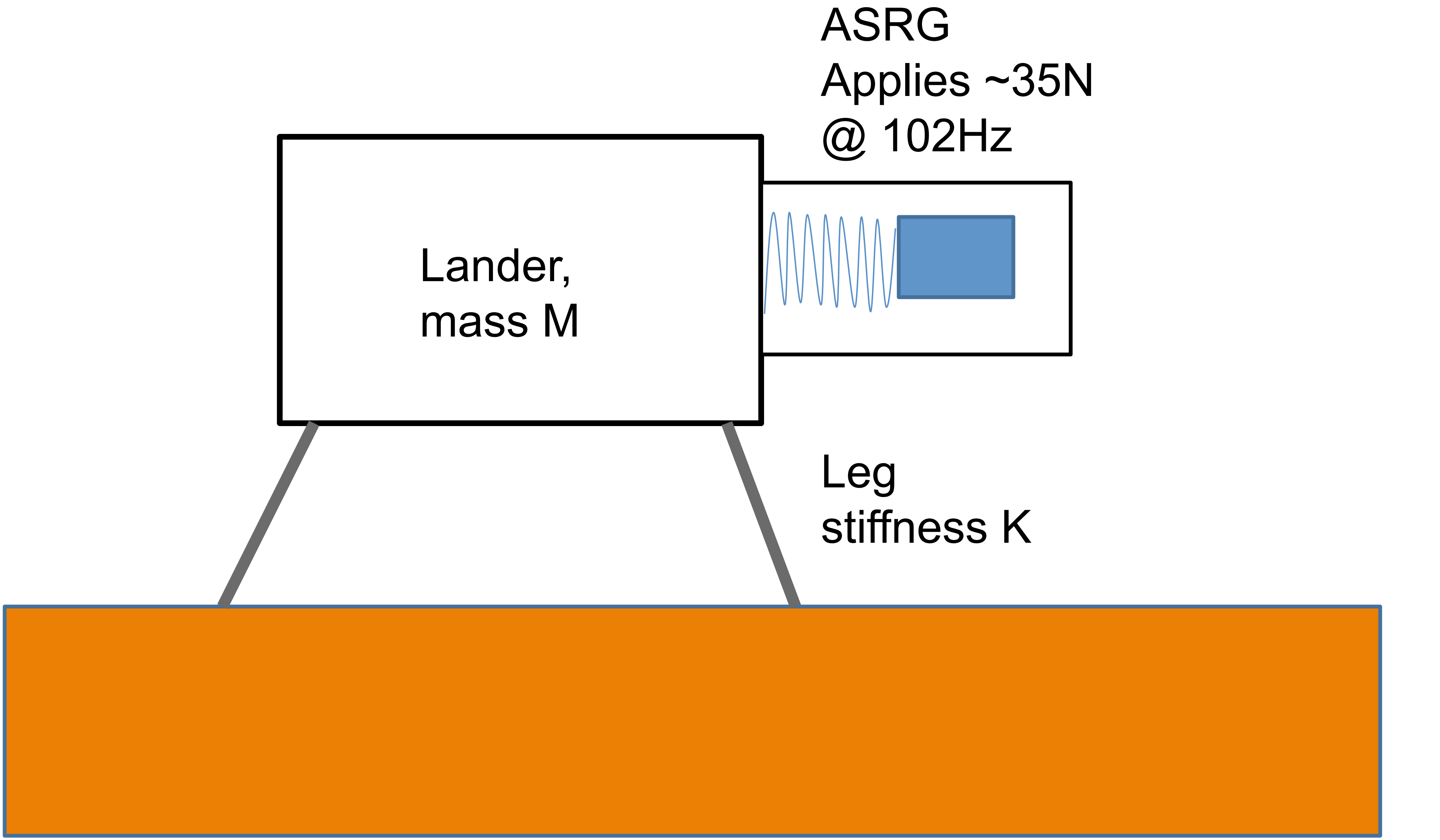


Fig. 5. Measured velocities at the landing site of automatic interplanetary station Venera 10.

Only Venus surface wind measurements are those from cup anemometers on Venera 9 and 10, 49-minutes and 90-seconds long, at 0.4 Hz with ~0.2 m/s resolution. Described statistically as (mean, s.d.) of (0.4,0.1) and (0.9, 0.15) respectively.
Winds estimated from Groza microphone on Venera 13, 14 to be similar.

Wind fluctuations of this magnitude correspond to dynamic pressure of winds ~20 m/s on Mars, ~100 nm displacement


ASRG
Applies ~35N
@ 102Hz
Lander,
mass M
Leg
stiffness K

ASRG Interface Control Document (Discovery 2010 Program library) specifies operation at 102Hz, with F=35N reaction force on a large object.

If lander leg stiffness is zero, and lander mass M~600kg, then this implies F/M~6mg, velocity of 90 microns/s displacement of ~141nm.

Lander stiffness is harder to estimate. 4cm tube, 1m long with 5mm walls has bending stiffness k=1E5 N/m. Surveyor lander stuffness ~3E5 N/m (Sutton and Duennebier, 1970). Examination of Viking wind displacements suggests k~2E7 N/m. Required stiffness to suppress motion >> 35N/141nm~2.5E8 N/m.

Although electronic filtering in Seismometer electronics tends to effectively suppress signals (e.g. 6^{th} order Butterworth filter on Viking, 60dB/decade at 4Hz suppresses 100Hz signal by 10^8), detector could be mechanically saturated.

Need to mechanically isolate Stirling system from seismometer.

Assuming same activity as Earth (~10 magnitude 7 quakes/yr, 100 magnitude 6, etc…), but uniformly distributed, and foregoing magnitude-displacement relationship, we would expect the following number of events as a function of detection threshold

1nm (few x better than Viking, slightly poorer than Apollo)
~ 7000 events, mostly from nearby 3,4 magnitude events
[NB wind noise at terrestrial sites, even in deep boreholds ~0.1nm: Microseisms at coastal sites ~1-2nm]

10nm (reasonable goal ?)
~660 events, mostly 4 and 5.

100nm (unmitigated ASRG vibration levels)
~34 events, magnitude 5-7.

In 50 day mission, with 10nm threshold, might expect ~100 events. If seismic activity is 10x poorer, could still determine that to ~30%.

Conclusions

Study has estimated likely cooling needs of 100-200 W

Goal lifetime should be 200 days, with 50 day floor.

Wind measurements are essential to support seismic investigation, as well as in their own right.   Wind noise on installed seismometers, and via ground coupling, needs further study.

If uniform Earth-like seismicity, a 10nm movement threshold (determined by wind shielding, vibration isolation) should yield useful number of seismic events.