Model Payload for Ice Giant Entry Probe Missions

D.H. Atkinson JPL/Caltech
O. Mousis (LAM), T.R. Spilker (Independent Consultant)

Workshop on In Situ Exploration of Ice Giants
Laboratory for Astrophysics, Marseille, France
27 February 2019

Significant material borrowed from

- Spilker, et al., "Giant Planet Entry Probe Science," 8th International Planetary Probe Worskhop. Portsmouth, VA, 2011
- Hofstadter and Reh, Pre-Decadal Study Summary ESA Headquarters, 31 January 2017
- Reh, et al. Return to the Ice Giants Pre-Decadal study summary, IPPW-14, 12-16 June, 2017

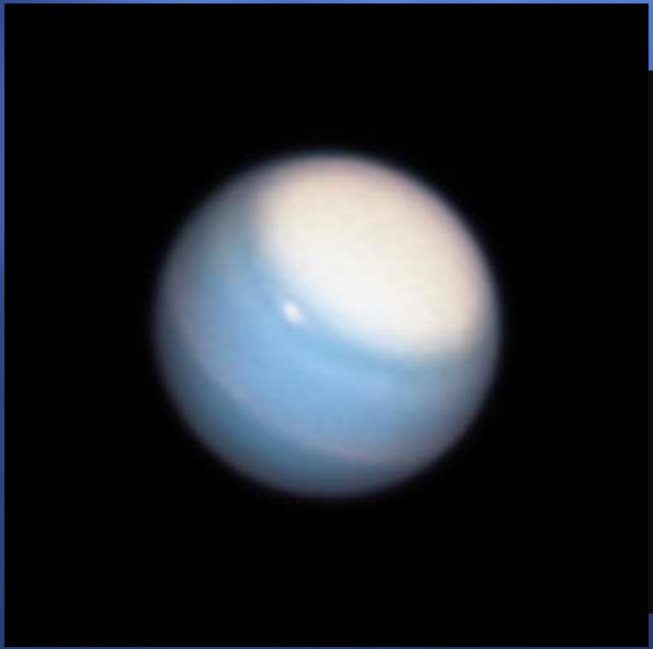
Jet Propulsion Laboratory
California Institute of Technology

Science Justification for Outer Planet Entry Probes

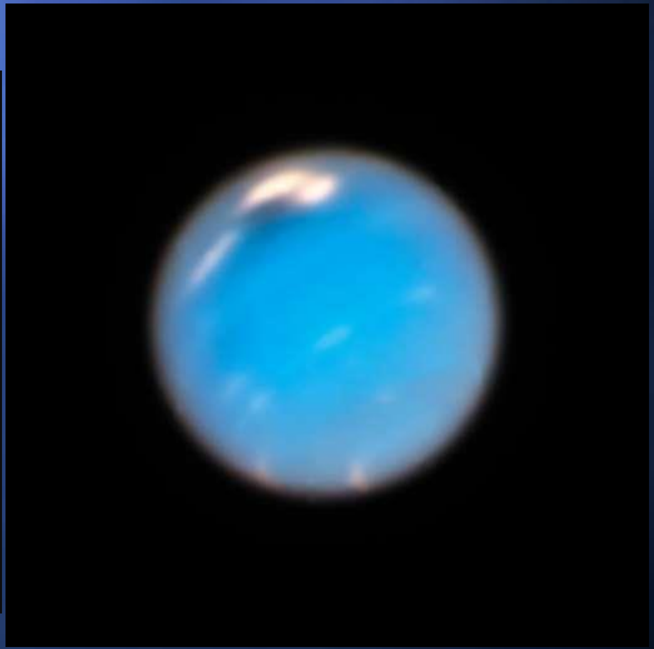
Comparative planetology *of* *<u>well-mixed atmospheres</u>* *of the outer planets is key to the origin and evolution of the Solar System, and, by extension, extrasolar systems.*

Atreya, S. K. et al., "Multiprobe exploration of the giant planets – Shallow probes," Proceedings of the 3rd International Planetary Probes Workshop, Anavyssos, Greece, 2005.

For all the capabilities of remote sensing, only *in situ* exploration by descent probe(s) can completely reveal the composition and structure of the deep, well-mixed atmosphere from the epoch and location of giant planet formation.



Hubble image of Uranus, taken in Nov. 2018. NASA, ESA, and A. Simon (NASA Goddard Space Flight Center), and M. Wong and A. Hsu (University of California, Berkeley)



Hubble image of Neptune, taken in 2018. NASA, ESA, and A. Simon (NASA Goddard Space Flight Center), and M. Wong and A. Hsu (University of California, Berkeley)

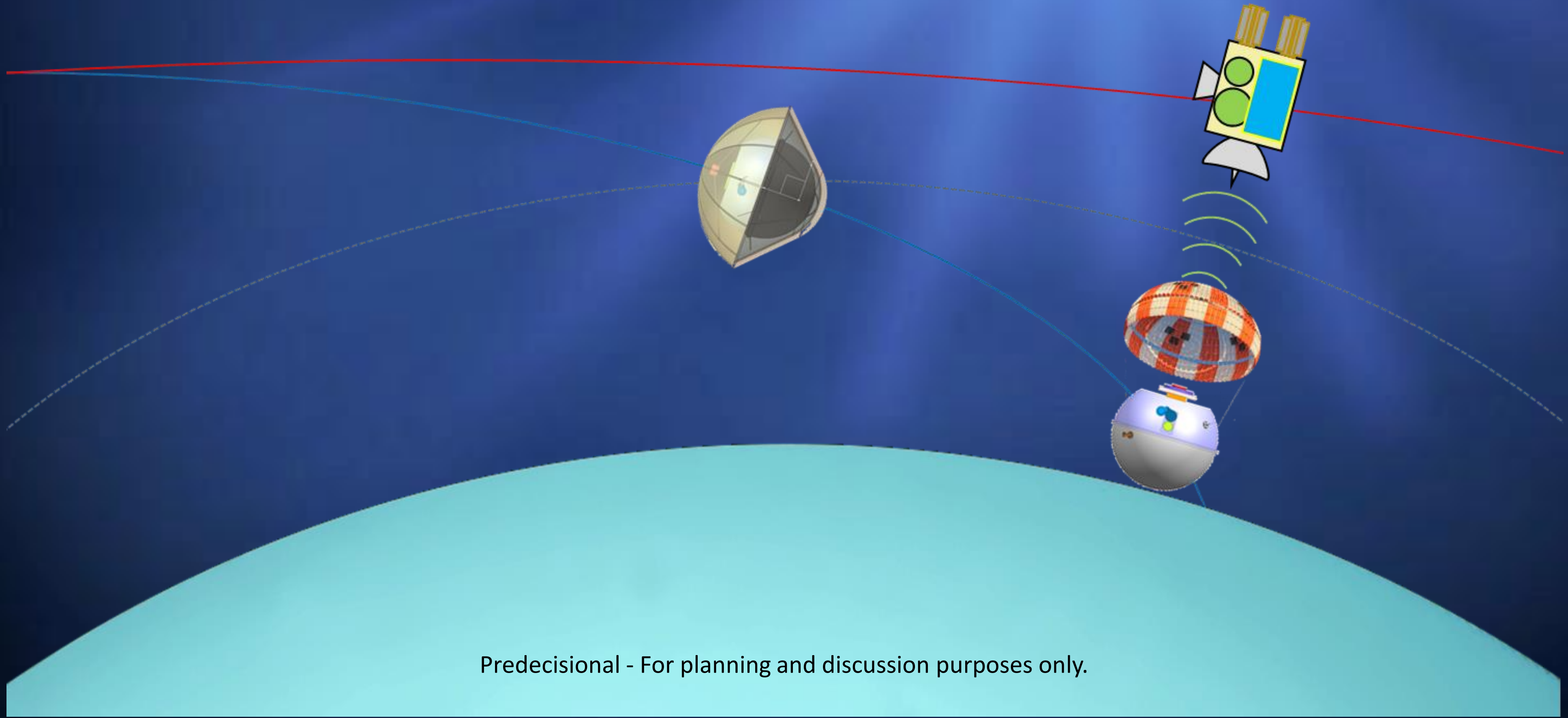
Ice Giant Probe Mission Concept

From Reh, et al. Return to the Ice Giants Pre-Decadal study summary, IPPW-14, 12-16 June, 2017

Release:
- ~60 days prior to entry
- Spin stabilized
- RHUs for coast heating

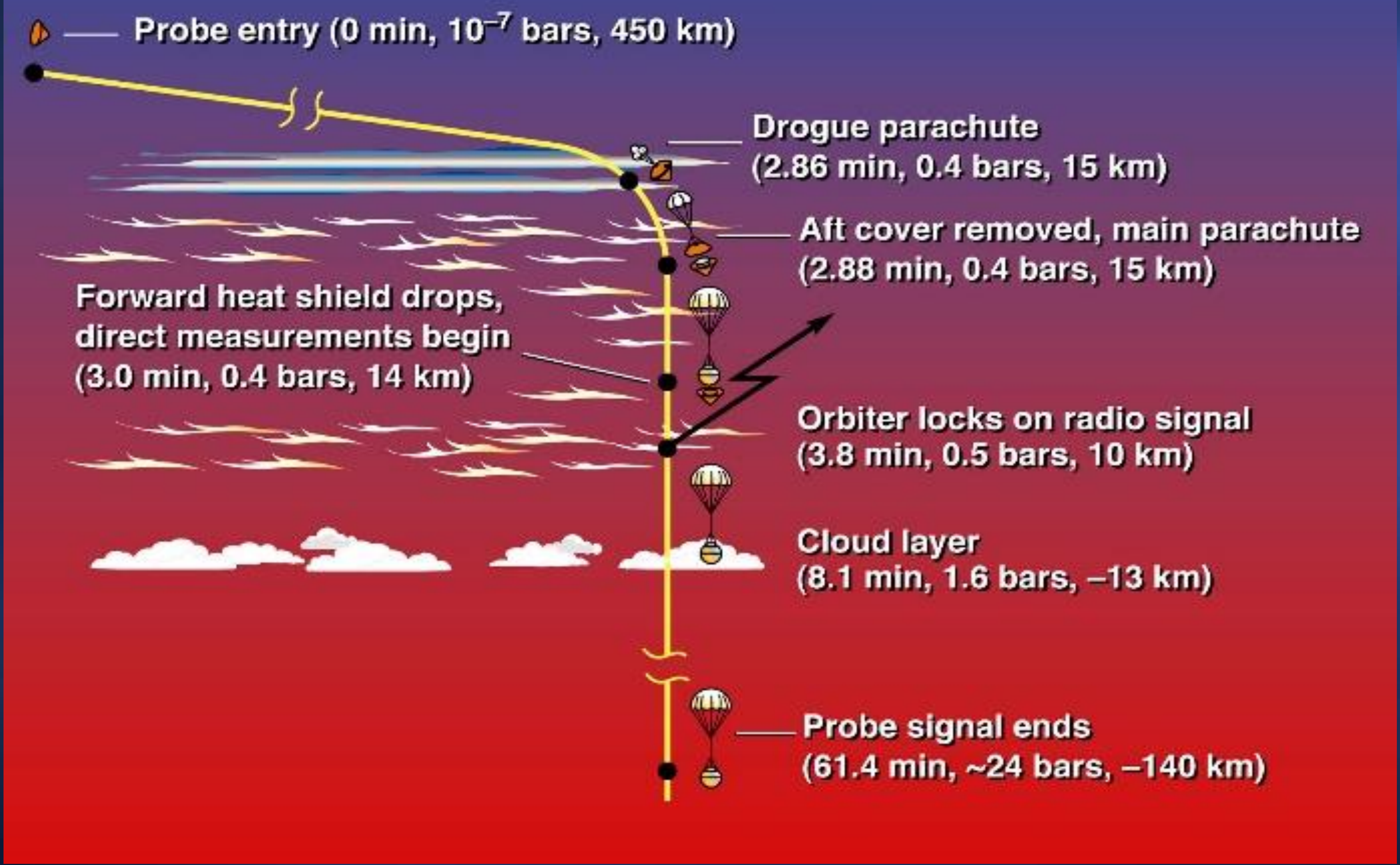
Uranus/Neptune Entry:
Entry V = 23.5/24.1 km/s

Telecomm to Carrier Relay Spacecraft:
Duration: >1 hr
Max Range: <100,000 km



Predecisional - For planning and discussion purposes only.

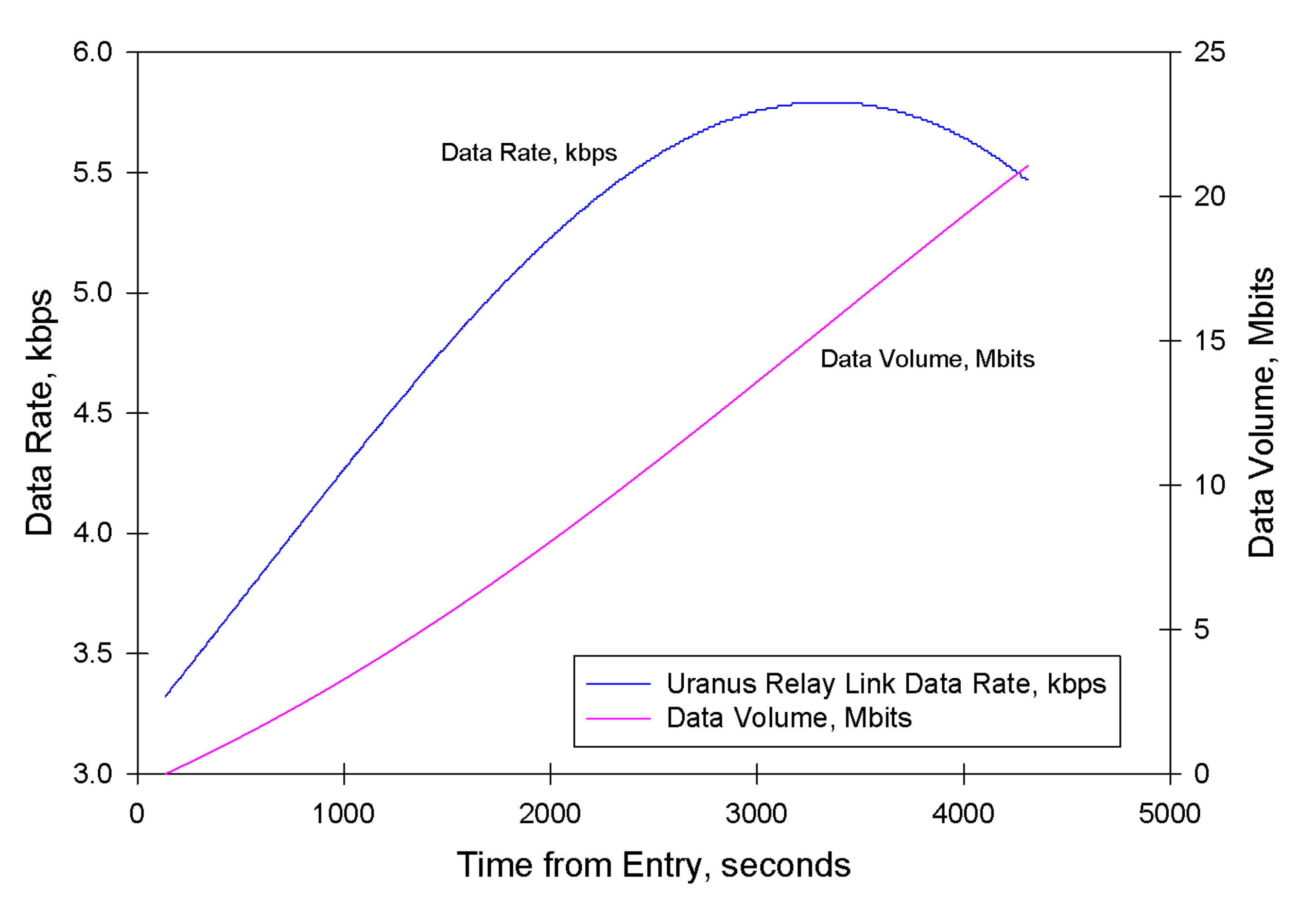
Galileo Probe Mission



Predecisional - For planning and discussion purposes only.

Telecommunications

- Outer planet atmospheres primarily H_2/He but with significant radio-absorbing species: NH_3, H_2S, and possibly H_2O.
- At UHF frequency, atmosphere relatively clear to 12 bars (~0.15 dB) to 20 bars (~2 dB). Absorption increases at S-band to ~1 dB at 10 bars, ~65 dB at 20 bars.
- Telecomm link parameters assumed
  - Tx Power: 25 Watts
  - Tx Antenna gain: 5 dB (Galileo Probe: 9.6 dB)
  - Rx Antenna gain: 15 dB (Galileo RRA: 20.8 dB)
  - Tx Antenna 3 dB beamwidth: +/-35 deg (Galileo probe Tx: +/-28 deg)
  - Link Margin assumed: 6 dB
  - 1.5x atmospheric opacity



PSDS Giant Planets

The prioritized science objectives for a Uranus Orbiter and Probe mission include (PSDS 7-35):

Highest Priority Science Objectives

- Determine the atmospheric zonal winds, composition, and structure at high spatial resolution, as well as the temporal evolution of atmospheric dynamics.

??

Medium Priority Science Objectives

- Determine the noble gas abundances (He, Ne, Ar, Kr, and Xe) and isotopic ratios of H, C, N, and O in the planet's atmosphere and the atmospheric structure at the probe descent location.

??

Lower Priority Science Objectives

- Determine the vertical profile of zonal winds as a function of depth in the atmosphere, in addition to the presence of clouds as a function of depth in the atmosphere.

High-Priority Large-Class Missions (PSDS 9-13)

The third highest priority Flagship mission in the 2013-2022 Planetary Science Decadal Survey is the Uranus Orbiter and Probe mission comprising a spacecraft that *deploys* *a small atmospheric probe to make in situ measurements of noble gas abundances and isotopic ratios* for an ice giant atmosphere.

Entry Probe Science Objectives

Threshold Science Objectives (5-10 bars)

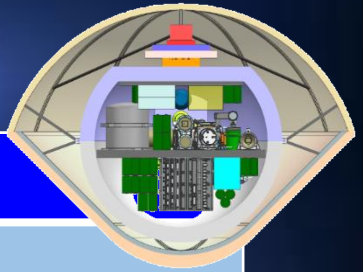
- Composition
  - Abundances of noble gases He, Ne, Ar, Kr, and Xe *(incl. isotopes)*
  - Isotopic ratios of H, C, N, and O
- Atmospheric Thermal Profile
  - Atmospheric Temperature vs. Pressure (depth)

Entry Probe Science Objectives

Baseline Science Objectives

- Vertical profile of zonal winds vs. depth (pressure)
- Cloud location, structure, composition, number densities
- Abundance of atmospheric helium
- Altitude profile of net radiative fluxes: upwelling thermal IR, deposition of solar (visible) radiation

Strawman Payload



Threshold	
Instrument	**Measurement**
Mass Spectrometer	Atmospheric composition including noble gases and key isotopes
Helium Abundance Detector	Abundance of atmospheric helium
Atmospheric Structure Instrument	Primary: Pressure and temperature → static stability, density 2ndary: descent acceleration (turbulence), atmospheric electricity/ lightning
Baseline	
Radio Science Experiment	Atmospheric dynamics: winds and waves Secondary: atmosph uwave absorption → abundance of key molecules
Nephelometer	Cloud location, structure, number densities, properties
Net Flux Radiometer	Profile of net radiative fluxes: upwelling thermal IR, deposition of solar (visible) radiation
Other	
Acoustical Properties	Speed of sound, Ratio of Ortho to Para H_2
Tunable Laser Spectrometer (TLS)	Abundance of key targeted disequilibrium species: CO, PH_3, AsH_3, SiH_4, GeH_4

Other Considerations

Doppler Wind retrieval requires accurate reconstruction of entry interface location, entry trajectory, and descent location to ~.05 degree longitude and latitude:

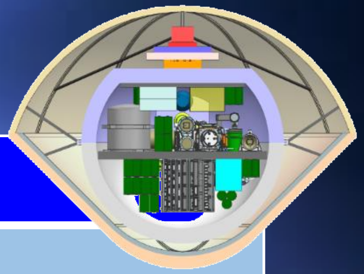
- Probe release dynamics via Doppler tracking of Carrier during release sequence
- Imaging of probe post-release for optical navigation
- Tradeoff between time of release and coast period (Galileo: 150 days / Huygens: 20 days) with power and thermal, D-V necessary for carrier deflection, and required accuracy of entry location reconstruction.
- 3-axis entry accelerometry to reconstruct entry trajectory
- Sensors to retrieve time-varying probe mass due to heat shield ablation permits reconstruction of pressures, temperatures, and densities in upper atmosphere
- To achieve stability required for DWE, probe USO requires power-on at least several hours prior to entry.

Conclusion

Achieving key goals for exploring and understanding ice giant atmospheres, and thereby constraining our knowledge and understanding of the formation and evolution of the solar system requires measurements that can only be made within the atmosphere by direct sampling of noble gases and key isotopes.

Questions/Discussion?

Strawman Payload



Highest Priority	
Instrument	**Measurement**
Mass Spectrometer	Elemental and chemical composition, esp. noble gases and key isotopes
Atmospheric Structure	Pressure and temperature → static stability, density
Doppler Wind Experiment	Atmospheric dynamics: winds and waves
Nephelometer	Cloud location, structure, aerosol composition, number densities
Net Flux Radiometer	Altitude profile of net radiative fluxes: upwelling thermal IR, deposition of solar (visible) radiation
Helium Abundance Detector	Abundance of atmospheric helium (MS measurement redundancy)
Other	
Acoustical Properties	Speed of sound, Ratio of Ortho to Para H_2
Tunable Laser Spectrometer (TLS)	Abundance of key targeted disequilibrium species: CO, PH_3, AsH_3, SiH_4, GeH_4