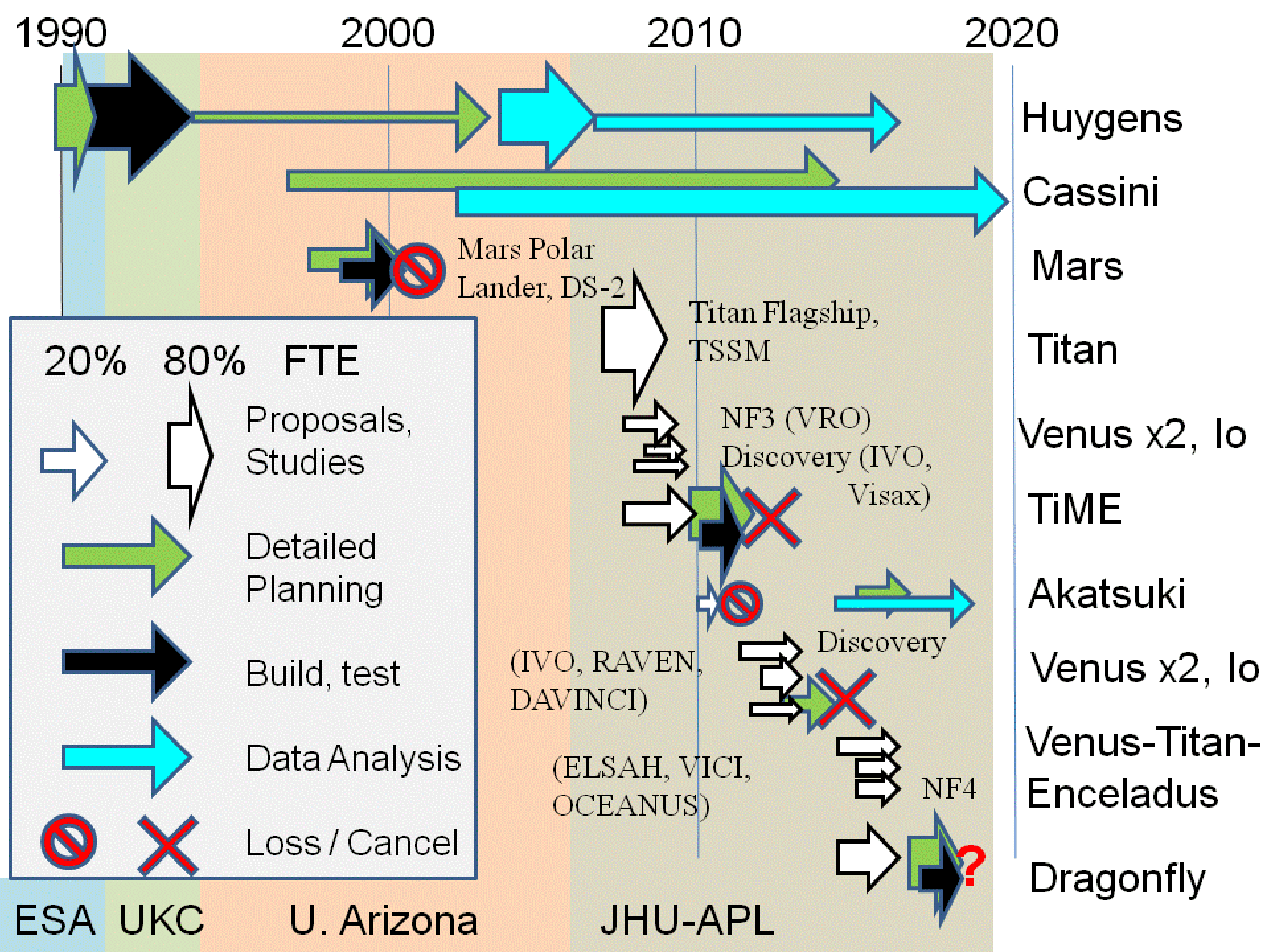
JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Ortho:Para Hydrogen Ratio and Acoustic Measurements

R. D. Lorenz, 'Speed of Sound in Outer Planet Atmospheres' *Planetary and Space Science*, vol.47 pp.67-77, 1999

Ralph D Lorenz

ralph.lorenz@jhuapl.edu

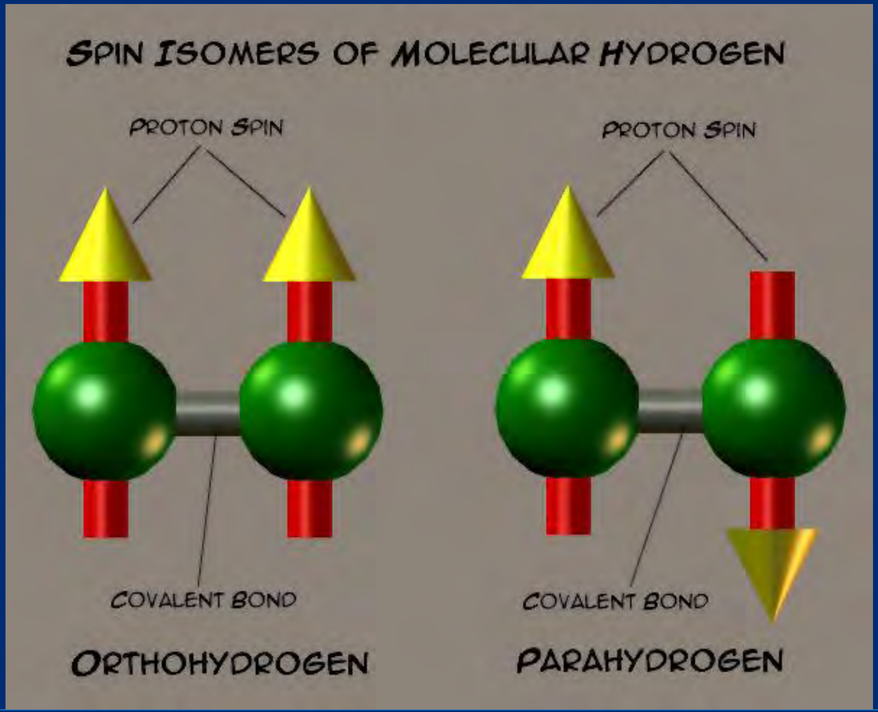


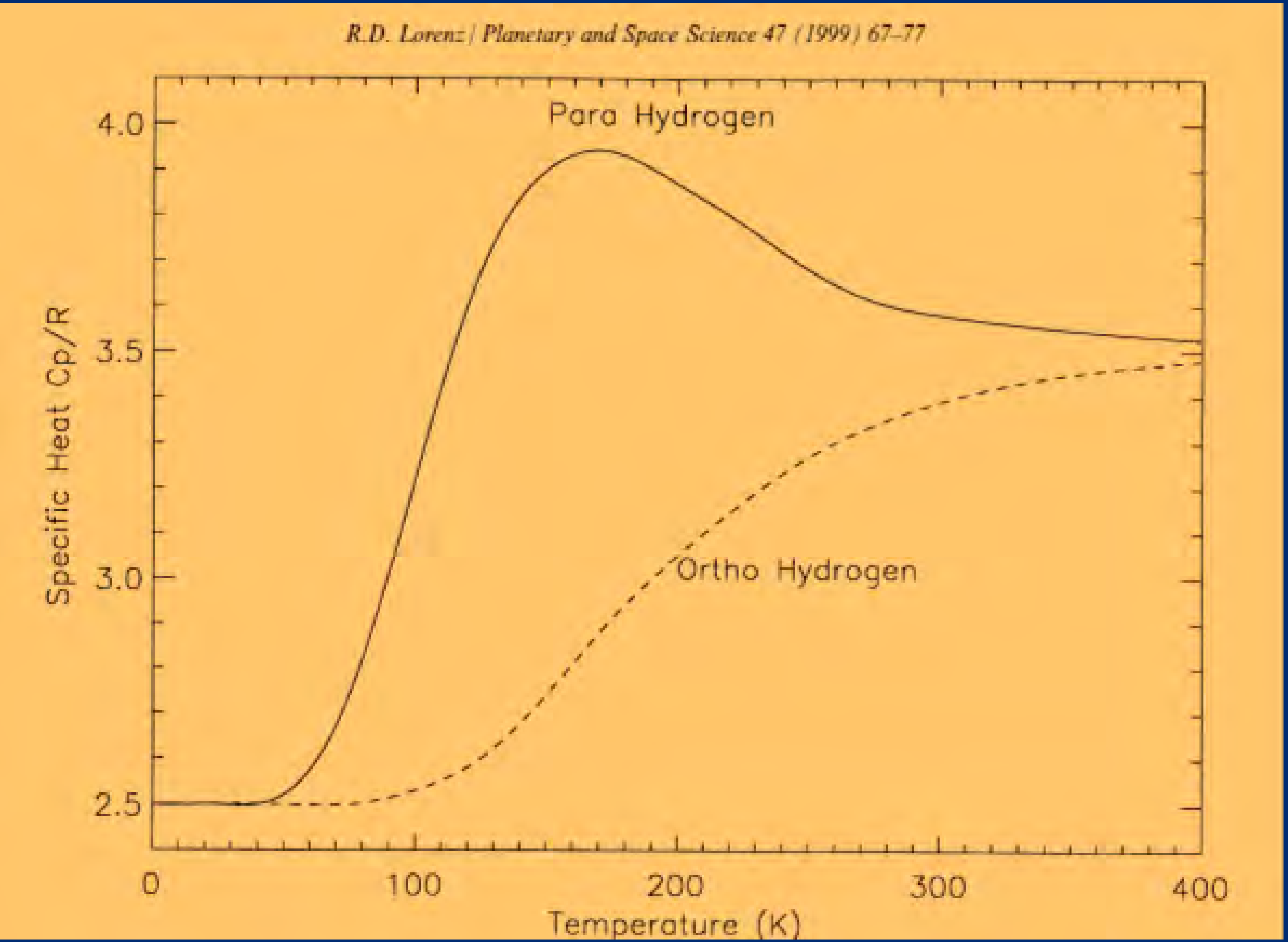
Lorenz Career Graphic as at mid-2018

Mission proposals space-constrained, learn to portray multiple dimensions of information on a single graphic (see e.g. Tufte, Visual Display of Quantitative Information)

Ortho:Para Hydrogen

- Thermodynamic properties of molecular hydrogen depend on whether the proton spins of the two atoms are parallel or antiparallel





Ortho:Para Ratio as a Tracer

- Equilibrium ratio is a function of temperature, and varies substantially at ice giant temperatures
- Relaxation to equilibrium takes a finite time.
- If parcel of gas is moved quickly from low T to high T, it will ‘remember’ its earlier condition. Thus detection of nonequilibrium conditions indicates transport

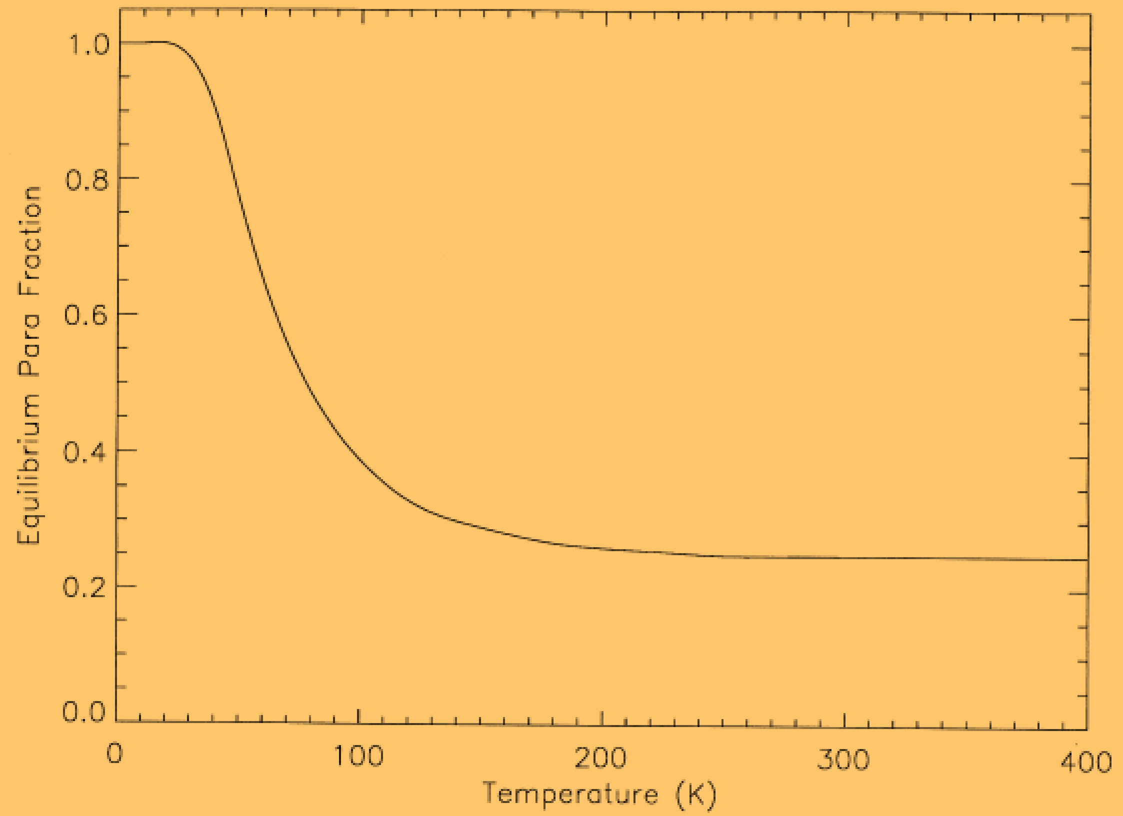


Fig. 2. The equilibrium para hydrogen fraction as a function of temperature (e.g., Massie and Hunten, 1982).

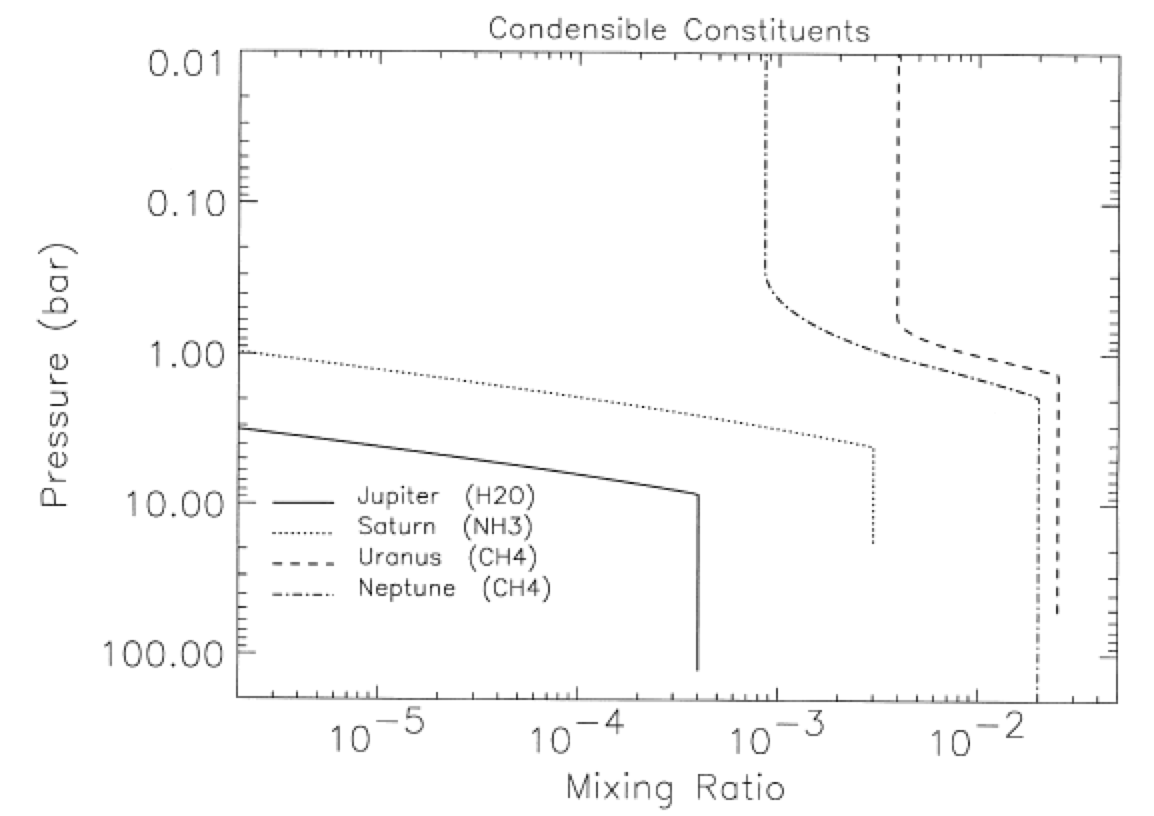
Measurable Effect

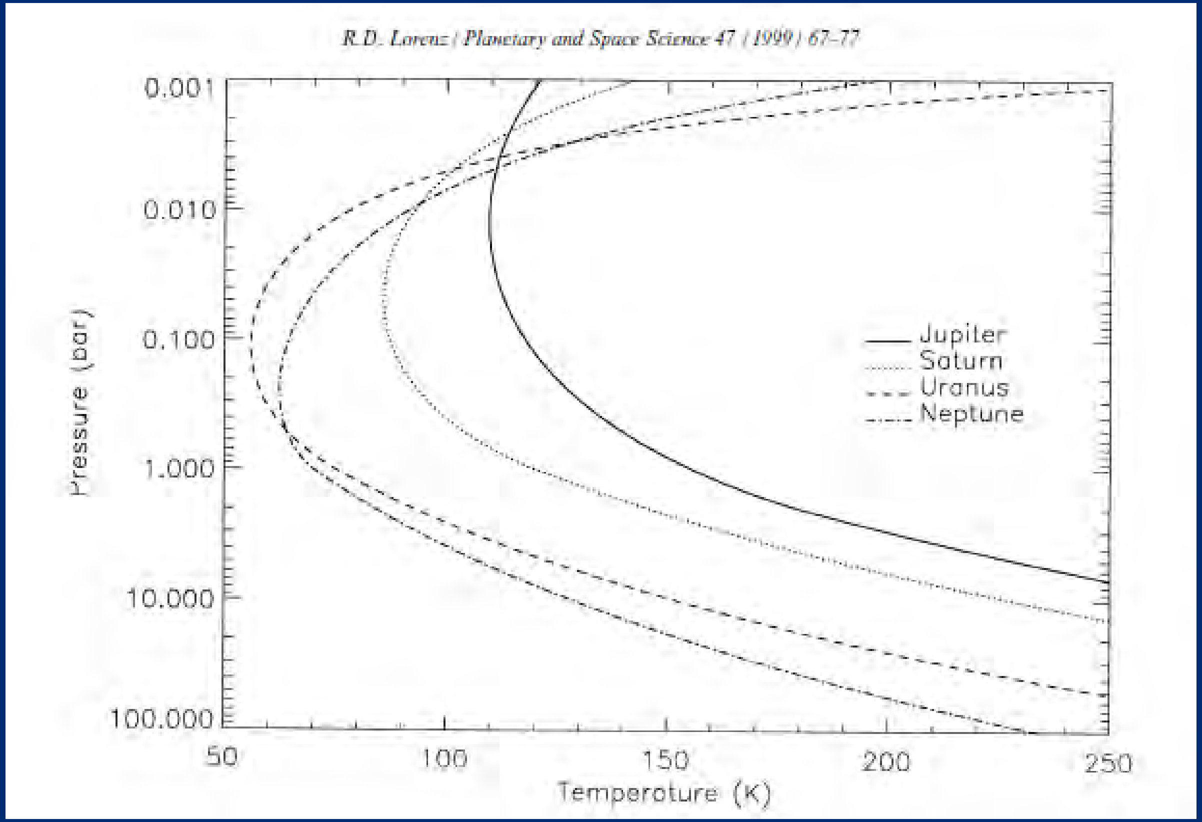
- O:P can be determined remotely by spectroscopy (e.g. for Neptune by Trafton, 1974) by relative depth of the quadrupole lines S(I, ortho) 636.8nm and S(0, para) 643.5nm
- Similarly thermal infrared spectra (Voyager IRIS, Cassini CIRS) can be examined, but inversion is 'an "ill-posed" problem. Arbitrarily small changes in *Ilcan map into finite changes in the re*trieved profiles, so in the presence of even quite small measurement errors, the results are usually catastrophic' (Conrath et al., 1998). Strong filtering is invoked, resulting in poor altitude resolution

- Cp affects adiabatic lapse rate g/C_p (but is the lapse rate adiabatic?
- Cp also affects sound speed, easy to measure locally $c=(\gamma RT/M)^{0.5}$

Model Atmospheres

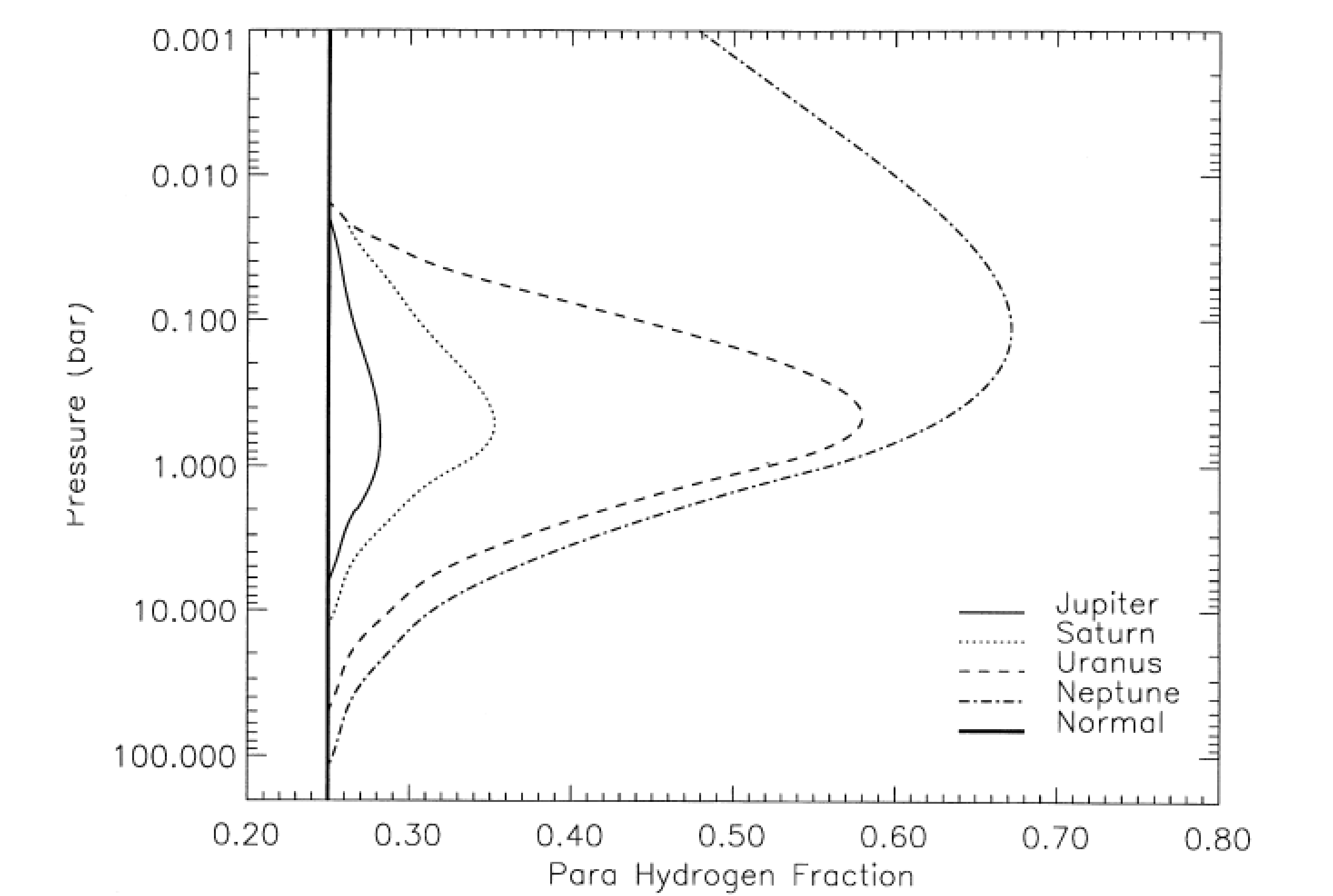
- Simple analytic functions of T(z), X(z) chosen to be representative of Voyager etc. data





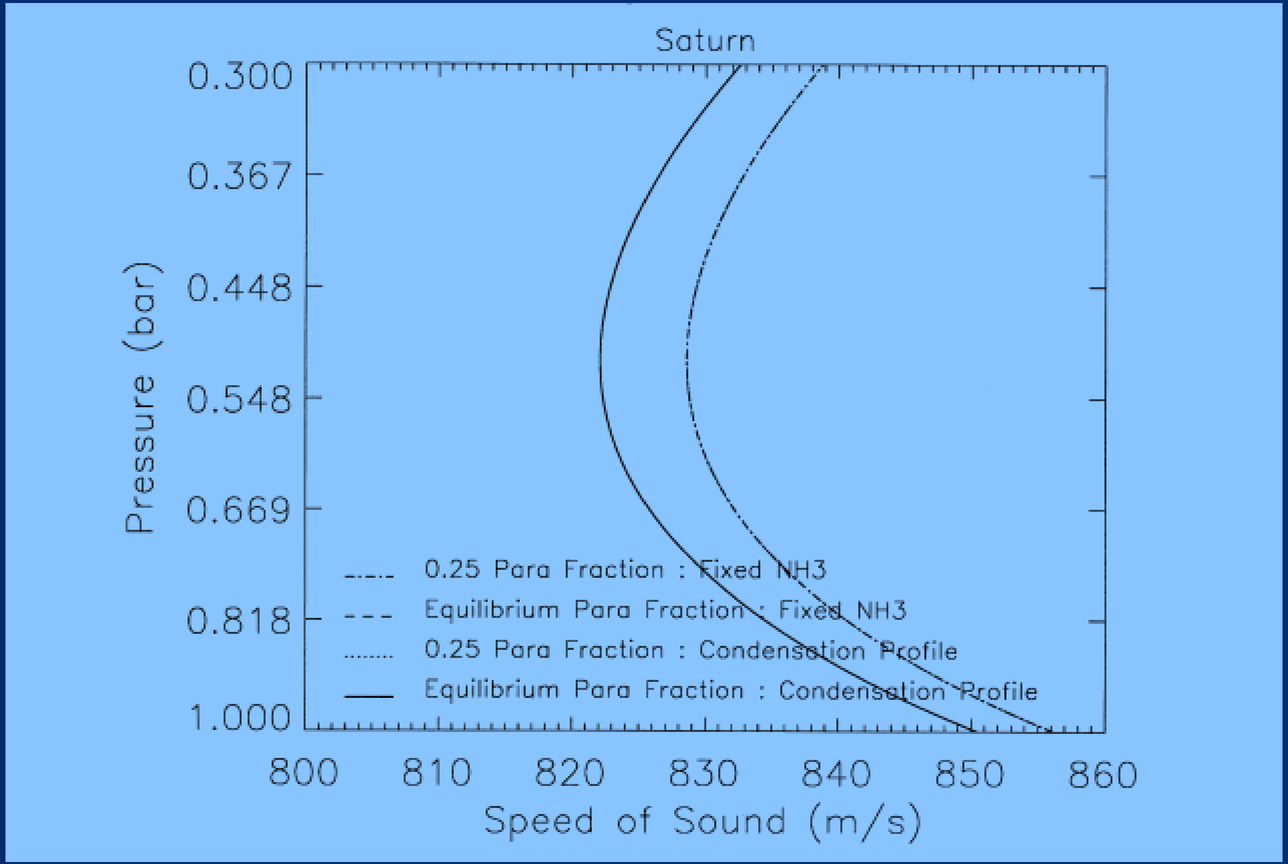
Equilibrium Ortho:Para Ratio

- Jupiter, Saturn so warm that o:p deviation from room temperature is small
- Uranus, Neptune could deviate appreciably
- Uranus para enhancement more localized, more interesting as a tracer



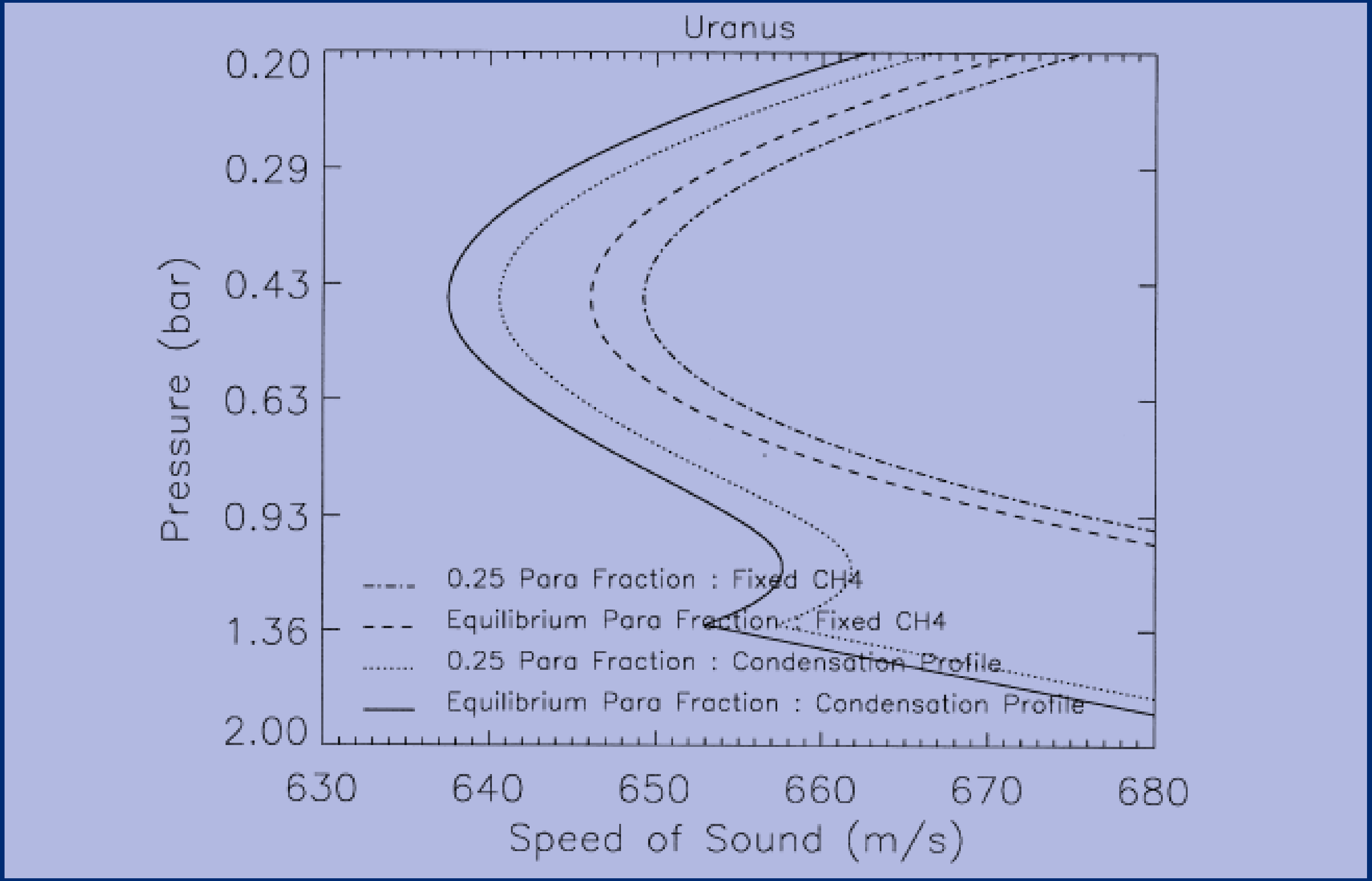
Saturn (and Jupiter)

- 1 quantity (c) but 3 unknowns
- (T, X[cond], fHp)
- If T, X[cond] known from ASI, composition data, fHp should fall out
- For Jupiter & Saturn, condensate concentration is small, but fHp also small



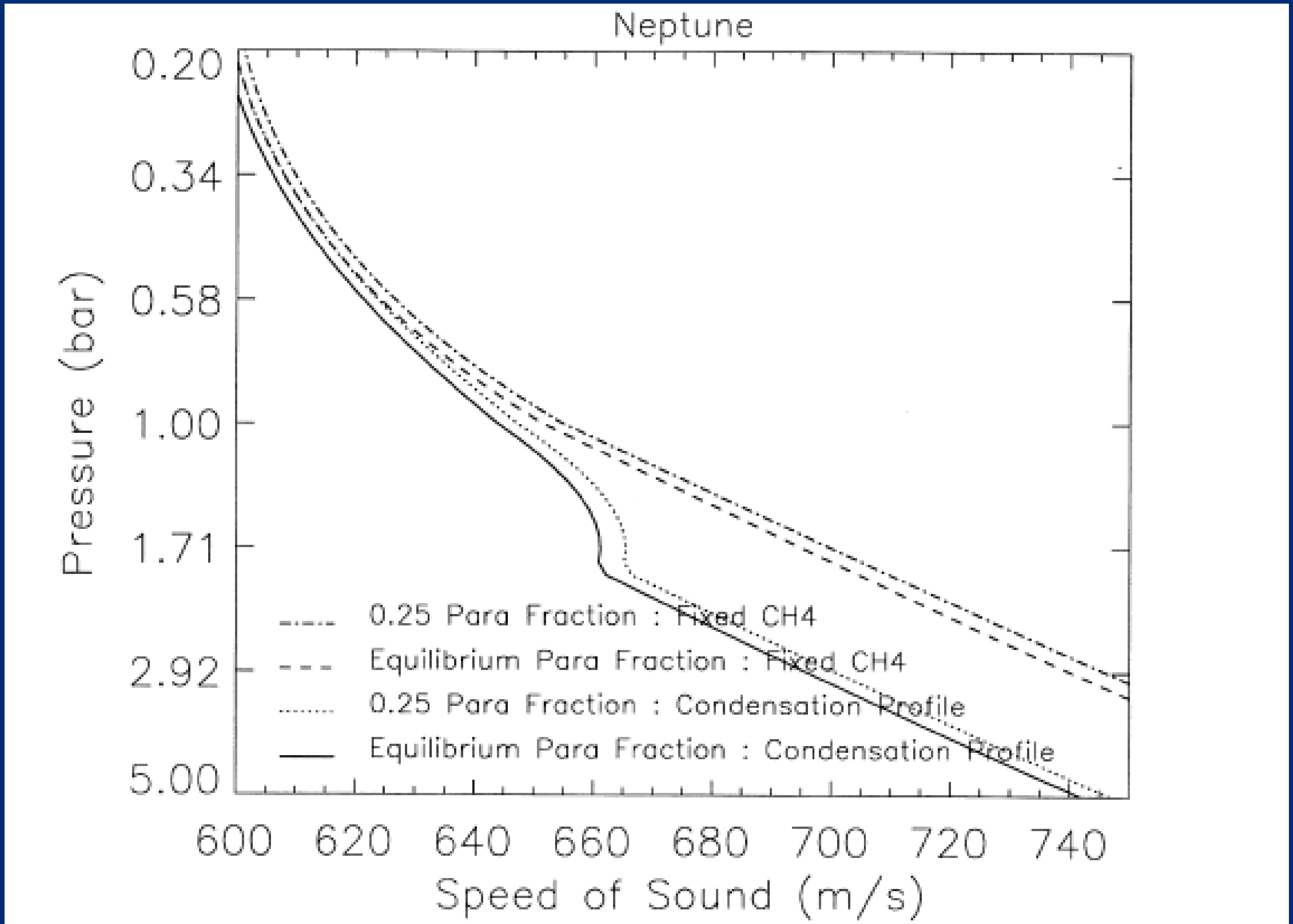
Uranus

- Role of condensible on sound speed more profound at Uranus. Larger effect than fHp



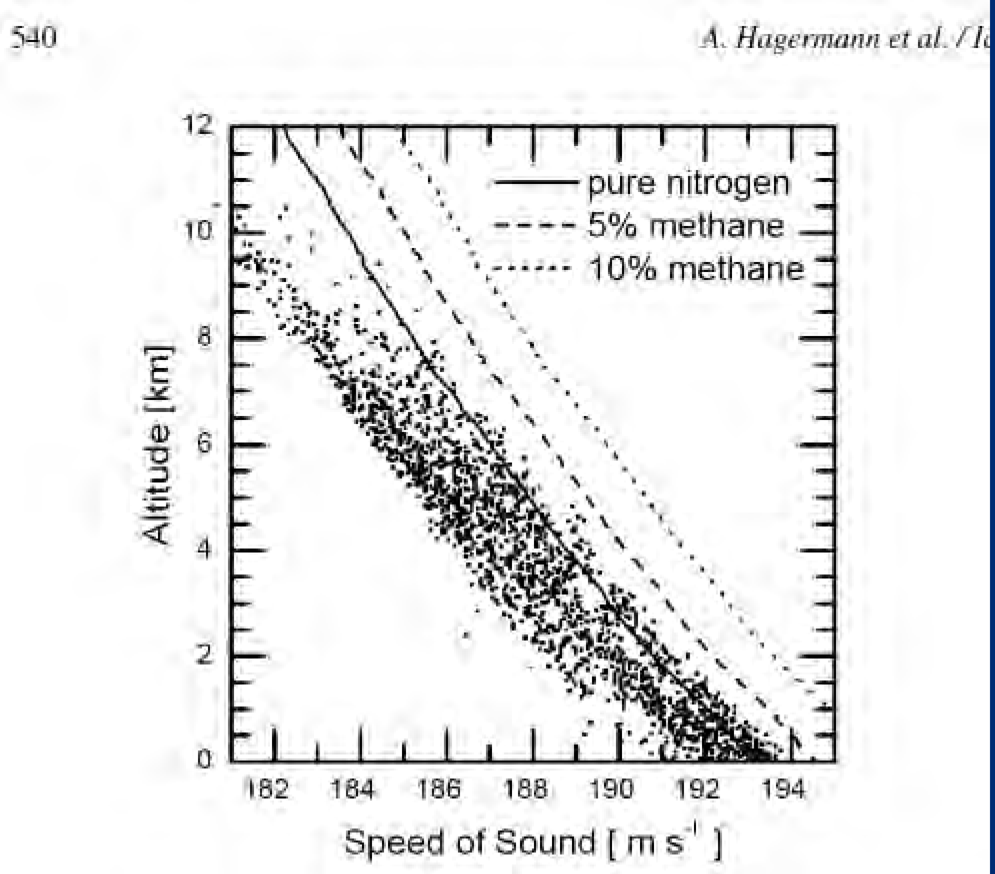
Neptune

- The change in sound speed due to the change in methane abundance across the Neptune cold trap would change the note of a whistle say an F at 249 Hz to an F# at 269 Hz
- But o:p effect is still very small (<1%). Need high precision to detect / measure



Instrumentation for Ortho:Para Sensing

- Free-space pulse ToF a poor choice for a fast-moving probe – turbulent scattering of energy (see Huygens experience – Hagermann+)
- Resonant cavity* approach used in harsh industrial settings a better choice?
- Could be forced by transducer, or by airflow (‘whistle’)
- Temperature knowledge critical.



* Hanel, R. & Strange, M. (1966) Acoustic experiment to determine the composition of an unknown planetary atmosphere Journal of the Acoustical Society of America 39, 785

Venera 11, 12

- Microphone included in Groza lightning package to detect thunder

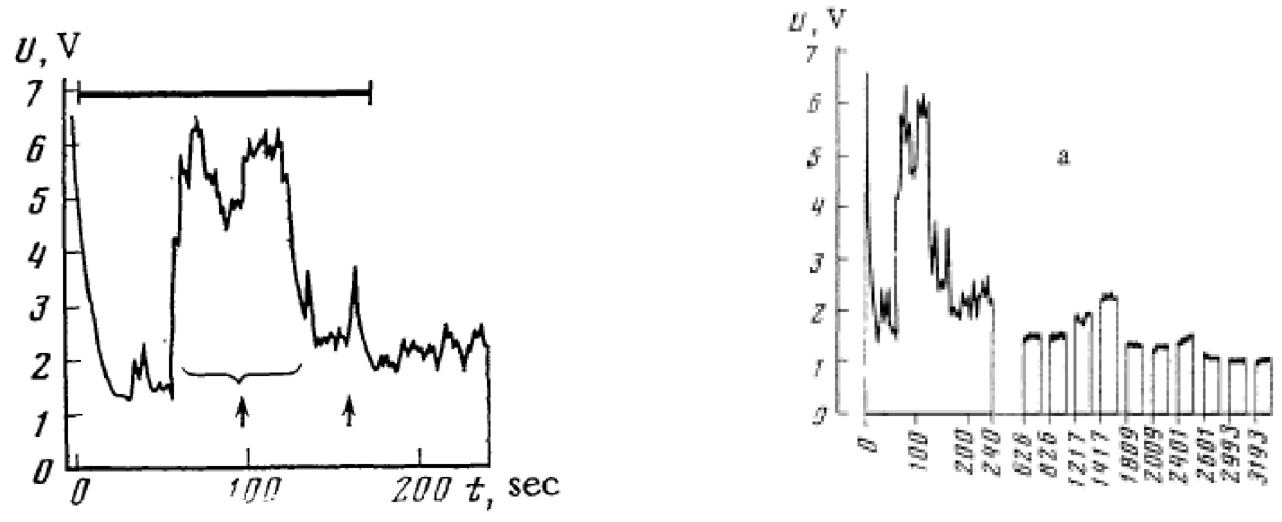


FIG. 1. Acoustic noise recorded by the Venera 14 lander on the surface of Venus, March 5, 1982. Vertical axis, output signal U (the full scale corre-sponds to the range from 55 to 82 dB; horizontal axis, elapsed time after landing. The heavy bar indicates the period when the spacecraft systems were operating. The arrows indicate noise associated with equipment opera-tion. Presumably the signal from t = 180 to 240 sec represents wind noise in the microphone armature.

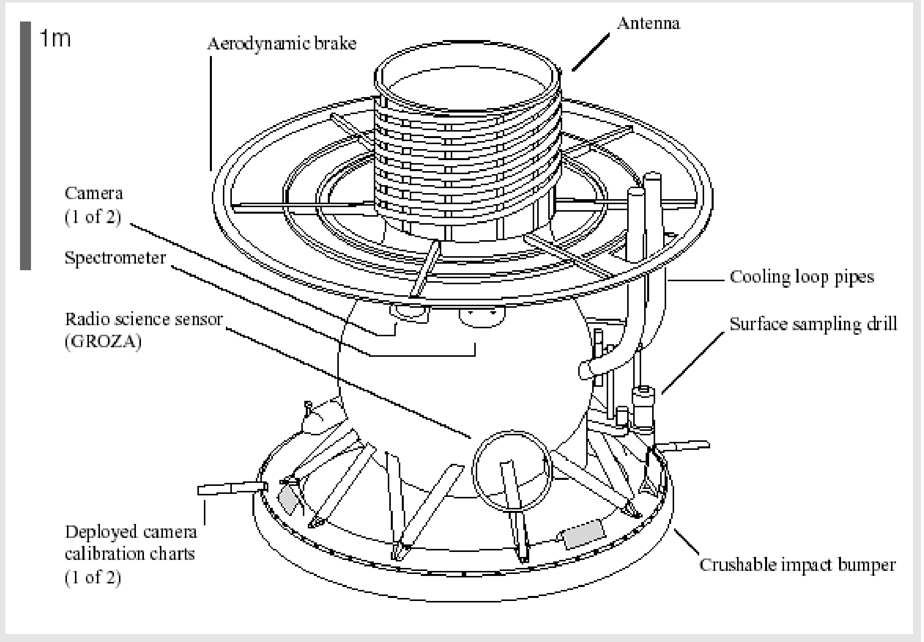


Figure 18.9 Venera 11, 12.

- Aeroacoustic noise during descent
- Lander operations
- Background noise level on surface used to estimate wind

Mars Polar Lander, Phoenix

- MPL : Planetary Society microphone with DSP chip. Integrated with Russian Lidar instrument. Mission Lost
- Phoenix : microphone integrated with MaRDI descent camera. Camera not operated due to software safety concerns.

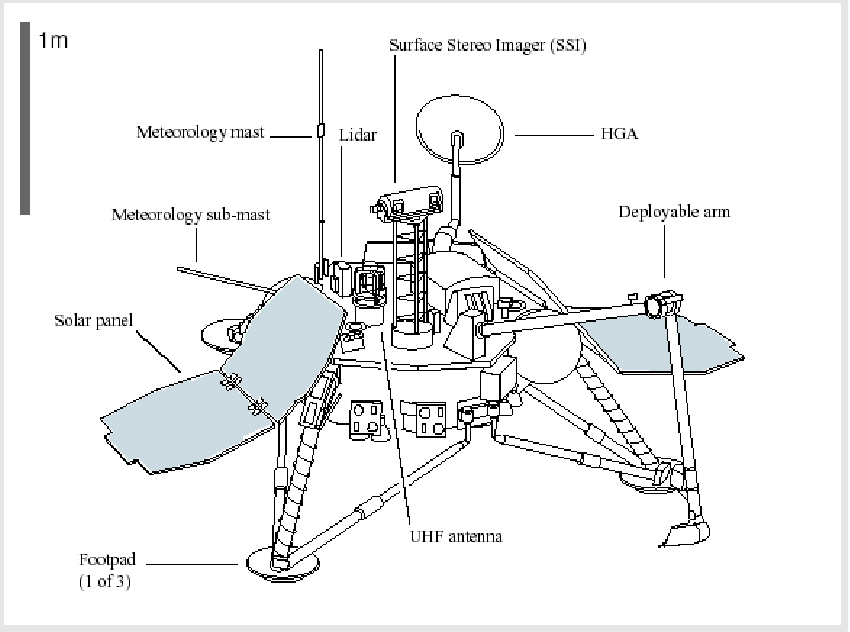
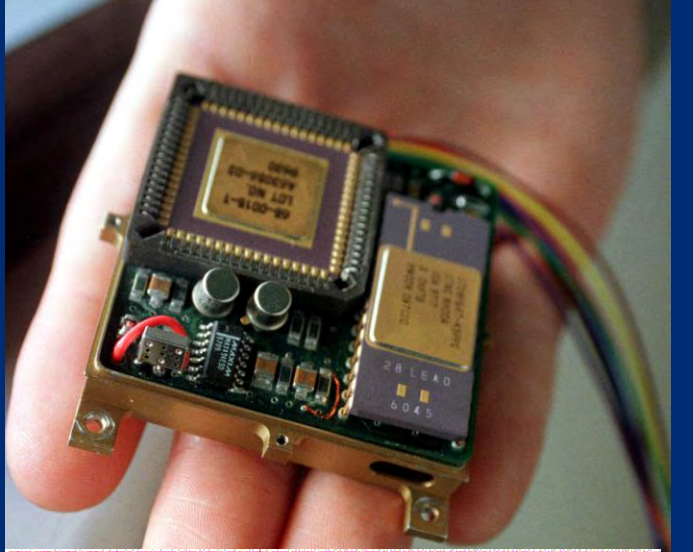
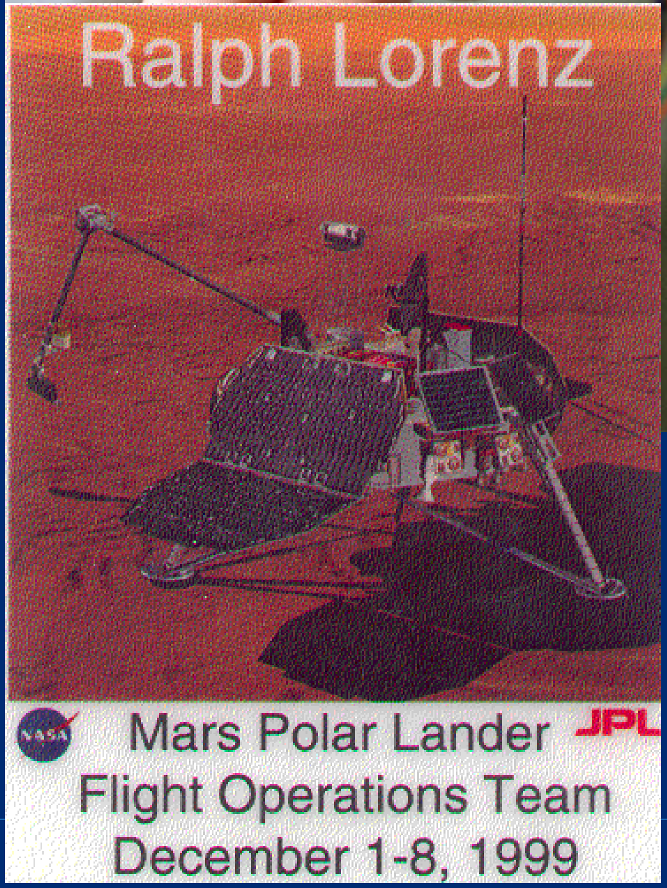


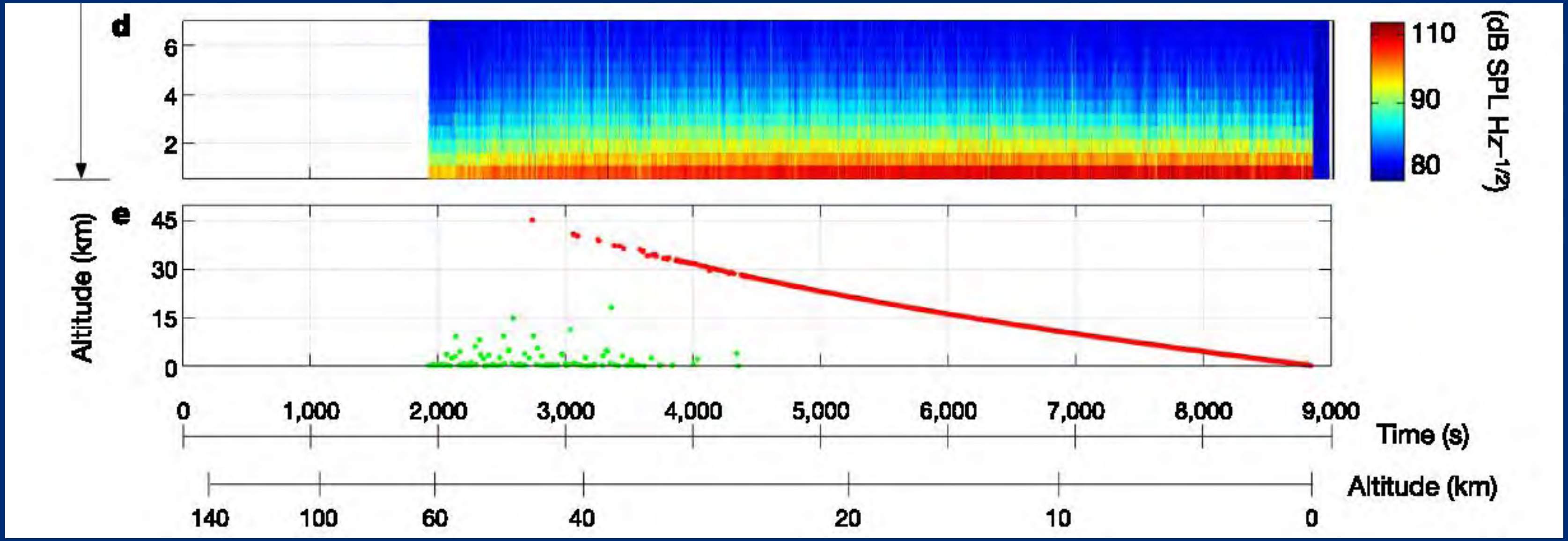
Figure 18.13 Mars Polar Lander.

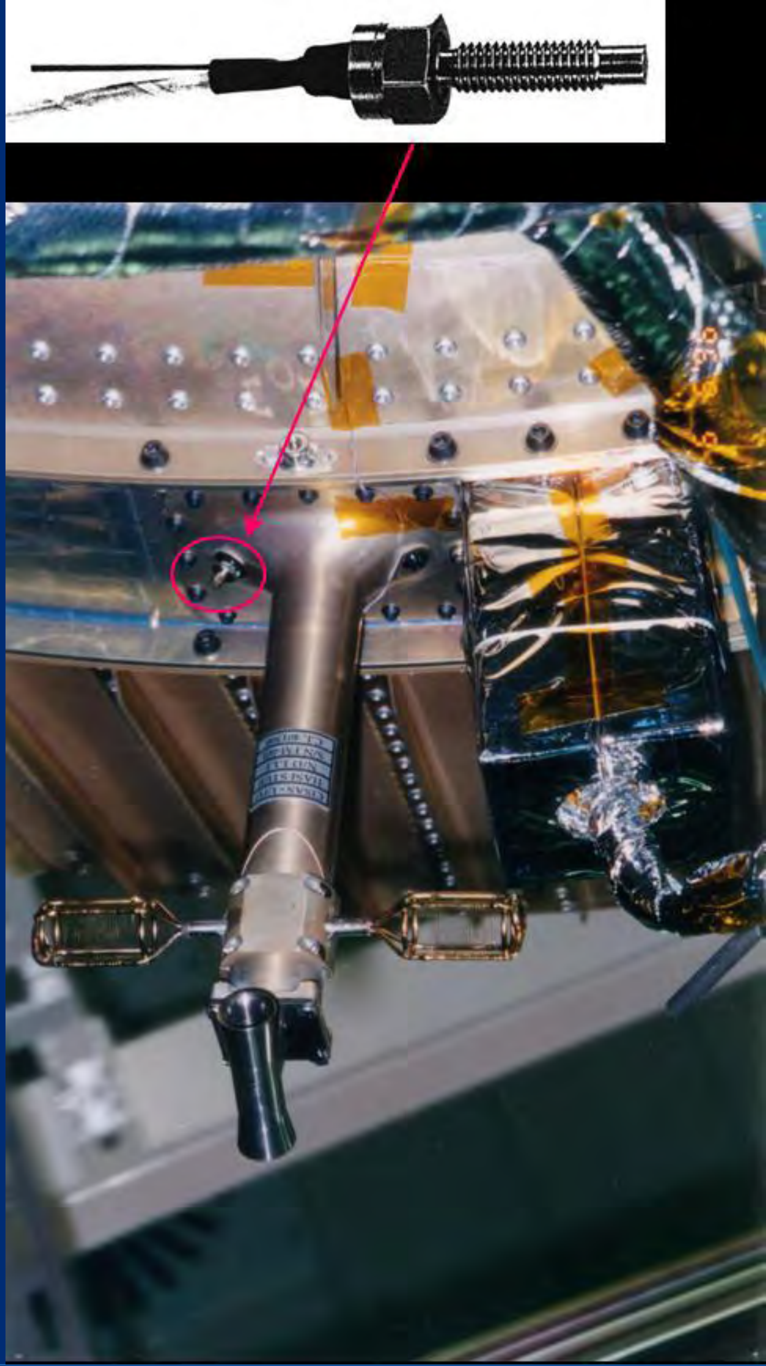




Huygens

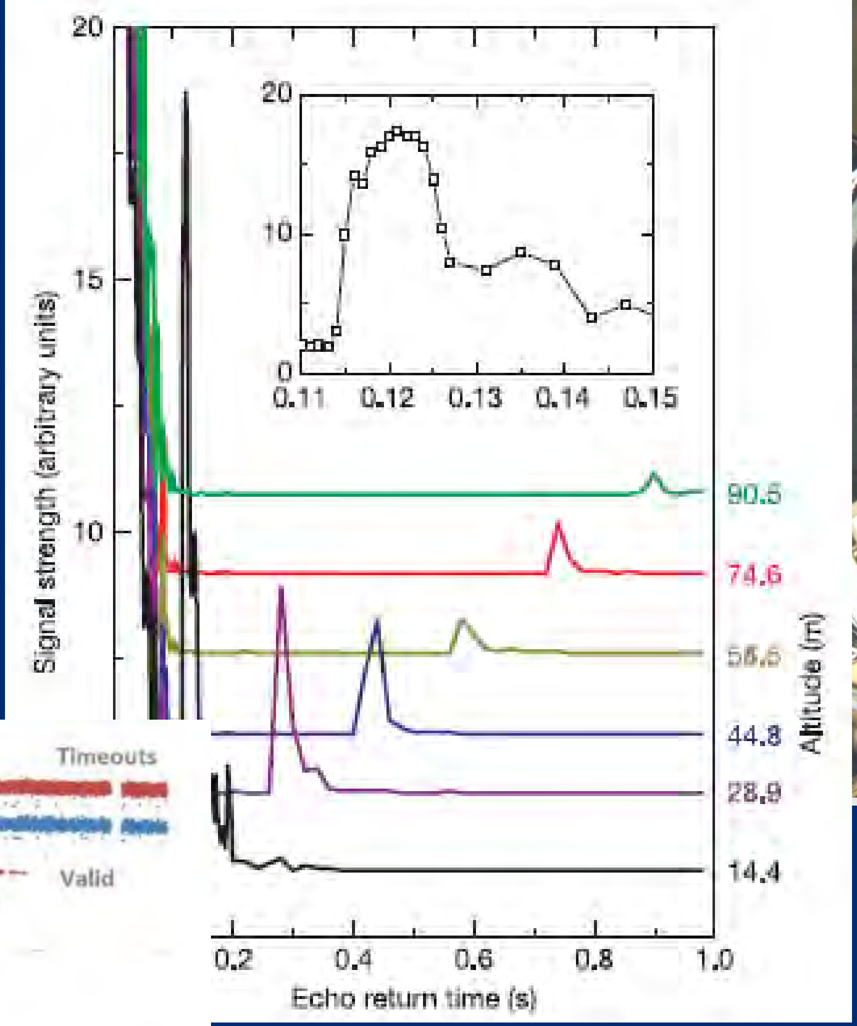
- Passive microphone in HASI experiment (thunder)
- Only recorded aeroacoustic noise

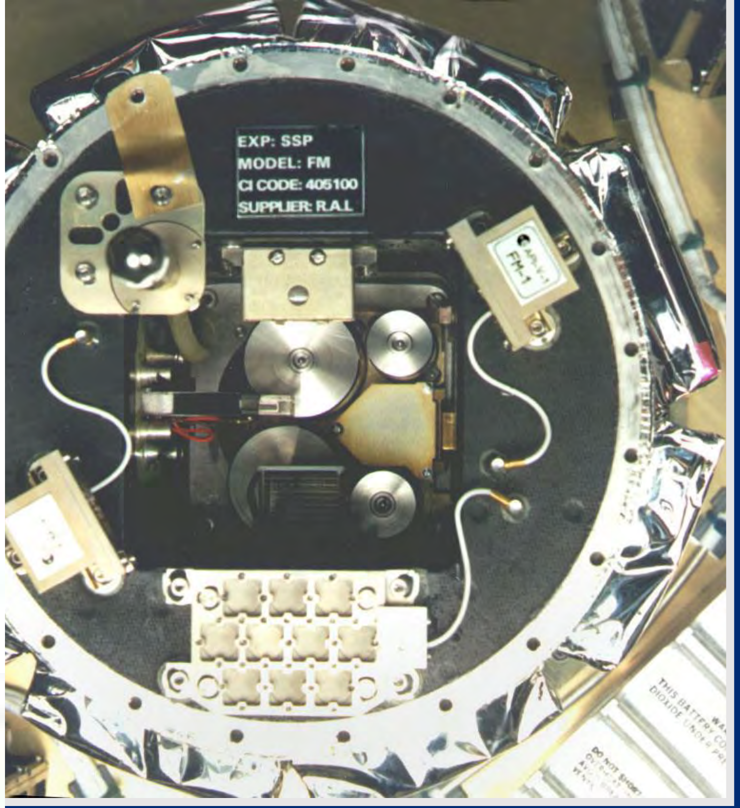


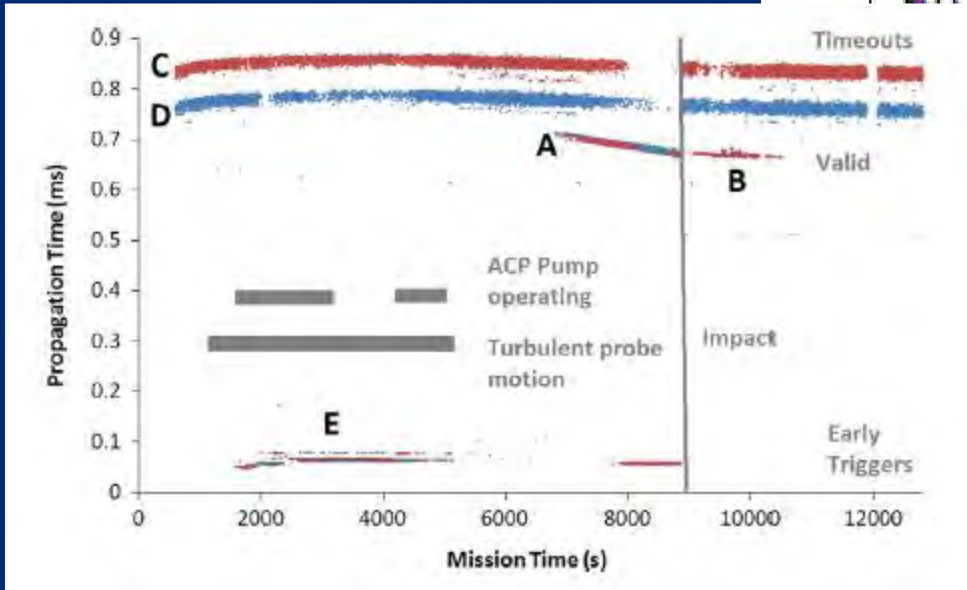


Huygens

- 1 MHz Speed of sound (SSP)
- 15 kHz echo sounder (SSP)

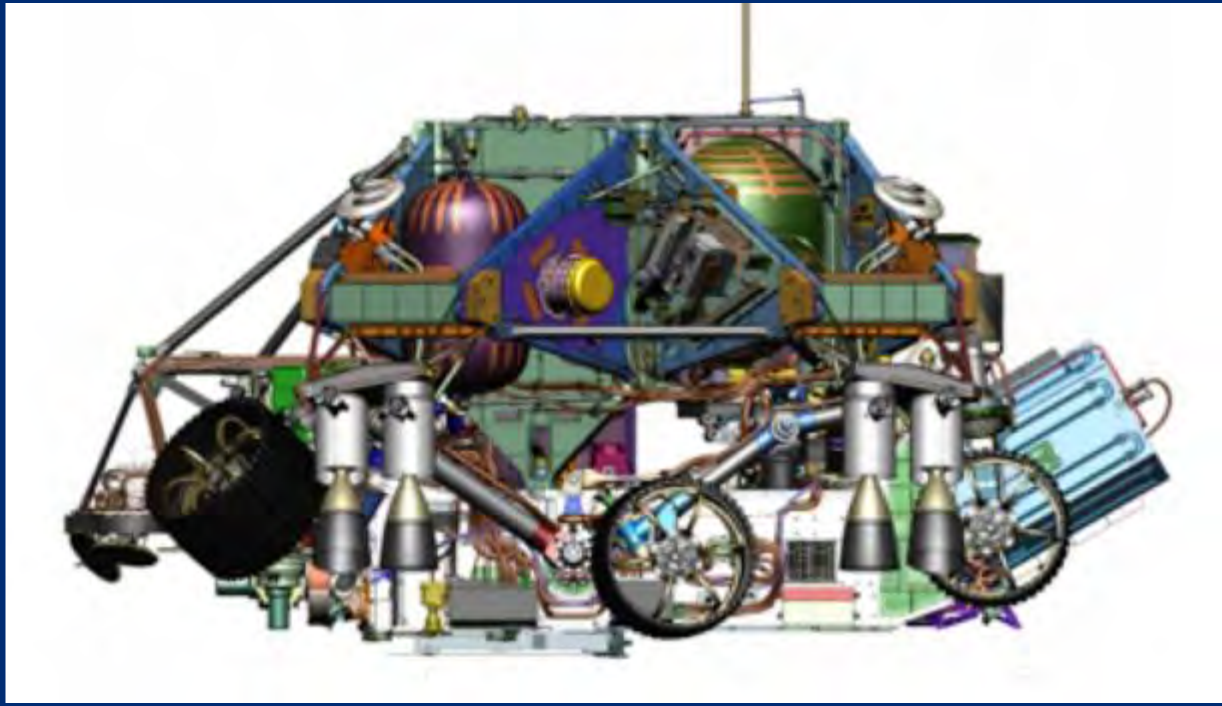


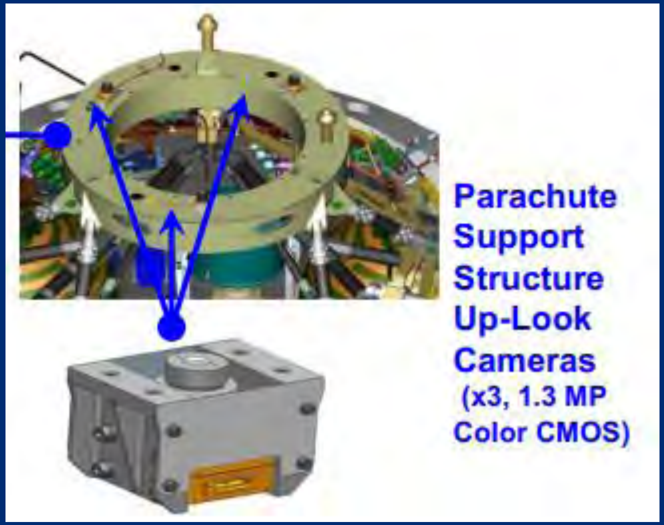




Mars 2020

- Microphone in EDL camera package (inflation, descent engines)
- Also microphone in Supercam LiBS/Raman instrument (to listen for ‘crack’ from laser pulse, but can operate passively to estimate wind etc.)





Dragonfly !

- Ultrasonic altimeter for last few meters
- DraGMet Geophones on skids (passive seismic sensing, plus drill excitation)
- DraGMet Microphone (as situational awareness/drill diagnostic)

Ortho:Para Measurements and Acoustic Outlook

- Speed of sound a low-resource measurement, worthwhile for Uranus & Neptune.
- Huygens lessons
- Needs T, X context (or serves as X backup)
- New era (?) of planetary acoustics with Mars 2020 and Dragonfly

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY