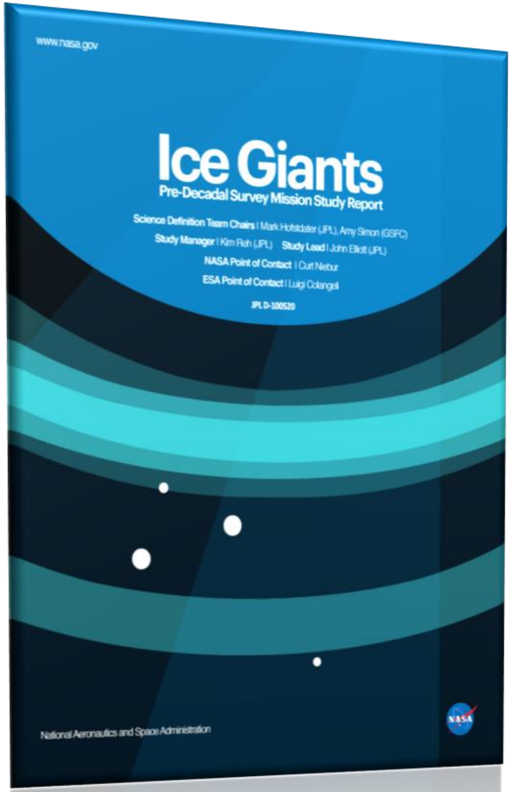
Jet Propulsion Laboratory
California Institute of Technology

Ice Giant Systems 2020

Mission Design Prospects for the Ice Giants

John O. Elliott
January 21, 2020

Mission Design Space



- Recent Ice Giants Pre-Decadal study investigated wide range of mission design options in the time span of 2024-2037
- Surveyed chemical-only missions, as well as missions augmented with SEP in the inner solar system

Getting to the Ice Giants

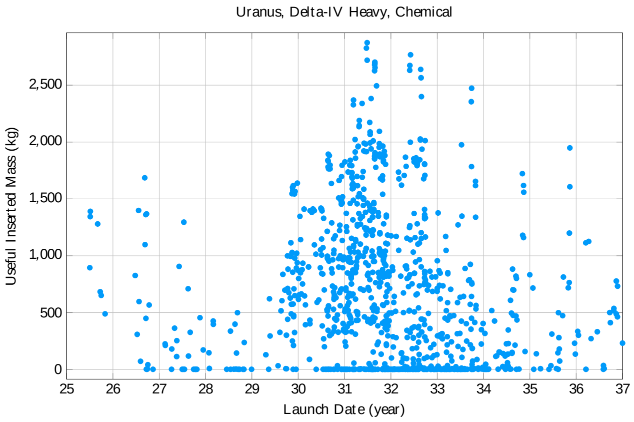
- Launch interval studied: [2024 – 2037]
- Total mission duration < 15 years including at least 2 years of science
- Interplanetary flight time:
  - 6 – 12 years to Uranus
  - 8 – 13 years to Neptune

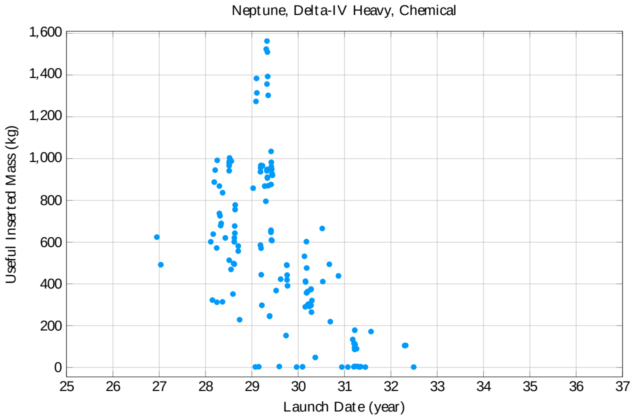
Launch Vehicles	Interplanetary Trajectory	Gravity Assist (up to 4 per Traj.)	Target Bodies	SEP Power	EP Engines	Orbit Insertion
• Atlas V • Delta-IV Heavy • SLS-1B	• Chemical + DSM + GA • SEP + GA • REP + GA • Dual Spacecraft	• Venus • Earth • Mars • Jupiter • Saturn	• Uranus • Neptune	• 15 kW • 25 kW • 35 kW	• NEXT 1+1 (SEP) • NEXT 2+1 (SEP) • NEXT 3+1 (SEP) • XIPS (REP)	• Chemical (Bi-Prop) • Chemical (cryo) • REP • Aerocapture

Tens of thousands of trajectory options to both planets were examined

Chemical Trajectories

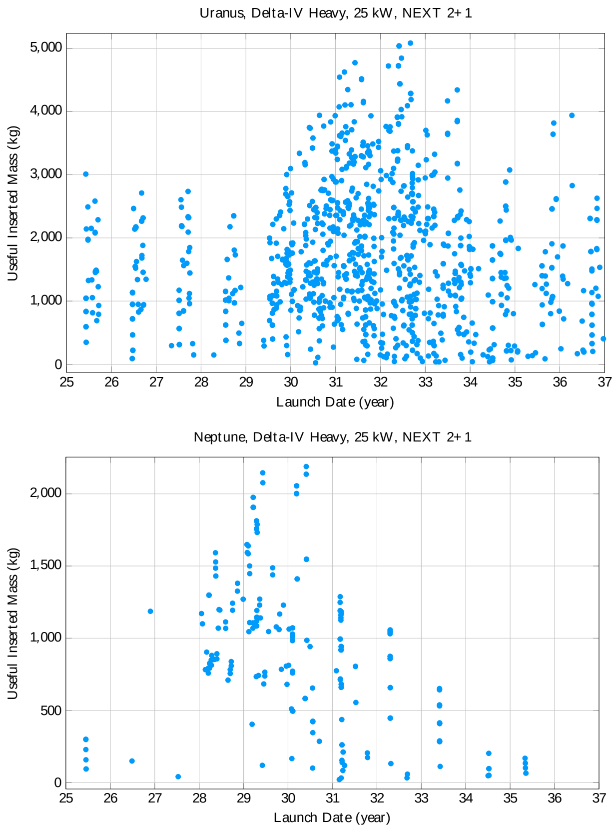
- Availability of Jupiter gravity assist maximizes delivered mass
- Preferential launch windows for Uranus missions lie in the 2030–2034 timeframe with a corresponding window of 2029–2030 for Neptune
    - In these favorable periods chemical trajectories could deliver ample mass for the Uranus missions studied in an 11-year flight time, using a launch performance capability similar to the Atlas V 551.
- No all-chemical trajectories to Neptune were found that yield a mission duration less than 15 years
- If a Saturn flyby is preferred over the Jupiter gravity assist, only trajectories to Uranus are available in the time period studied, and launch must occur before mid-2028





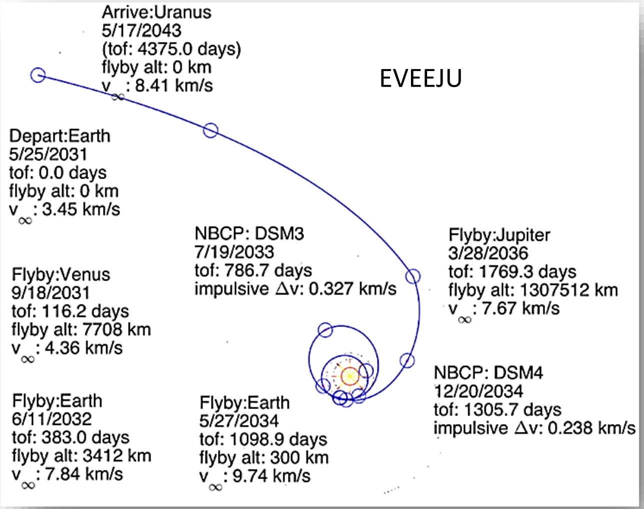
SEP-enhanced trajectories

- A variety of trajectories to Uranus and Neptune were evaluated assuming inclusion of an additional solar electric propulsion (SEP) flight element (SEP stage)
    - Self-contained stage with solar arrays and ion propulsion system
    - Used in the inner solar system as far out as 6 AU, at which point the SEP stage would be jettisoned.
- For Uranus missions SEP can significantly reduce flight times and/or increase delivered mass.
    - Well-performing trajectories are possible in any year of the period studied.
- Neptune trajectories utilizing SEP can deliver a useful mass to Neptune orbit in 13 years using launch performance capability similar to the Delta IVH.



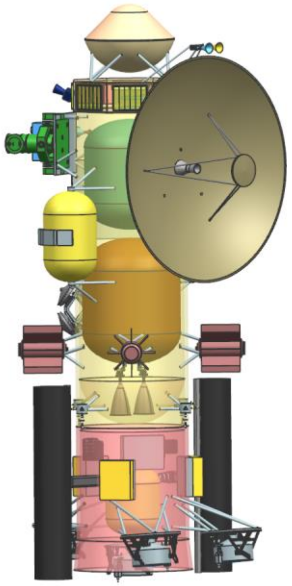
Mission Design Takeaways

- Existing propulsion technologies and launch vehicles are sufficient to enable Ice Giant flagship missions in the next decade
  - Optimal launch opportunities are between 2030-2034 for Uranus, 2029-2030 for Neptune, using Jupiter gravity assist
- Chemical trajectories deliver a flagship class orbiter (>1500 kg dry mass) to Uranus in < 12 years using Atlas V
  - Delta-IV Heavy can reduce interplanetary flight time by 1.5 years
- No chemical trajectories exist for delivering a flagship class orbiter to Neptune in < 13 years using Atlas V or Delta-IV Heavy launch vehicles. SLS or Longer flight times would be needed.
- SEP Enables a flagship orbiter to Neptune in 12-13 years
  - Implemented as separable stage to minimize propellant required for insertion

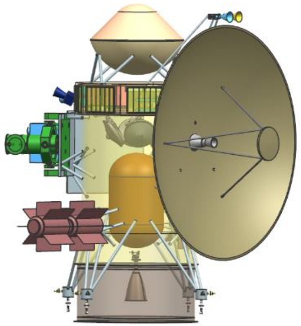


Key architectures fully assessed using common building blocks

Launch mass:
7364 kg

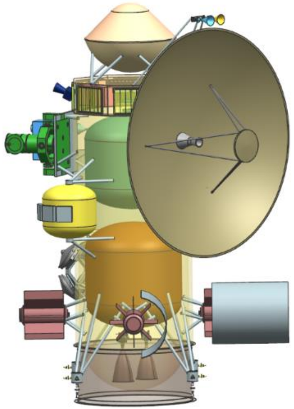


Neptune Orbiter with Probe, SEP, and 50 kg payload



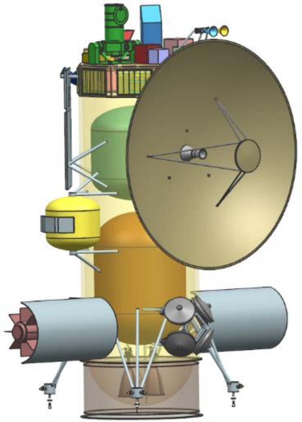
Launch mass:
1525 kg

Uranus Flyby with Probe and 50 kg payload



Launch mass:
4345 kg

Uranus Orbiter with Probe and 50 kg payload



Launch mass:
4718 kg

Uranus Orbiter with 150 kg payload

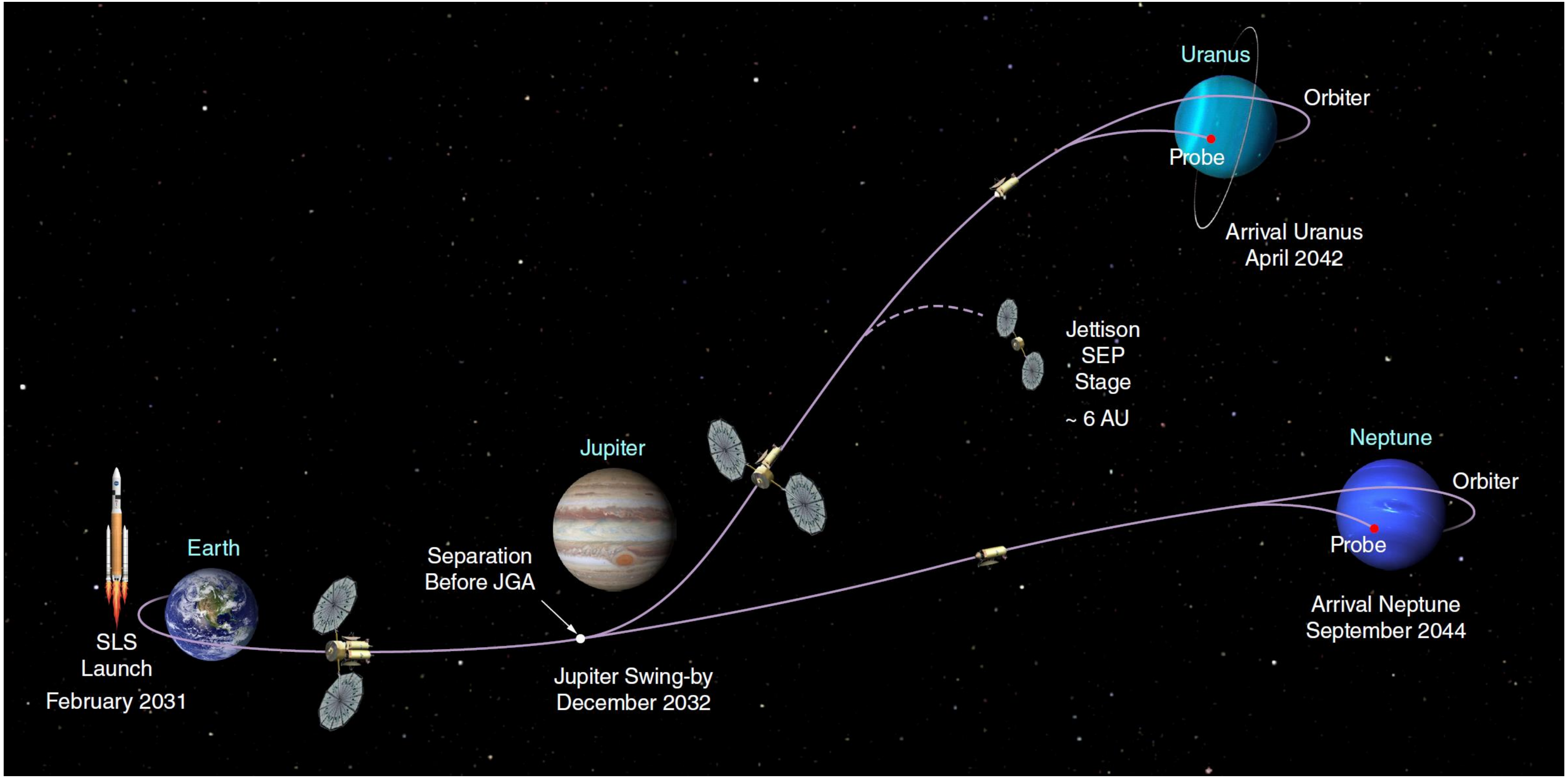
Concept Summary

				
Case Description	Neptune Orbiter with probe and <50 kg science payload. Includes SEP stage for inner solar system thrusting.	Uranus Flyby spacecraft with probe and <50 kg science payload	Uranus Orbiter with probe and <50 kg science payload. Chemical only mission.	Uranus Orbiter without a probe, but with 150 kg science payload. Chemical only mission.
Science	Highest priority plus additional system science (rings, sats, magnetospheres)	Highest priority science (interior structure and composition)	Highest priority plus additional system science (rings, sats, magnetospheres)	All remote sensing objectives
Team X Cost Estimate* ($k, FY15)	1971	1493	1700	1985
Aerospace ICE ($k, FY15)	2280	1643	1993	2321
Payload	3 instruments† + atmospheric probe	3 instruments† + atmospheric probe	3 instruments† + atmospheric probe	15 instruments‡
Payload Mass MEV (kg)	45	45	45	170
Launch Mass (kg)	7365	1524	4345	4717
Launch Year	2030	2030	2031	2031
Flight Time (yr)	13	10	12	12
Time in Orbit(yr)	2	Flyby	3	3
Total Mission Length (yr)	15	10	15	15
RPS use/EOM Power	4 eMMRTGs/ 376W	4 eMMRTGs/ 425W	4 eMMRTGs/ 376W	5 eMMRTGs/ 470W
LV	Delta IVH + 25 kW SEP	Atlas V 541	Atlas V 551	Atlas V 551
Prop System	Dual Mode/NEXT EP	Monopropellant	Dual Mode	Dual Mode

**Includes cost of eMMRTGs, NEPA/LA, and standard minimal operations, LV cost not included*

†includes Narrow Angle Camera, Doppler Imager, Magnetometer ‡*includes* Narrow Angle Camera, Doppler Imager, Magnetometer, Vis-NIR Mapping Spec., Mid-IR Spec., UV Imaging Spec., Plasma Suite, Thermal IR, Energetic Neutral Atoms, Dust Detector, Langmuir Probe, Microwave Sounder, Wide Angle Camera

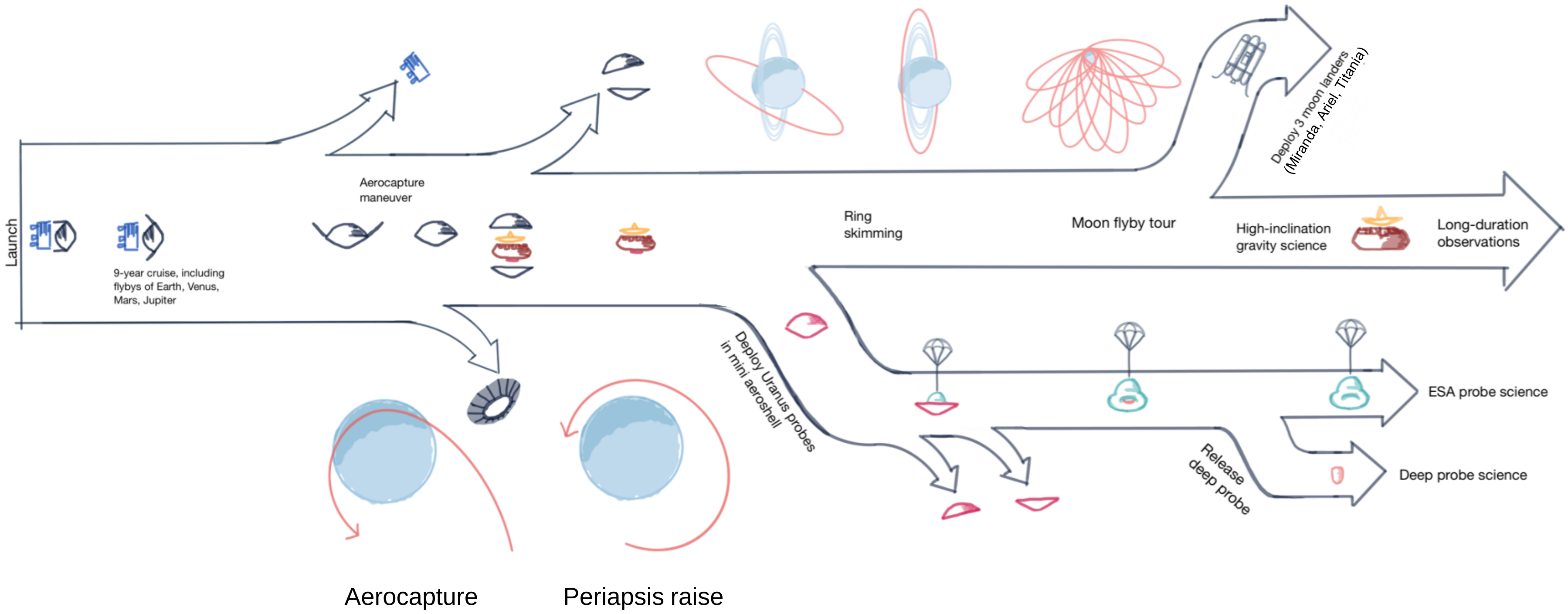
Two Planet-Two Spacecraft Mission Concept



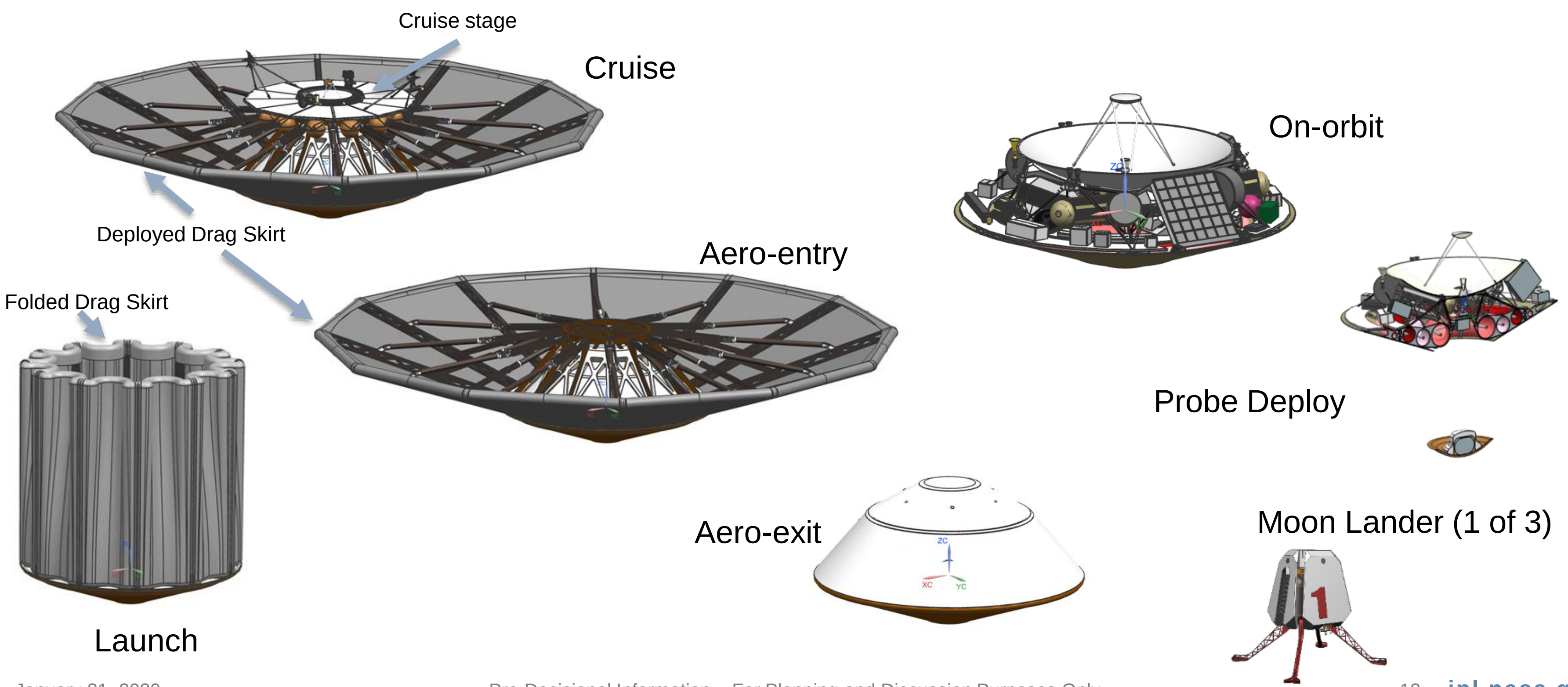
Recent study looked at impacts of new technologies

- Aerocapture
  - Use of aerocapture allows a significant (20-30%) reduction in flight time, providing earlier return of science and longer science mission at destination
  - Effectively decouples dry mass from orbit insertion requirements, allowing flexibility in payload accommodation
  - Enables lower mass orbiter (after aeroshell release), leaving room for more payload mass and increasing the effectiveness of REP
- Radioisotope Electric Propulsion
  - Enabled by Next-Gen RTGs
  - Allows large amounts of DV during orbit tour, allowing flexibility in targeting moons and rings
- Efficiently packaged shallow probe
  - Tailored configuration allows delivery of shallow and deep probes using a single aeroshell. Shallow probe also provides relay for deep probe data
- Kilobar deep probe
  - Provides measurements of composition, temperature and cloud structure at unprecedented depths in atmosphere
- 3 Moon Landers
  - Enabled by REP tour
  - Allows direct in situ composition measurement of moons, and long-term seismic measurements, enabled by RHU-based RPS

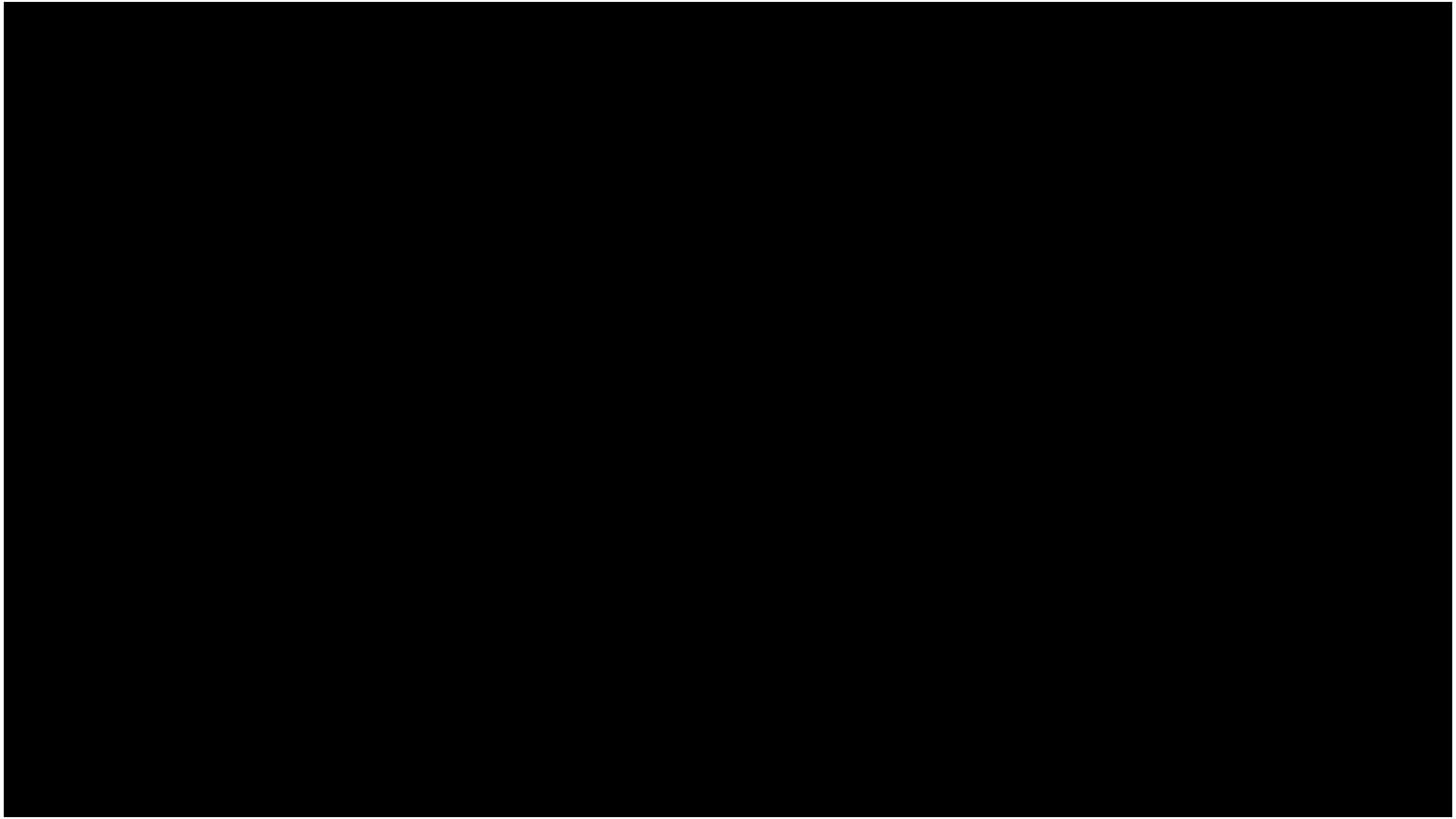
Uranus Mission Concept Overview



Flight System Configurations



Uranus Tempest Mission Concept Overview



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov