Scientific rationale for Uranus and Neptune in situ explorations

O. Mousis[1], D.H. Atkinson[2], T. Cavalié[3], L.N. Fletcher[4], M.J. Amato[5], S. Aslam[5], F. Ferri[6], J.-B. Renard[7], T. Spilker[8], E. Venkatapathy[9], and P. Wurz[10]

[1]Laboratoire d'Astrophysique de Marseille, Aix Marseille Université, Marseille, France, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA, [3]LESIA, Observatoire de Paris, Meudon, France, [4]Department of Physics & Astronomy, University of Leicester, Leicester, UK, [5]NASA Goddard Space Flight Center, Greenbelt, USA, [6]Università degli Studi di Padova, CISAS, Padova, Italy, [7]LPC2E, CNRS-Université d'Orléans, Orléans, France, [8]Solar System Science & Exploration, Monrovia, USA, [9]NASA Ames Research Center, Moffett field, USA, [10]Space Science & Planetology, Physics Institute, University of Bern, Bern, Switzerland

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Motivation and Background

- Giant planets have played a significant role in shaping the architecture of the solar system, including the smaller, inner terrestrial planets.

- The efficiency of remote sensing observations has some limitations, especially to study the bulk atmospheric composition. In particular, the measurement of noble gas and helium abundances requires in situ measurements.

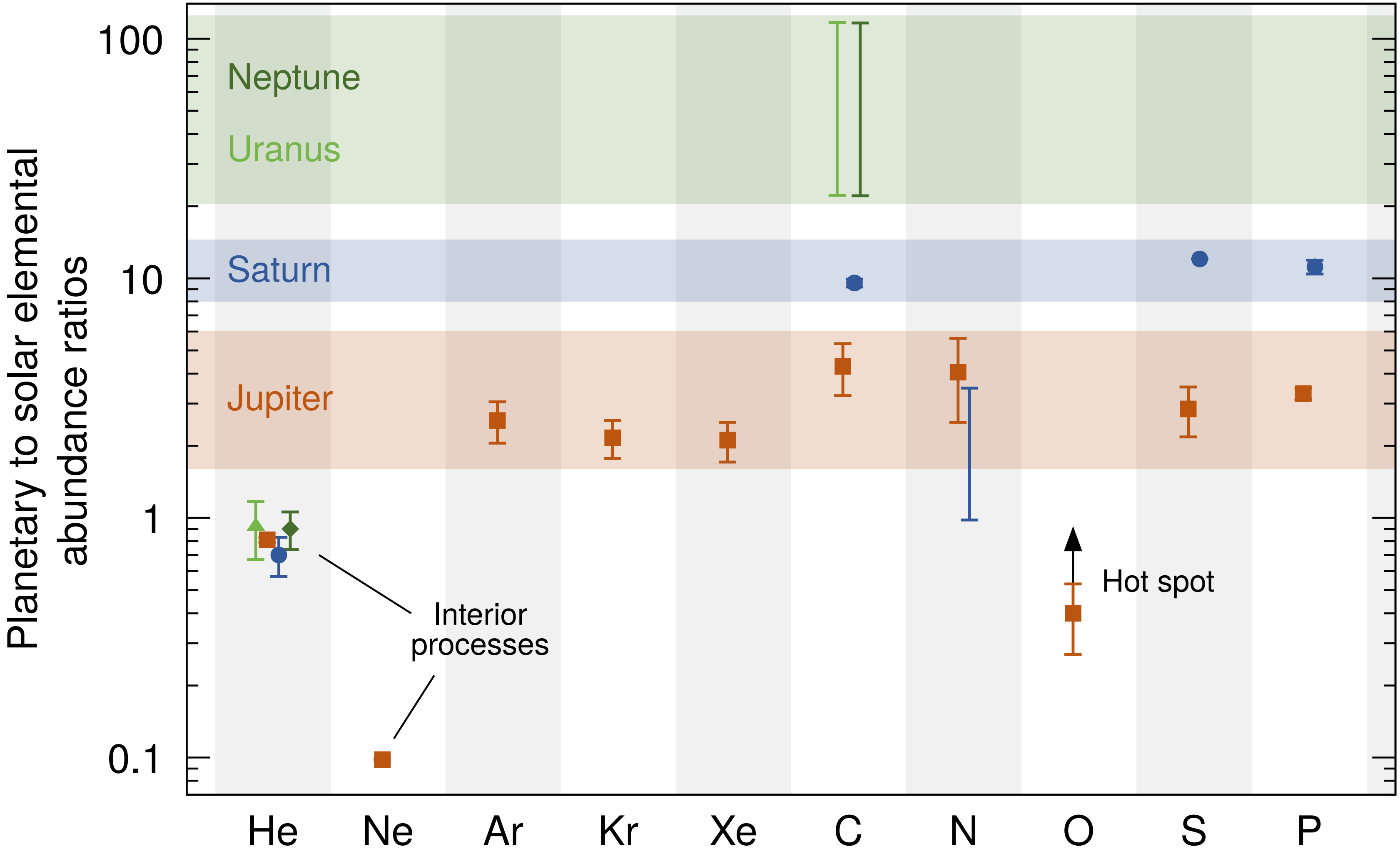
- The Galileo probe provided a giant step forward regarding our understanding of Jupiter.

However, it remains unknown whether these measurements are unique to Jupiter or are representative of all gas giants including Saturn, and how the composition, processes, and dynamics of the giant planets are similar and different from the ice giants.

Key Measurements Needed

- **Bulk composition**: Elemental abundances including O, C, N, S, He, Ne, Ar, Kr, Xe
- **Isotopic ratios**: Noble gas isotopes, D/H, $^{13}C/^{12}C$, $^{15}N/^{14}N$
- **He/H_2 ratio**: For planetary heat balance, interior processes, and thermal history
- **Ortho/Para H_2 ratio:** For thermal structure and deep dynamics

Existing Measurements



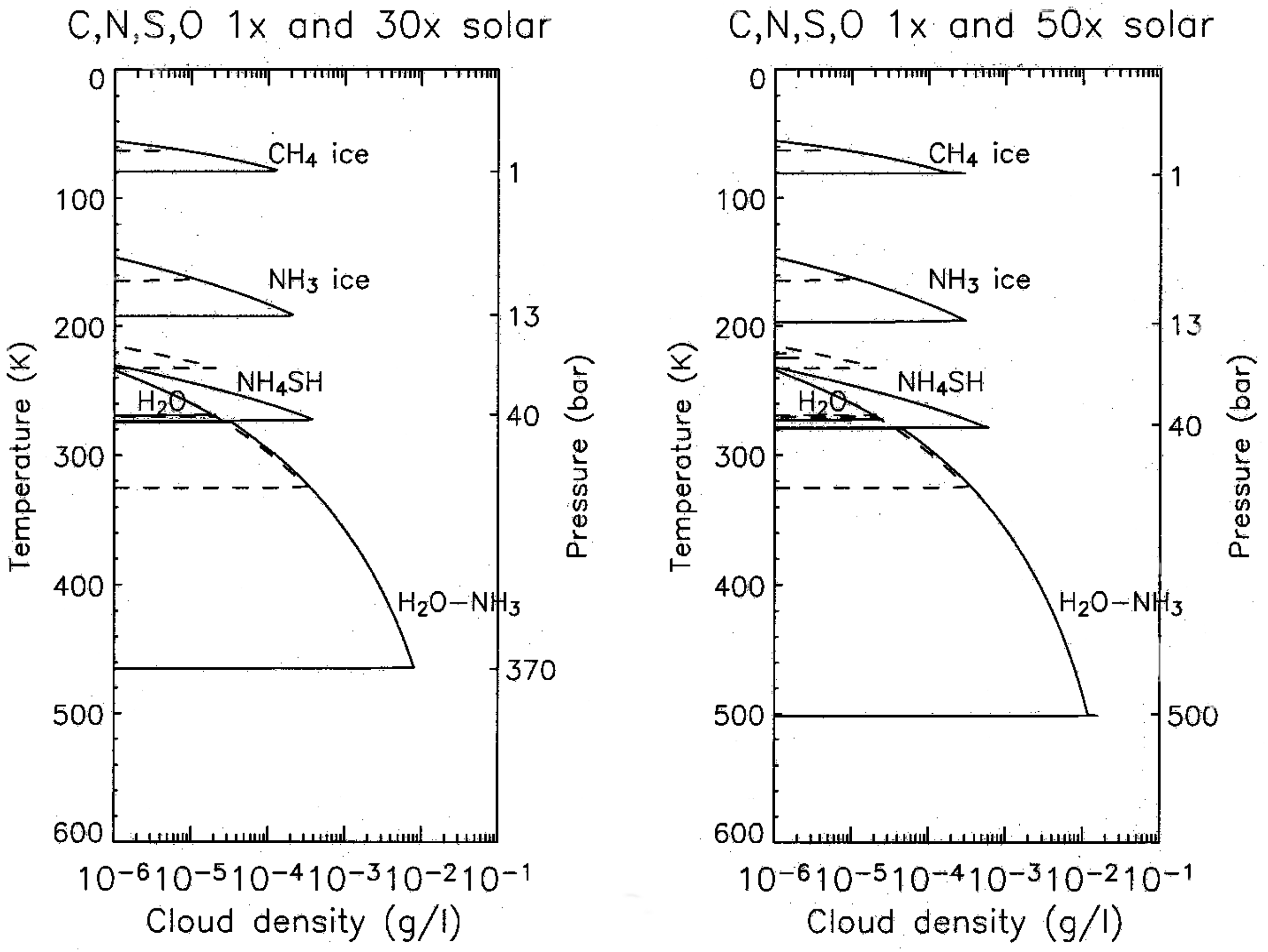
Atreya et al. (2018), Mousis et al. (2018)

Predicted Cloud Layers

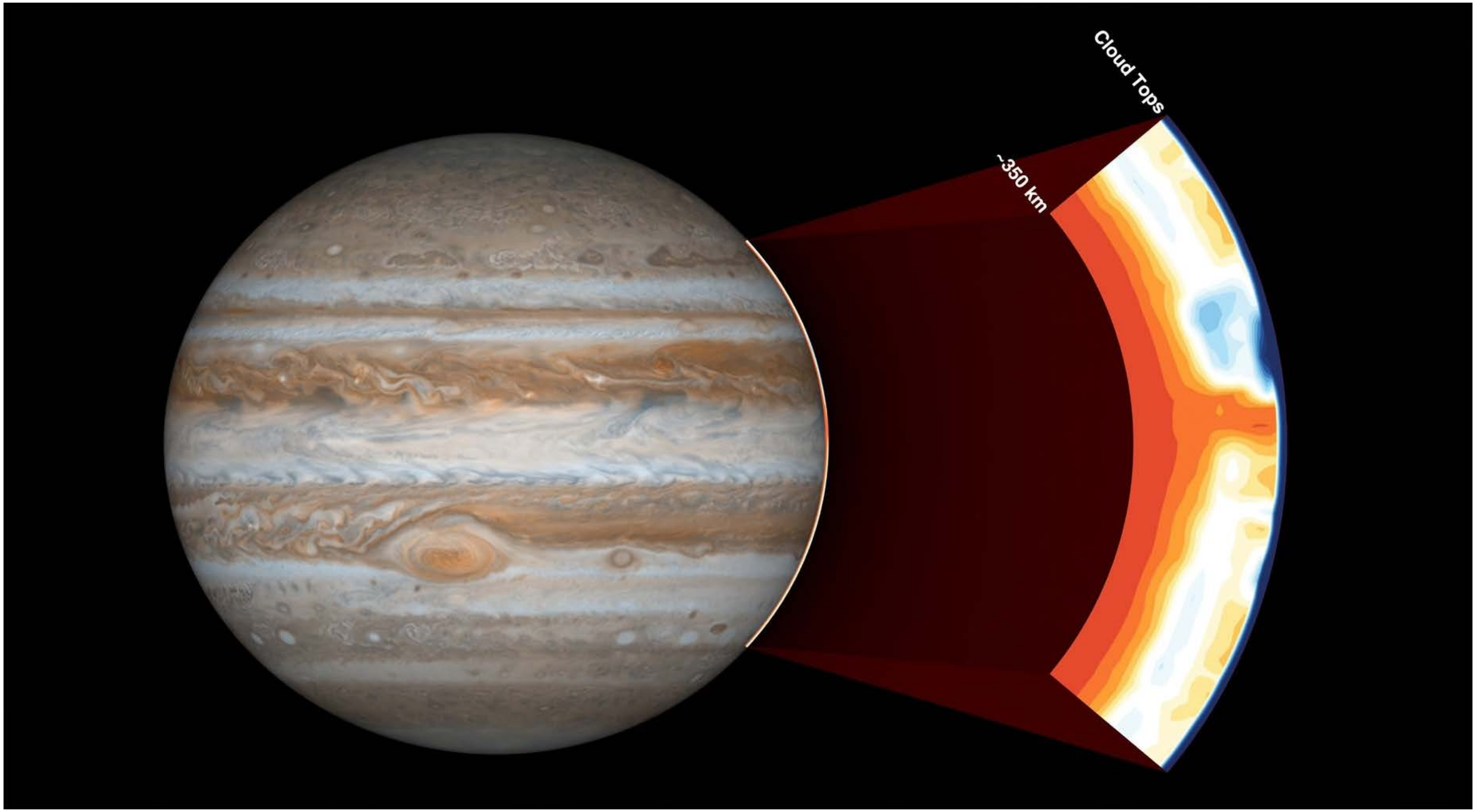
Neptune

Uranus water cloud at 500 bars; elements enriched by same factor as C, i.e. 80x solar

Elements enriched by 30x and 50x solar



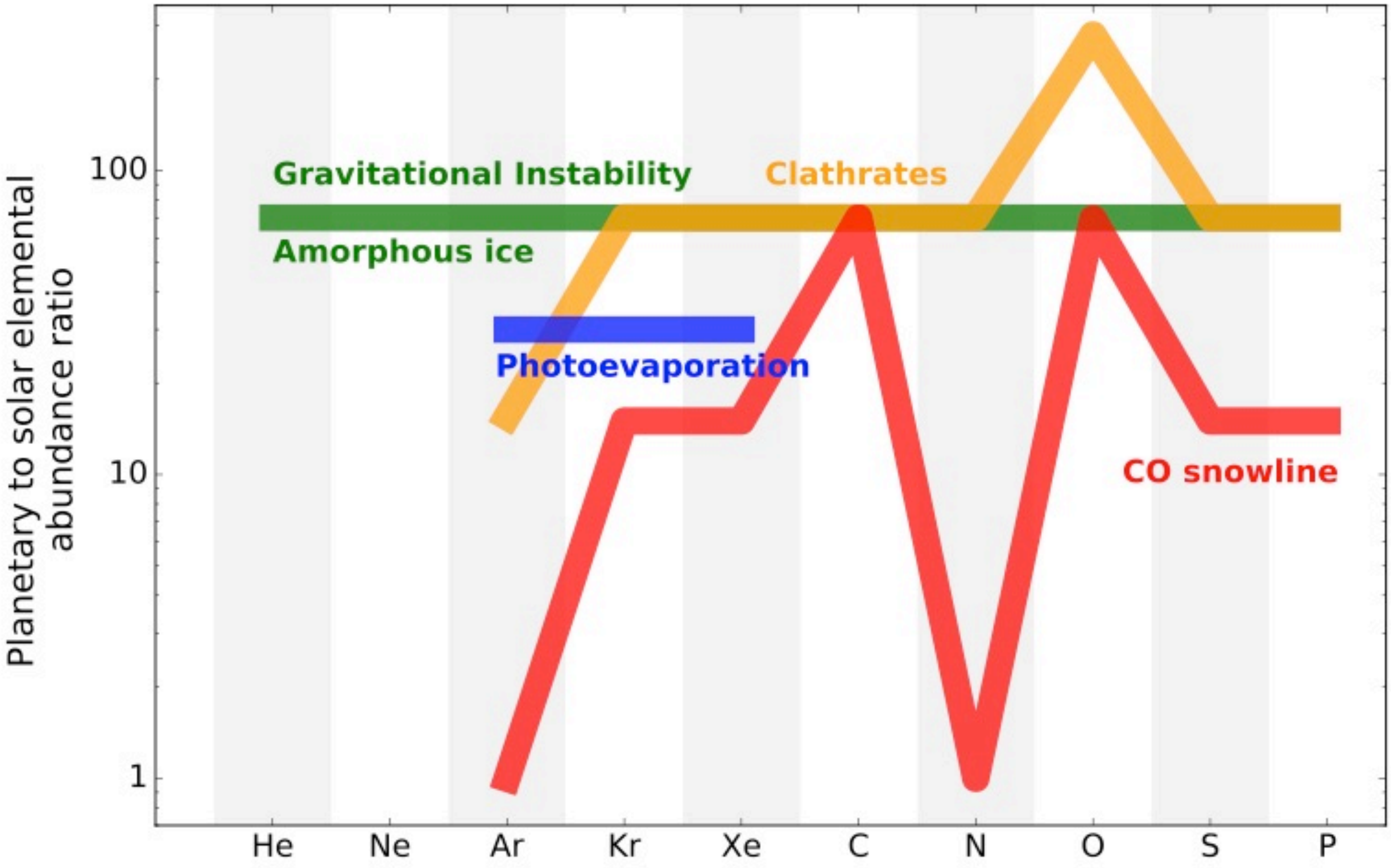
Lessons From Juno



Jupiter thermochemical equilibrium models predict NH_3 cloud base at ~700mb.

However Juno MWR data show a highly complex distribution of ammonia over Jupiter. **Near the equator, well-mixed ammonia is reached at atmospheric pressures ~100 bars.** (Bolton et al. 2017; Ingersoll et al. 2017)

Different Scenarios of Giant Planet Volatile Enrichment



Mousis et al. 2018, PSS, in press

Strawman Science Payload

Instrument	Measurement
Mass Spectrometer	Elemental and chemical composition, especially noble gases and key isotopes
Atmospheric Structure Inst.	Pressure and Temperature → Thermal structure, density, stability Entry Accelerations → Density
Radio Science Experiment	Atmospheric dynamics: winds and waves; Atmospheric absorption → composition
Nephelometer	Cloud structure, microphysics, aerosol number densities & characteristics
Net Flux Radiometer	Net radiative fluxes: Thermal IR, solar visible
Helium Abundance Detector	Helium Abundance

Core mission profile modeled after Galileo probe

NASA provided HEEET would enable significant mass savings over CP for range of EFPAs

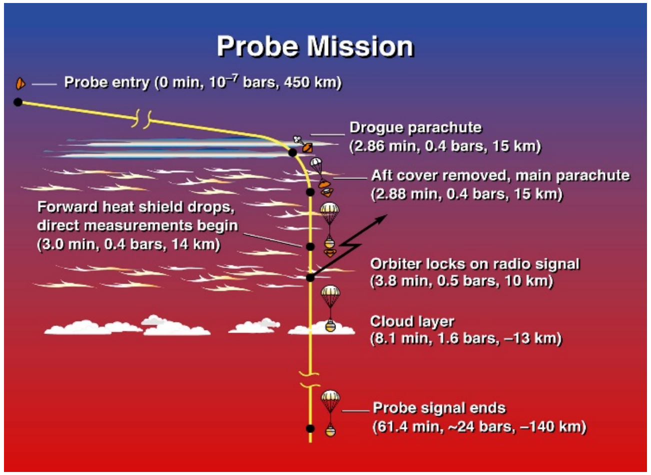


Table E.1 Entry System Mass Estimates

Entry Flight Path Angle (EFPA), degrees	-8		-19	
	Mass, kg			
TPS Material	**HEEET**	**Carbon Phenolic**	**HEEET**	**Carbon Phenolic**
Entry System (total mass)	215	255	199	223
Deceleration module	92.6	132.6	76.6	100.6
Forebody TPS (HEEET)	40	80	24	48
Afterbody TPS	10.5	10.5	10.5	10.5
Structure	18.3	18.3	18.3	18.3
Parachute	8.2	8.2	8.2	8.2
Separate Hardware	6.9	6.9	6.9	6.9
Harness	4.3	4.3	4.3	4.3
Thermal Control	4.4	4.4	4.4	4.4
Descent Module	122.7	122.7	122.7	122.7
Communication	13	13	13	13
C&DH Subsystem	18.4	18.4	18.4	18.4
Power Subsystem	22[1]	22[1]	22[1]	22[1]
Structure	30	30	30	30
Harness	9.1	9.1	9.1	9.1
Thermal Control	4.3	4.3	4.3	4.3
Science Instrument	25	25	25	25
Separate Hardware	0.9	0.9	0.9	0.9

Note. *Deceleration of (or Entry System) module 1m diameter aeroshell, 36 km/s inertial velocity, 10 deg latitude). The descent module mass estimate, except for the Science Instruments, are the same as that of Galileo Probe. Additional mass savings are likely when the descent system structure is adjusted for reduction in scale as well as entry g-load. Galileo design-to g-load was 350. Saturn probe entry g-load with 3-sigma excursions will be less than 150 g's.*

Next Stop: Ice Giants!

www.nasa.gov

Ice Giants

Pre-Decadal Survey Mission Study Report

Science Definition Team Chairs | Mark Hofstadter (JPL), Amy Simon (GSFC)

Study Manager | Kim Reh (JPL) **Study Lead** | John Elliott (JPL)

NASA Point of Contact | Curt Niebur

ESA Point of Contact | Luigi Colangeli

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J.-B. Renard, T. Spilker, E. Venkatapathy, P. Wurz, K. Aplin, A. Coustenis, M. Deleuil,
M. Dobrijevic, T. Fouchet, T. Guillot, P. Hartogh, T. Hewagama, M.D. Hofstadter,
V. Hue, R. Hueso, J.-P. Lebreton, E. Lellouch, J. Moses, G.S. Orton, J.C. Pearl,
A. Sánchez-Lavega, A. Simon, O. Venot, J.H. Waite, R.K. Achterberg, S. Atreya,
F. Billebaud, M. Blanc, F. Borget, B. Brugger, S. Charnoz, T. Chiavassa, V. Cottini,
L. d'Hendecourt, G. Danger, T. Encrenaz, N.J.P. Gorius, L. Jorda, B. Marty, R. Moreno,
A. Morse, C. Nixon, K. Reh, T. Ronnet, F.-X. Schmider, S. Sheridan, C. Sotin,
P. Vernazza, G.L. Villanueva

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ABSTRACT