Ice Giants: Technology Assessment

Pre-Decadal study summary

Outer Planet Assessment Group, 23 Feb, 2018

Final Report can be found at http://www.lpi.usra.edu/icegiants/ or http://www.lpi.usra.edu/icegiants/mission_study/

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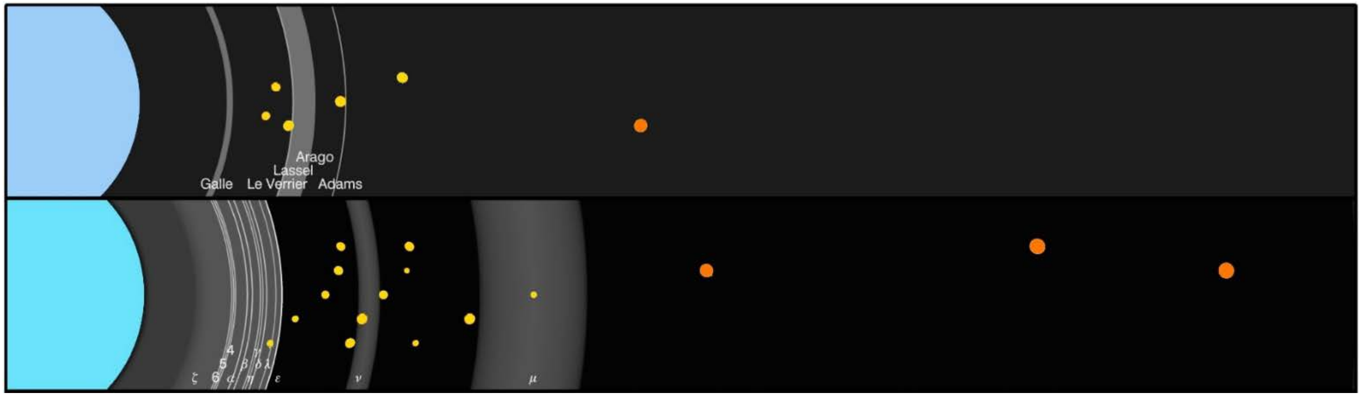


Study goal and objectives

Goal

- Assess science priorities and affordable mission concepts & options for exploration of the Ice Giant planets, Uranus and Neptune in preparation for the next Decadal Survey

Objectives

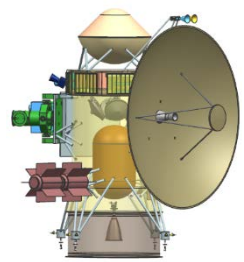
- Assess alternative architectures to determine the most compelling science mission(s) that can be feasibly performed within $2B ($FY15)
- Define mission concepts that can address science priorities based on what has been learned since the 2013–2022 Decadal Survey
- **Identify enabling/enhancing technologies**
- Assess capabilities afforded by SLS

Common architectural building blocks

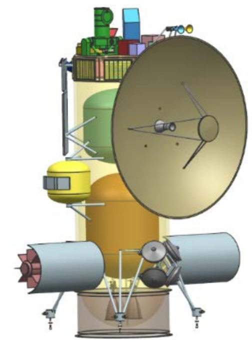
Flyby/Orbiter

- Avionics and structure
- Sensors and Telecom
- Chemical propulsion
- Radioisotope Power
- Payload accommodation
- SEP Stage
- Entry Probe

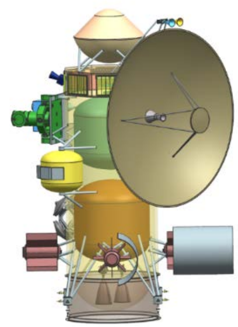
mission concept drawing



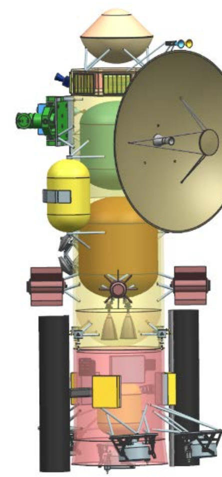
UFBy; 50 kg P/L
1525 kg wet



UO (no probe); 150 kg P/L
4718 kg wet



UOP; 50 kg P/L
4345 kg wet



NOP, SEP; 50 kg P/L
7364 kg wet

Payload Elements

<50 kg:
- NAC
- Doppler Imager
- Magnetometer

~90 kg (above plus):
- Vis/NIR imaging spectrometer
- Radio and Plasma suite
- Thermal IR
- Mid-IR (Uranus) or UV (Neptune) spectrometer

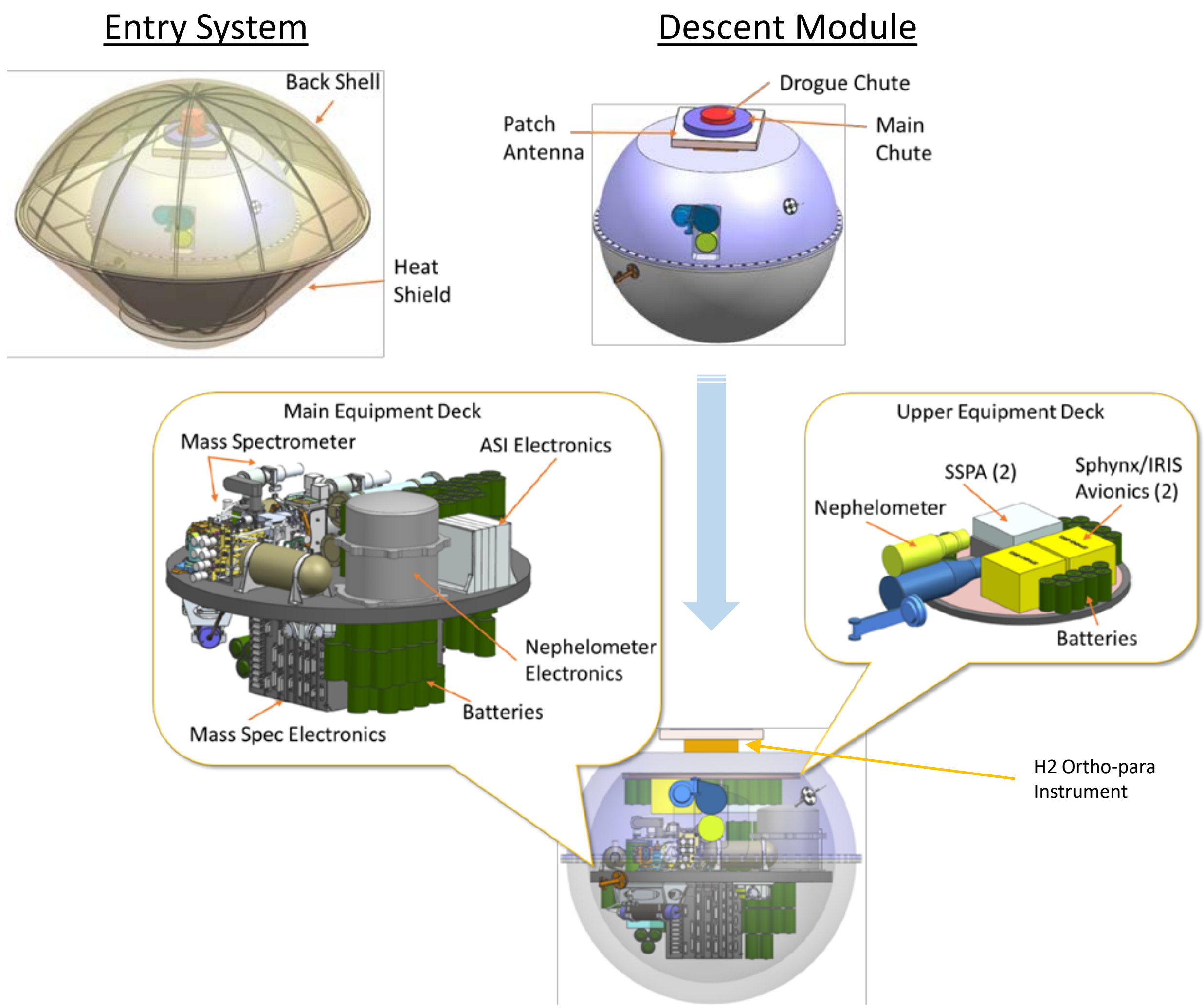
~150 kg (above plus):
- WAC
- USO
- Energetic Neutral Atoms
- Dust detector
- Langmuir probe
- Mwave sounder/Mass spec

Common probe concept

- Vented probe; 45 deg sphere-cone
- Redundant Avionics
- Redundant UHF telecom relay
- Redundant Power Electronics
- Primary batteries, 1.0 kW-hr EOM
- RHU heating, passive cooling
- HEEET Heatshield, Backshell
- Parachutes

Descent Module: 174 kg
Entry System: 147 kg
Total Entry Mass: 321 kg

mission concept drawing

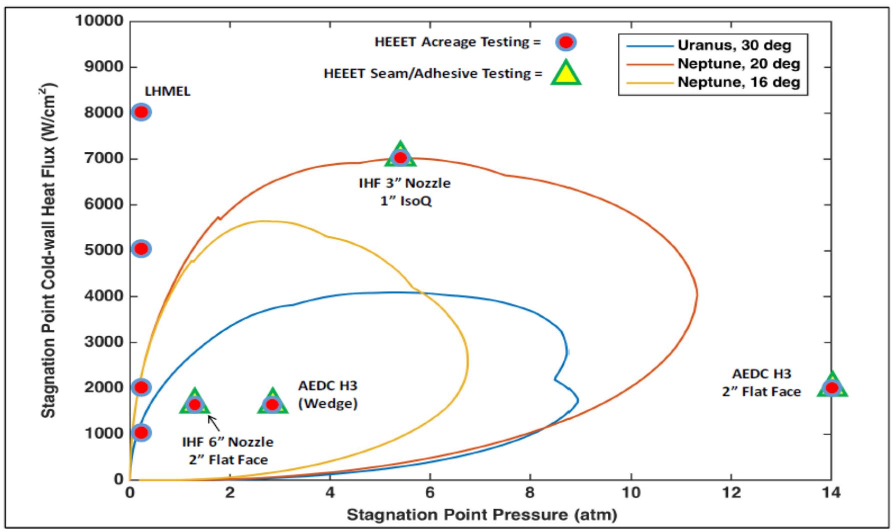


Technology considerations

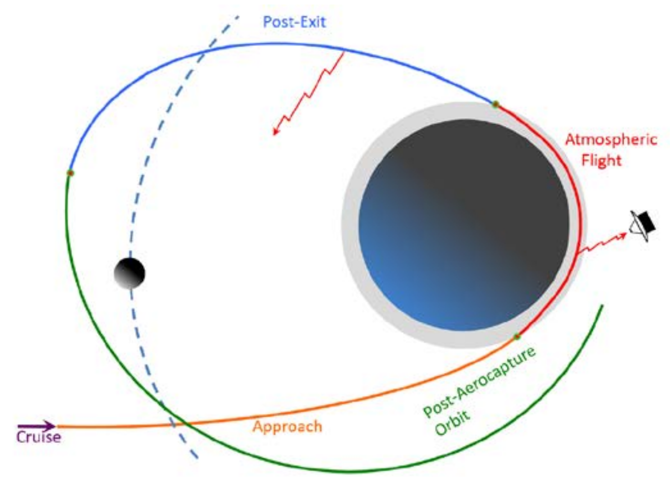
- HEEET thermal protection system (ENABLING)
- Advanced Radioisotope Power
  - Proposed eMMRTG (ENABLING)
  - Next Gen RTG concept; 500 We
  - High Power Stirling Radioisotope Generator (HPSRG) concepts
- In Space Transportation
  - Aerocapture
  - LOX-LH2 chemical propulsion
  - Radioisotope Electric Propulsion
- Optical communications

High Energy Entry Environment Technology (HEEET)

- HEEET technology is enabling for atmospheric entry at the Ice Giants (see Venkatapathy presentation)
- HEEET technology is enabling for the entry probe in all four Ice Giants concepts studies
- HEEET technology would also be enabling for any concept that involved the use of aerocapture for reaching orbit at the Ice Giants
- HEEET capabilities have been used as a constraints in assessing the utility of aerocapture at Ice Giants



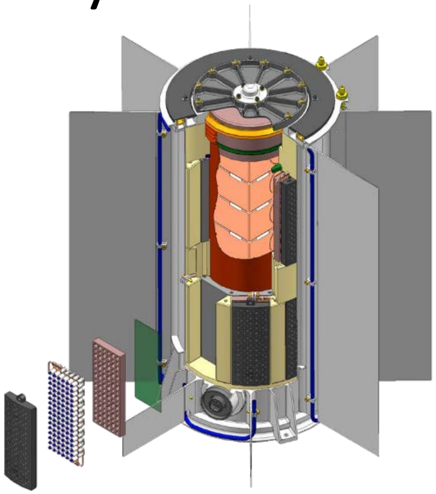
Uranus and Neptune entry probe environments



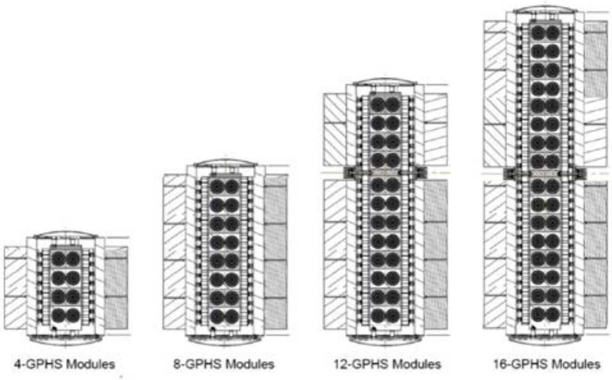
Profile of typical aerocapture maneuver

Advanced Radioisotope Power Systems

- Advanced radioisotope power is an enabling technology for Ice Giants missions
- All four Ice Giants concepts studied baseline the potential eMMRTG.
- eMMRTG would provide improved BOL and greatly improved EOL performance relative to MMRTG
- SMRTG or other higher performance RPS would enable even more mass or power for instruments or both



Enhanced MultiMission RTG



Segmented Modular RTG M

Artist's Concept

In Space Transportation- Aerocapture

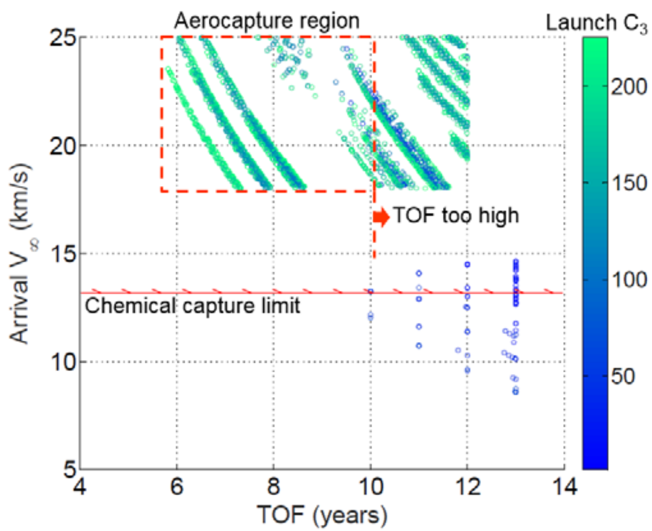
Concept and Benefits

- Use atmospheric drag instead of propulsion for orbit entry
- Launch the orbiter on smaller LV
- Increase delivered science payload
- Reduce the time of flight

Technology Status

- Orbital capture practical for arrival V_{inf} of up to 25 km/sec with HEEET
- Key challenge is providing sufficient control authority to handle trajectory uncertainties

Upper limit set by performance of HEEET and tolerable g loads



Dependence of Time of flight on arrival V_{inf}

Technology Options

- High L/D aerocapture vehicles
- Drag devices jettisoned once orbit is established
- Improved navigation and conventional planetary aeroshells similar to MSL
- Hybrid aerocapture chemical approaches

See companion presentation by Tom Spilker for details

In Space Transportation LOX –H2 propulsion

Concept/Benefits

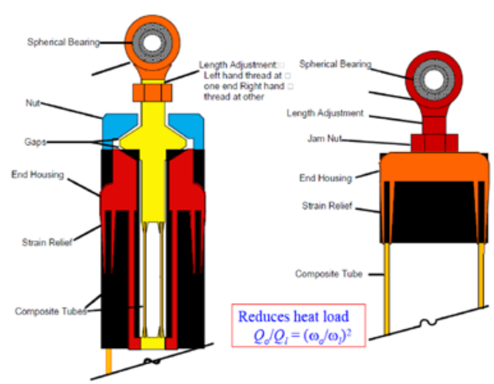
- Replace conventional propellants with cryogenic propellants
- Fast trajectories to the outer planets enable passive cooling of cryogens
- LOX-H2 has very high I_{sp} enabling smaller LVs, shorter flight times, and increased delivered science payload

Technology Status

- Passive On-Orbit Disconnect Struts (PODS) developed to reduce heat load
- Significant investment required to develop cryogenic engine in the desired thrust range

Performance Comparison Conventional Propellants to LOX-H2

Target Delta V	2 km/sec	5 km/sec
Delivered Mass - conventional	1850 kg	350 kg
Delivered Mass – LOX H2	2300 kg	900 kg
Increase (kg)	450 kg	550 kg
Increase (%)	24%	157%



Passive On-Orbit Disconnect struts

In Space Transportation - Summary

- Aerocapture
  - Has greatest potential for short trip times of 3 to 4 years by handling arrival V_{inf} in excess of 20 km
  - Requires further engineering development to determine best approach for an outer planet mission

- LOX H2
  - Has significant impact on trip time, instrument payload for trajectories requiring insertion Delta V greater than 3.5 km/sec
  - Primarily an engineering and investment question. Are there other applications for this technology?

- Radioisotope Electric Propulsion
  - Pluto Orbiter study of 2015 found this to be enabling for a mission concept to a small airless body
  - Not competitive with aerocapture and LOX H2 for Ice Giants

Deep Space Optical Communication

- The Ice Giants study looked at the payoff from Deep Space Optical Communications (DSOC)
- DSOC is currently being developed for applications out to 3 AU
- The study assumed a global network of optical receivers which is NASA's Long Range Plan but is not currently funded. Joe Lazio has discussed the status
- Data rates up to 11 Mbs at Uranus and 4Mbs at Uranus with favorable link conditions

Flight Laser Transmitter (FLT)
50 cm telescope diameter, 20 watt output

	CBE Mass (kg)	CBE Power (W)
Flight Transceiver Telescope	45.6	0
Small Optics & Actuators	0.7	1
Laser	10.8	155
Pointing Detector	2	11
Electronics	6.3	20
Thermal/Structure	5.3	6
TOTAL	70.7	193

Link Performance

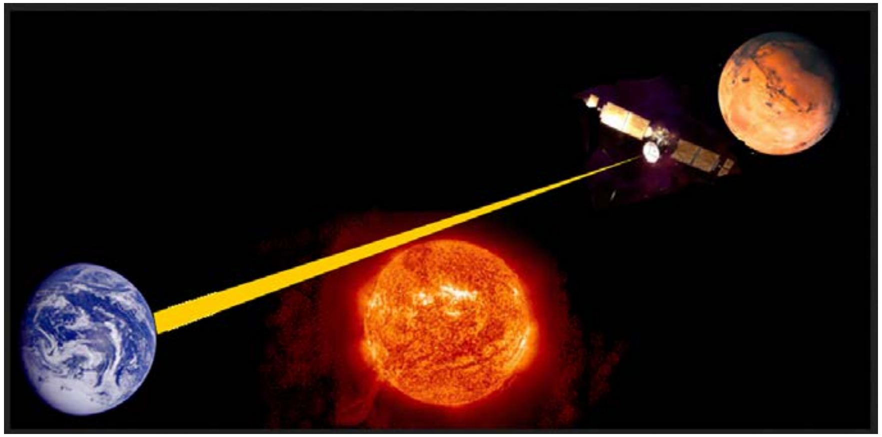
URANUS			128 PPM	256 PPM	128 PPM	256 PPM
Range	Link Condition	SEP	11.8 m (Mb/s)		5 m (Mb/s)	
21.68	Day	5	0.113	0.192	0.033	0.054
17.6	Night	150	11.35	11.7	1.557	1.647

NEPTUNE			128 PPM	256 PPM	128 PPM	256 PPM
Range	Link Condition	SEP	11.8 m (Mb/s)		5 m (Mb/s)	
31.84	Day	5	0.025	0.043	0.0122	0.0204
28.7	Night	150	3.81	4	0.68	0.706

DSOC for Ice Giants – Summary

Optical Link Performance

- Optical communications can dramatically increased the data return from an ice giants mission
- Performance degrades sharply for operation under daylight conditions and depends on proximity of Ice Giants to the sun during the mission



DSOC will be demonstrated out to 3AU on the Discovery Psyche mission

Tracking the ground station

- For operation out to 3AU, a laser beacon is sent up from the ground station and is used to point the FLT
- Beacon power increases as square of distance to the spacecraft which is impractical for a laser on the Earth's surface Possible solutions are:
  - Beacon above the atmosphere (balloon, spacecraft) where power can be increased without adverse environmental effects
  - Tracking the infrared image of the Earth from the orbiter
  - Tracking star fields from the orbiter

Other Technology Challenges

- Laser lifetime in cold radiation environments
  - Periodic annealing may be solution
- Need for ground infrastructure
  - Performance data assumes a network of 8 m telescopes. This is not funded at this time but could be available on the time frame of an Ice Giants mission

Summary

- Ice giants mission concepts as defined would be enabled by two technologies both of which are currently under development – HEEET and eMMRTG

- Benefits of several other technologies have been characterized which could yield faster trip times, larger instrument payload and higher data returns
  - For the Ice Giants mission concepts as defined these technologies would be enhancing but not enabling