Skylight Astronomical Society

Probes to the Outer Solar System
The Future

Terry P. Riopka, President of Skylight Astronomical Society - 2018

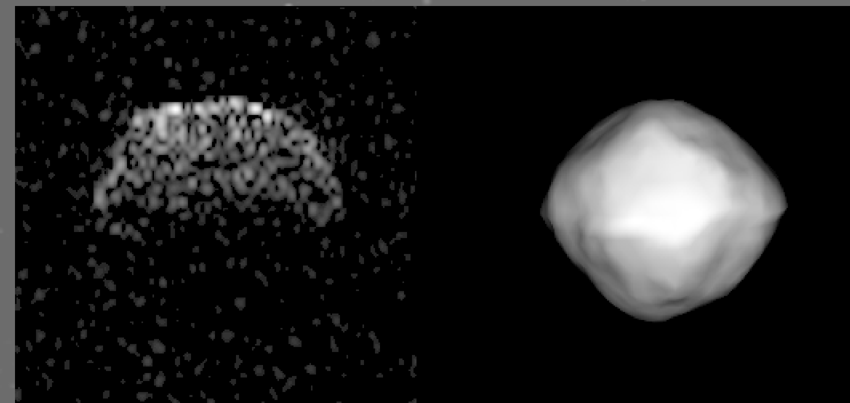
Future Missions to the Outer Solar System

Launch Date

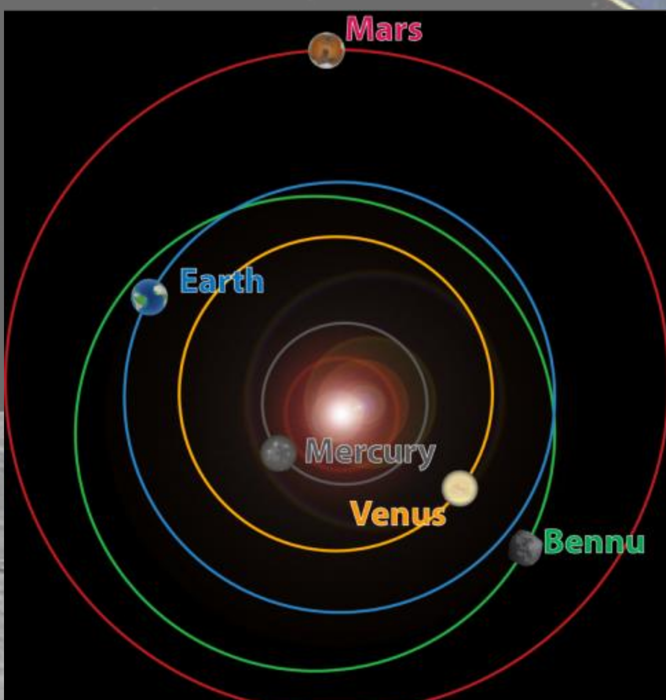
- 2016 — New Frontiers Mission 3 (*OSIRIS-Rex*)
- 2018 — Mercury BepiColombo [ESA-JAXA]
- 2018 — Mars Insight [NASA]
- 2021 — Trojan Asteroids – Lucy [NASA]
- 2022 — Jupiter Icy Moons Explorer (JUICE) [ESA]
- 2023 — Europa Clipper [NASA] / Asteroid 16 Psyche [NASA]
- 2024 — New Frontiers Mission 4 (DragonFly vs CAESAR)
- 2024-2037 — Ice Giants – Missions to Uranus and Neptune

New Frontiers Mission 3 (*OSIRIS-Rex*)

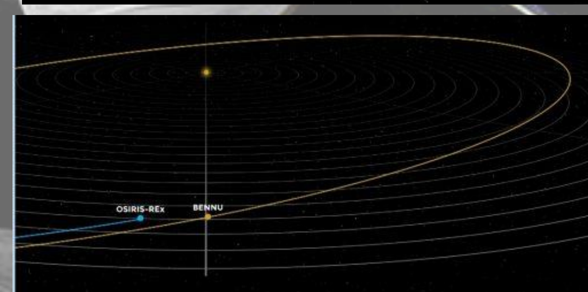
Acronym for: Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer



- Launched Sept. 8, 2016, to collect sample July 2020 from asteroid Bennu, and return it to Earth Sept. 24, 2023
- contains carbonaceous material, a key element in organic molecules



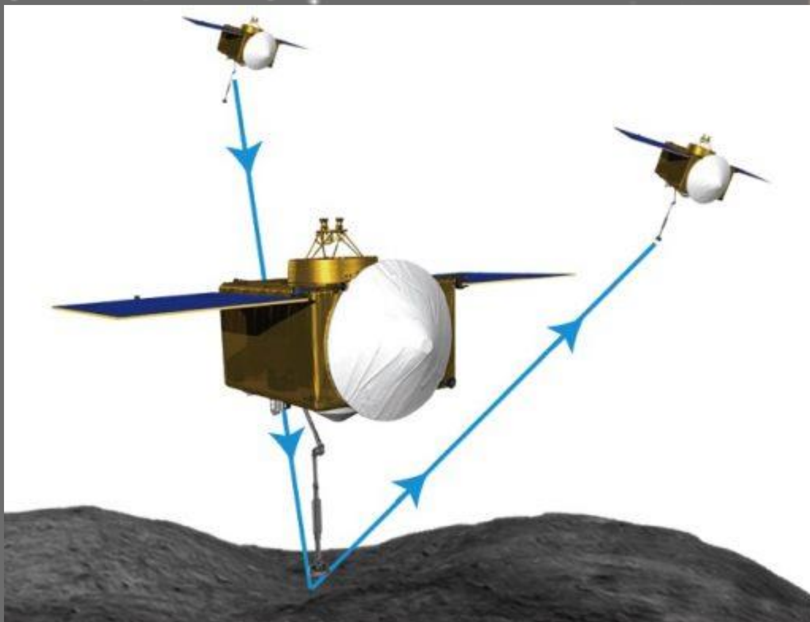
Earth gravity assist



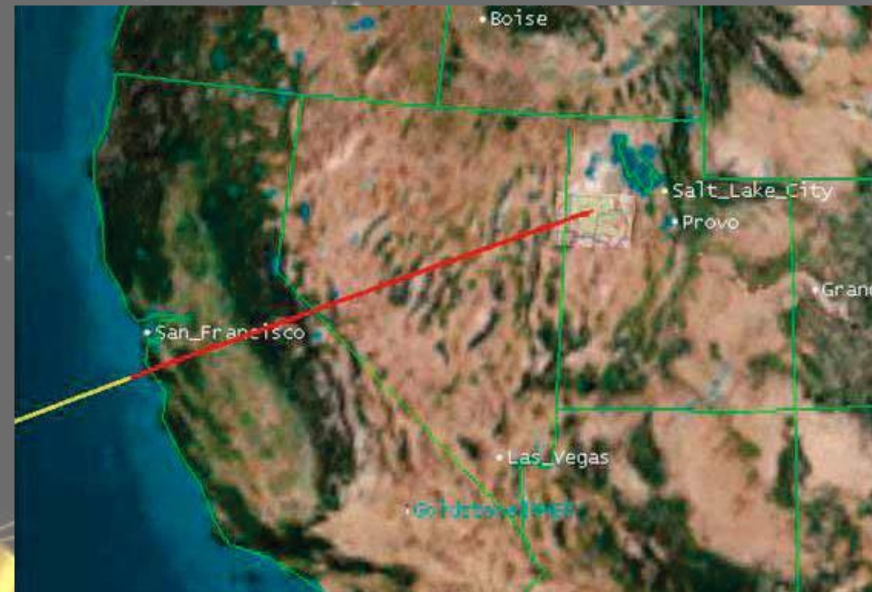
- Two rehearsals followed by “Touch and Go” maneuver

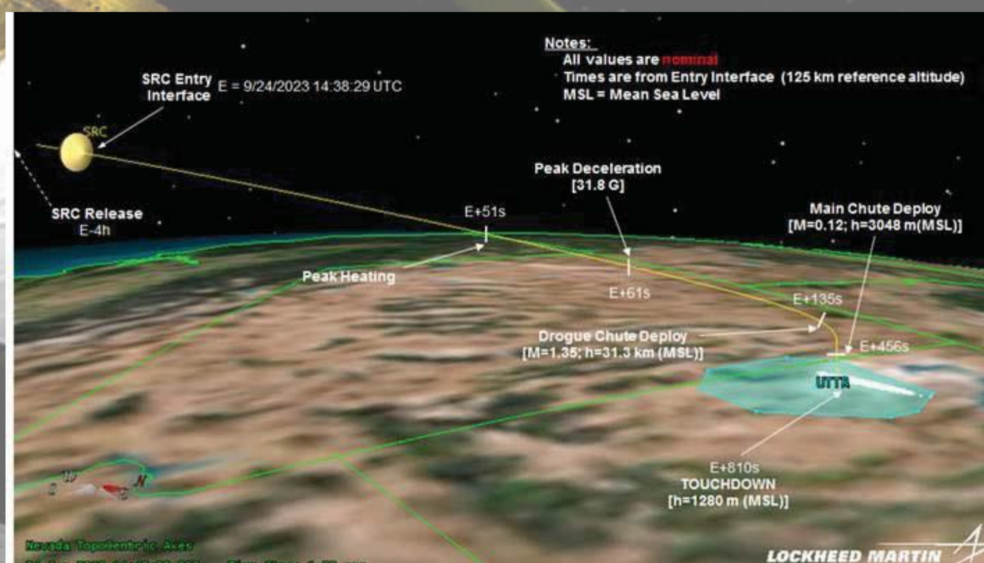
New Frontiers Mission 3 (*OSIRIS-Rex*)

Touch and Go Maneuver



Earth Reentry

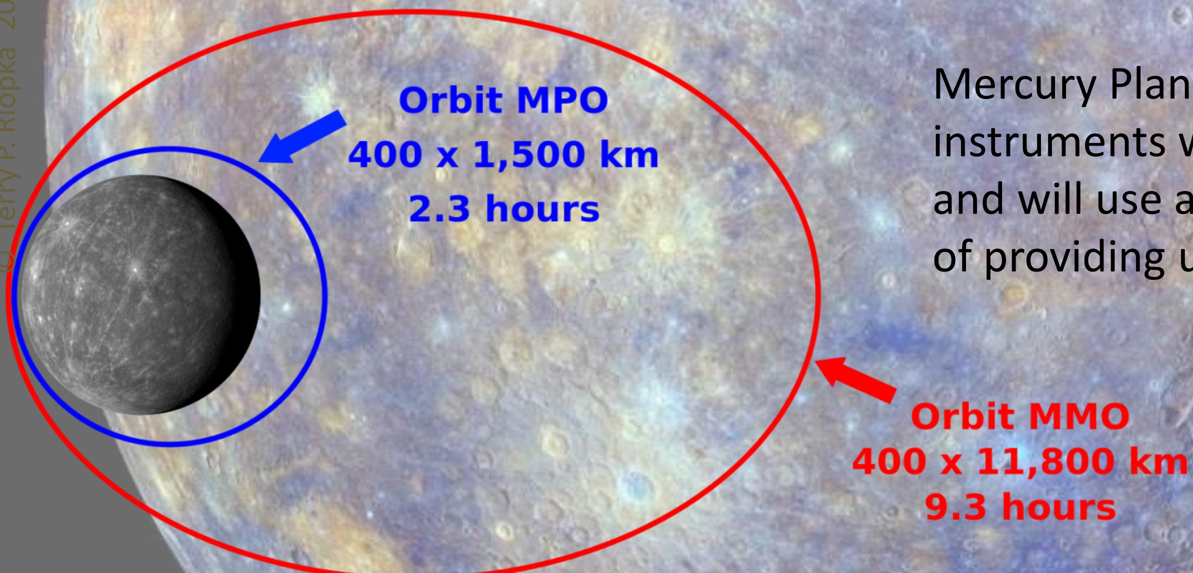




- will choose 12 landing sites in initial 5 km orbit and measure Yarkovsky effect
- will transition to 1 km orbit and select 4 out of the 12 sites for closer examination
- two rehearsals are planned bringing spacecraft to within 30 m
- maximum of 3 collection attempts
- built in margin of 27 weeks

BepiColombo – Mercury Mission

- scheduled to launch in Oct. 2018, with an arrival at Mercury planned for Dec. 2025
- comprises two satellites to be launched together: the **Mercury Planetary Orbiter** (**MPO**) and the **Mercury Magnetospheric Orbiter** (**MMO**)
- spacecraft will take 7 years to get to Mercury using solar-electric propulsion and 9 gravity assists, flying past the Earth and Moon in April 2020, Venus in 2020 and 2021, and 6 Mercury flybys between 2021 and 2025



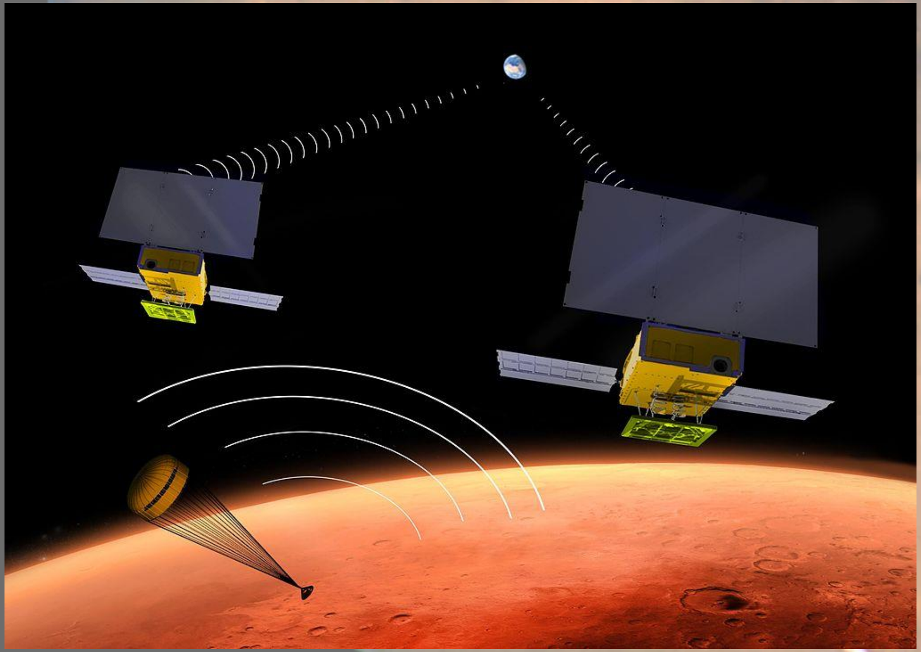
Mercury Planetary Orbiter (MPO) will have 11 instruments with a mass of 1,150 kg (2,540 lb) and will use a single-sided solar array capable of providing up to 1000 watts

- Will study huge liquid iron core, water/ice in shadowed craters, comet like exosphere and verify Relativity

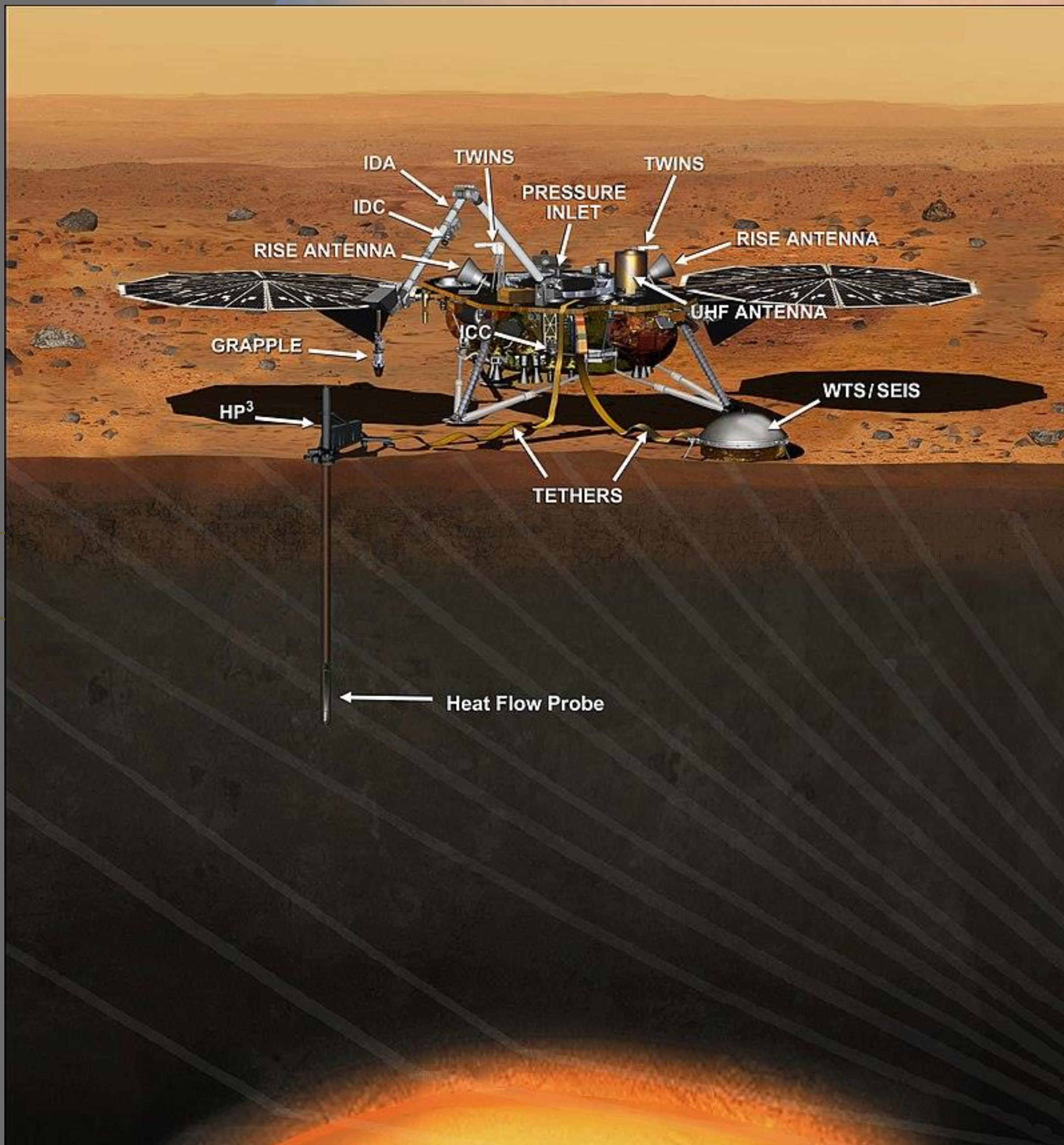
Mercury Magnetospheric Orbiter (MMO), developed and built mostly by Japan, has a total mass of 285 kg

InSight – Mars Lander

- acronym for **In**terior Exploration using **S**eismic **I**nvestigations, **G**eodesy and **H**eat **T**ransport
- originally planned for launch in March 2016, postponed to May 5th, 2018 due to failure of seismometer
- will land near the equator to enable optimum power for a projected lifetime of 2 years
- a set of two 6U CubeSats, will piggyback with the *InSight* mission to help relay communications during the probe's entry, descent and landing phase(MarCO system)



InSight – Mars Lander

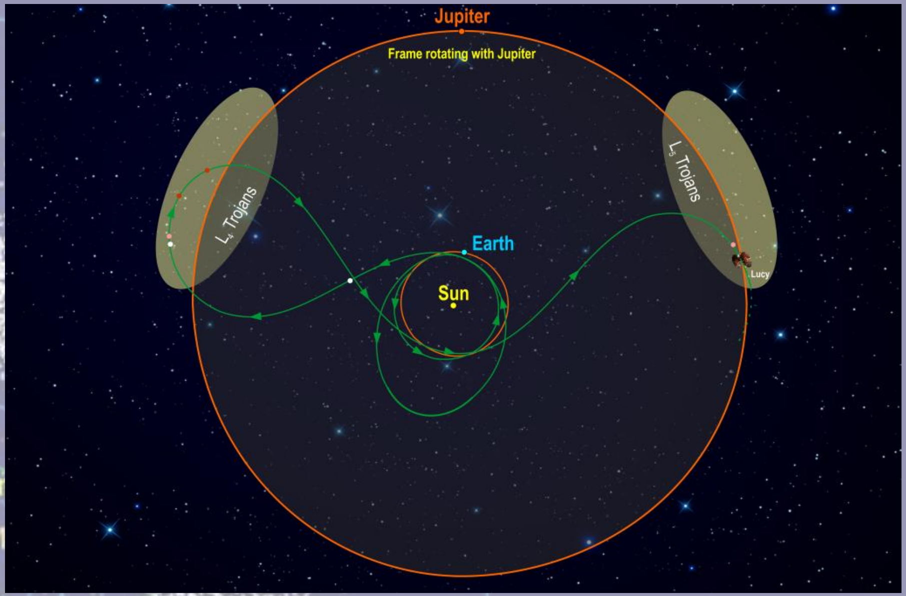


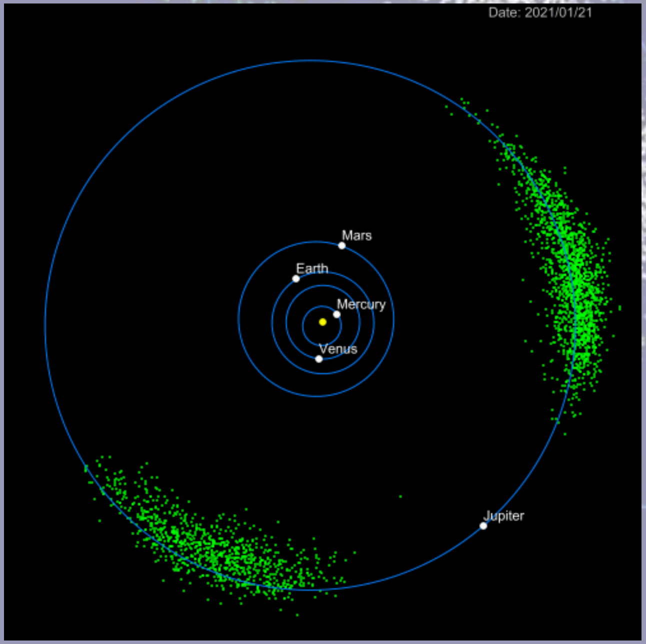
- equipped with a seismometer and heat transfer probe on the surface of Mars to study the planet's early geological evolution

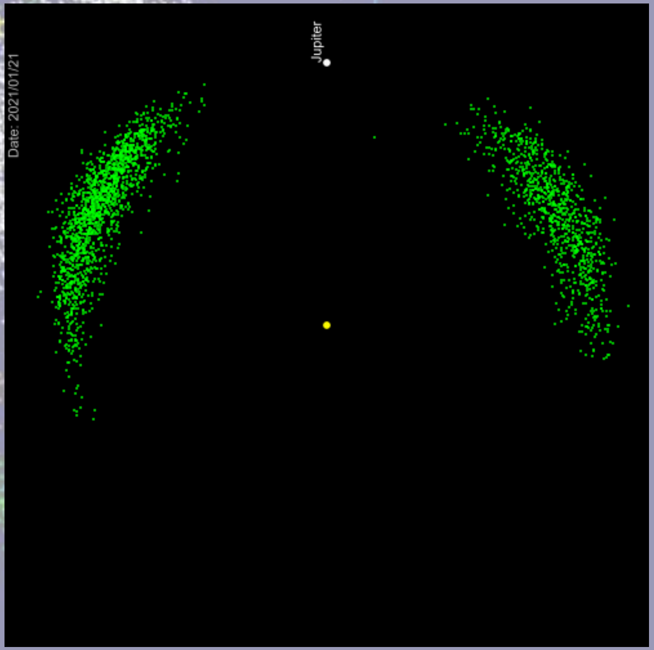
- will study the size, thickness, density and overall structure of Mars‘ core, mantle and crust (to determine how differentiation occurred)

Lucy – Mission to the Trojan Asteroids

- to launch in 2021, with a tour of 5 Jupiter trojans between an 2025-2033
- first Jupiter trojan discovered in 1906 - total of 6,515 Jupiter trojans as of May 2017
- total number of Jupiter trojans larger than 1 km in diameter is about 1 million
- very little known - dark bodies with no firm evidence of water, or any other compound - thought to be coated in organic polymers







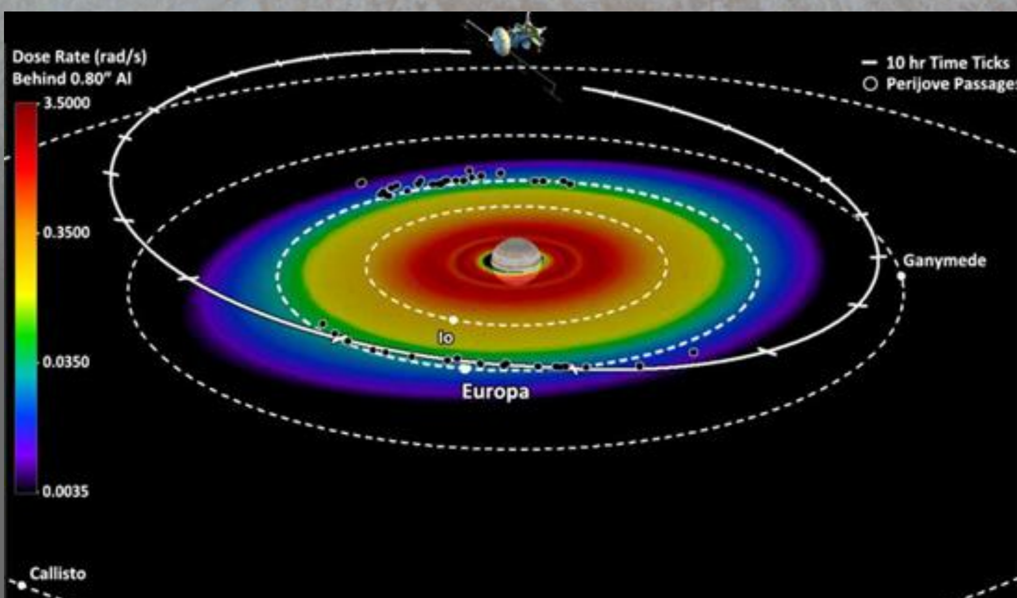
Jupiter Icy Moons Explorer (JUICE)

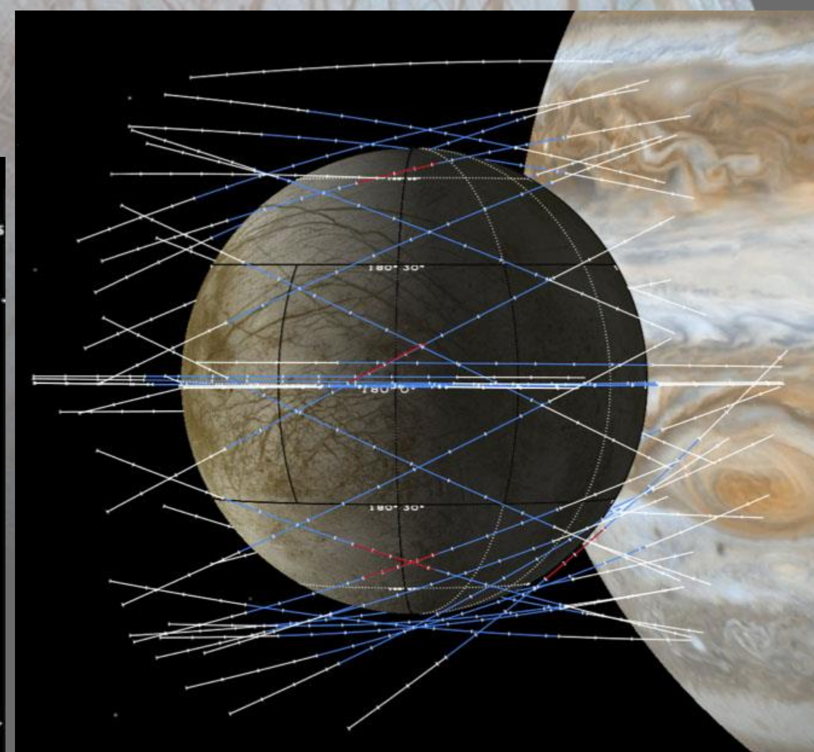
Ganymede (flybys + orbit) Callisto (multiple flybys) Europa (two flybys)

- set for launch in 2022 reaching Jupiter in 2030
- spacecraft will enter orbit around Ganymede in 2033 for its close up science mission - becoming the first spacecraft to orbit a moon other than the moon of Earth
- large number of flyby manoeuvres (more than 25 gravity assists, and two Europa flybys) requires the spacecraft to carry about 3,000 kg (6,600 lb) of chemical propellant
- 11 instruments to be supplied by ESA, USA and Japan
- cooperation with Russian Ganymede lander mission is being discussed

Europa Clipper

- flagship mission set for a launch around 2022-2025
- due to radiation from Jupiter's magnetosphere in Europan orbit, decided that it would be safer to inject a spacecraft into an elliptical orbit around Jupiter and make 45 close flybys of the moon instead
- between each of the flybys, the spacecraft will have 7to 10 days to transmit data stored during each brief encounter
- will let the spacecraft have up to a year of time to transmit its data compared to just 30 days for an orbiter - result will be almost three times as much data returned to Earth compared to cancelled orbiter
- may use CubeSats to fly through plumes, possible impactor probes





Psyche

- Discovery Mission #14 chosen on January 4, 2017, along with the Lucy Jupiter Trojan Mission (Discovery Mission #13)
- to launch in 2022, gravity assist from Mars in 2023 and arriving at asteroid Psyche in 2026
- Psyche is the heaviest known M-type asteroid, 157 miles in diameter
- thought to be the exposed iron core of a protoplanet which could have been as large as Mars but lost its surface in a series of violent collisions

3D Model based on light curve analysis

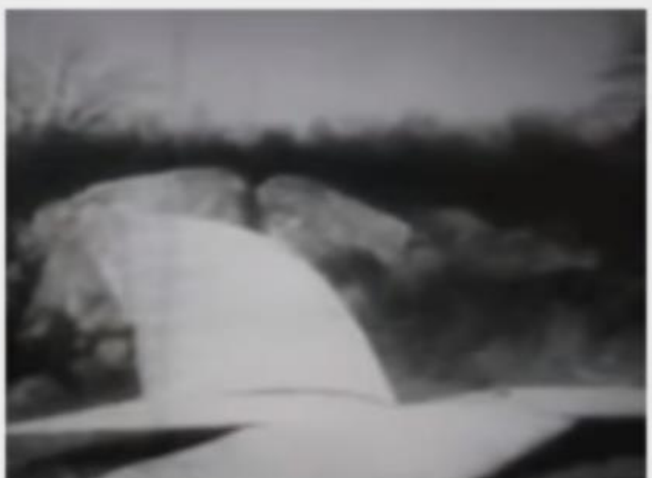
- will use 4 scientific instruments: a multispectral imager, a gamma ray and neutron spectrometer, a magnetometer, and an X-band radio gravity experiment
- will also test experimental laser communication technology called Deep Space Optical Communications (DSOC) yielding 10-100 times improved performance and efficiency

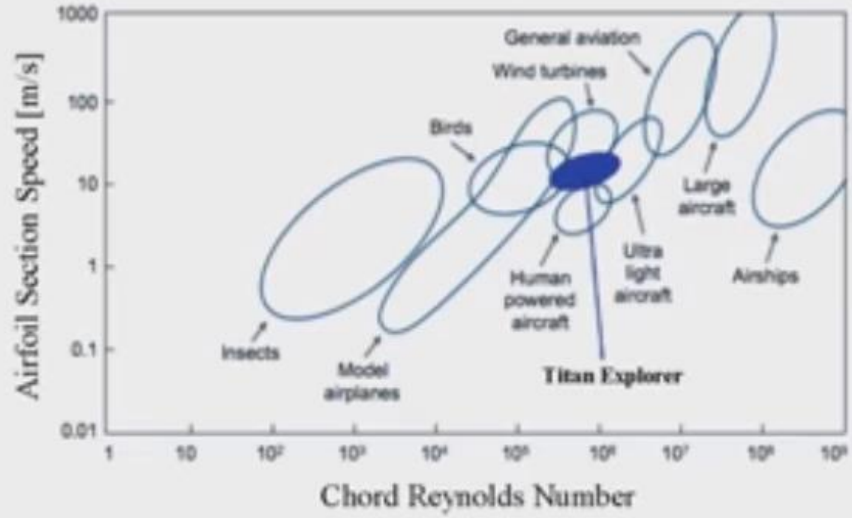
DragonFly (Titan Lander)

- one of two finalists for the next New Frontiers 4 mission to launch in 2024/2025
- mobile robotic rotorcraft lander to Titan
- power required to hover a given mass on Titan is 38 times less than that required on Earth

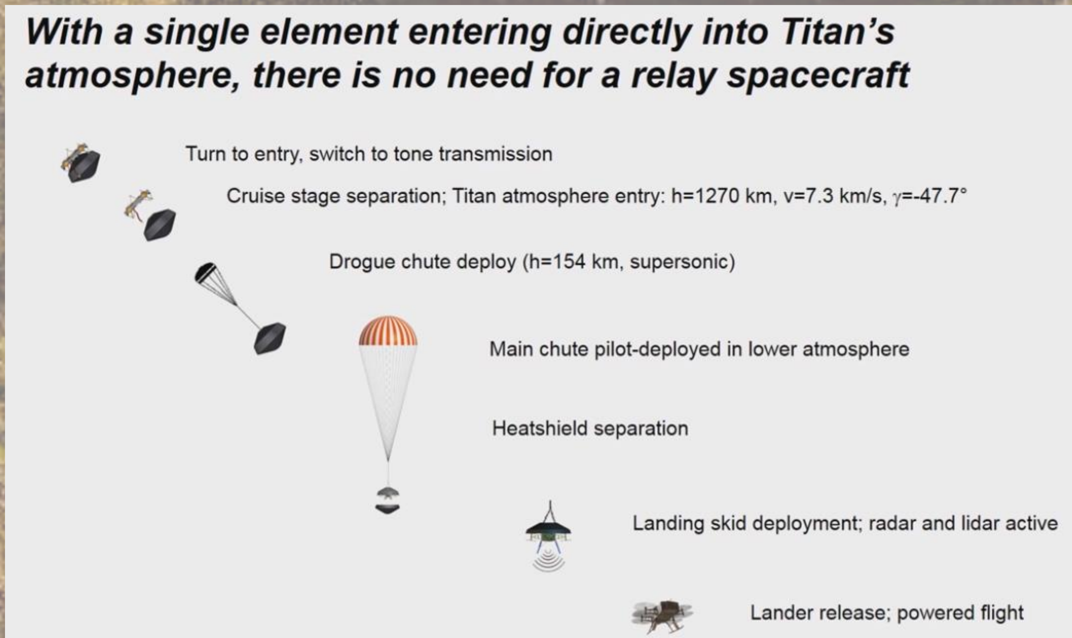
The easiest place in the Solar System to fly a quadcopter is on Titan!

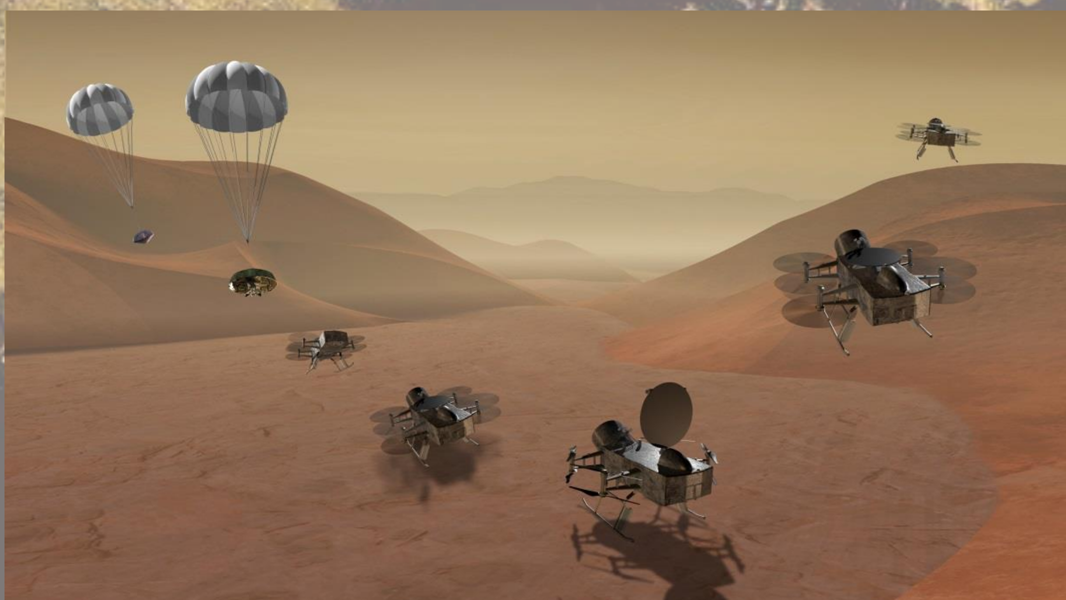
- Titan's dense atmosphere (> 4x that on Earth) and weak gravity (~ 1/7 Earth's) make it ideal for heavier-than-air flight.
- On Titan, a human could actually strap on wings, flap arms, and fly.





DragonFly (Titan Lander)





- aircraft would travel at about 36 km/h and climbs up to 4 km altitude
- rotorcraft could travel tens of kilometers on every battery charge and stay aloft for a few hours each time
- battery would be recharged by a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) during the night
- would remain on the ground during the Titan nights, which last about 8 Earth days
- activities during the night would include sample collection and analysis, seismological studies, meteorological monitoring, and local microscopic imaging using LED illuminators

Ice Giants Pre-Decadal Study

- Ice Giants Study commissioned by NASA in August 2015, released June 2017

Justification:

- class of planet not well understood : 65% water/ice with super-critical liquid water/methane/ammonia ocean
- most common exo-planet found so far
- narrow time window for planet formation challenges their common occurrence - rock/ice cores must become large enough to gravitationally trap hydrogen and helium gas just as the solar nebula is being dissipated by the early Sun

Ice Giants Pre-Decadal Study

Table 1-1. Mission concept analysis summary.

				
Case Description	Neptune Orbiter with probe and ~50 kg science payload. Includes SEP stage for inner solar system thrusting.	Uranus Flyby with probe and ~50 kg science payload. Chemical only mission.	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
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 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*

Required Enabling Technologies:

- eMMRTG for spacecraft power
- Heatshield for Extreme Entry Environment Technology (HEEET) for the entry probe

- no all-chemical trajectories to Neptune,that yield a mission duration less than 15 years
- no trajectories that allow a single spacecraft to encounter both Uranus and Neptune

- single SLS launch vehicle could, however, launch two spacecraft, one to each ice giant

Ice Giants Pre-Decadal Study

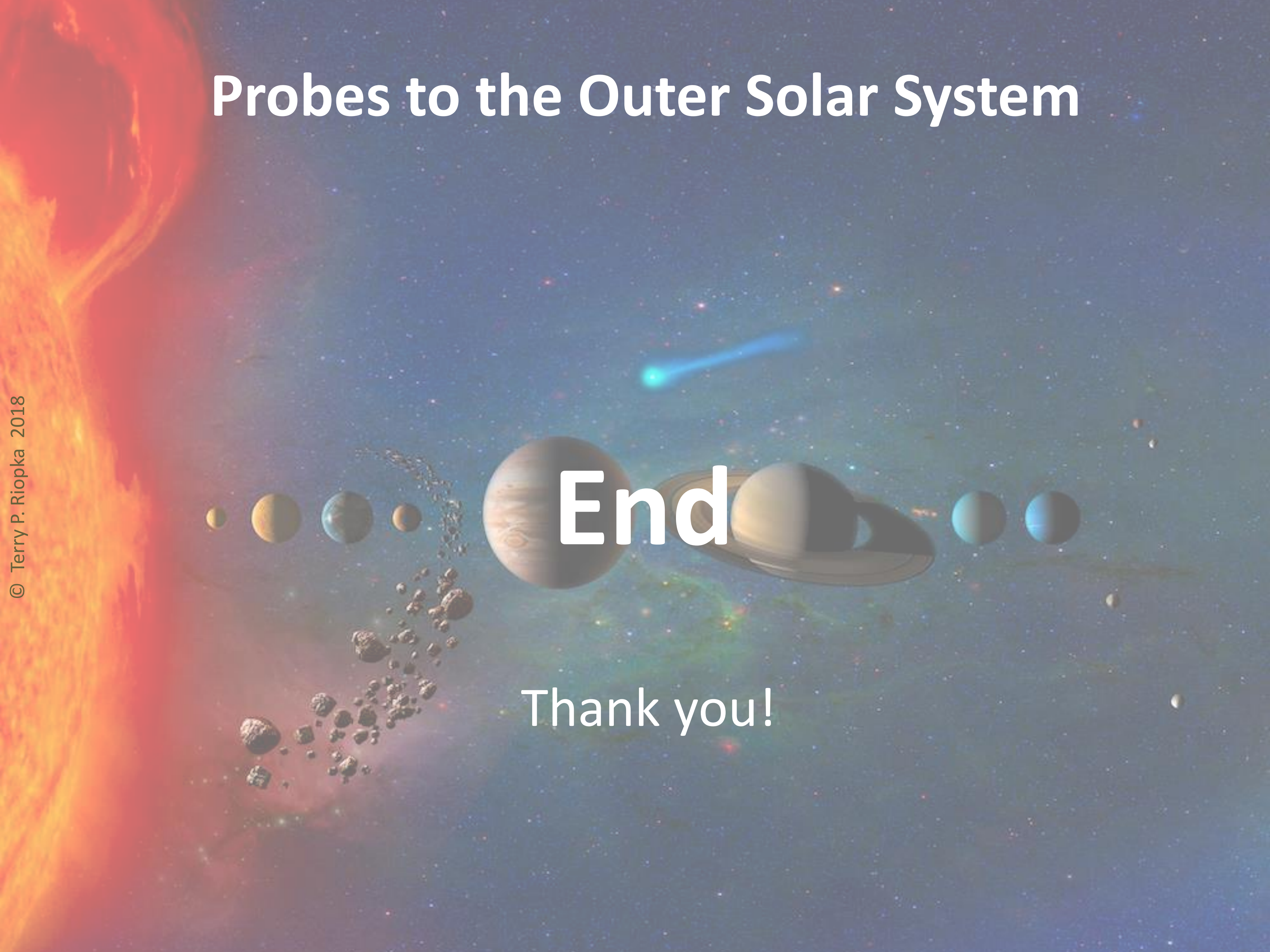
General solution approach - broad search followed by local pruning and optimization:

- an impulsive, patched-conic–based search algorithm (called **STAR**), capable of adding optimal powered flybys and impulsive leveraging/deep space maneuvers between flybys, was used for the initial broad search
- mission goals and constraints were then used to further prune the solution space
- subset of the remaining large set of trajectories was then refined using JPL's Mission Analysis Low-Thrust Optimizer (**MALTO**) software, a preliminary trajectory design tool

- entry trajectories and the aerothermal environments calculated using **TRAJ** (Allen et al. 1998, 2005), a NASA Ames-developed 3-DoF (depth of field) atmospheric entry simulation

- heating correlations utilize equilibrium gas thermodynamics based on the **Gordon and McBride program**, CEA (Chemical Equilibrium with Applications) (Gordon and McBride 1994; McBride and Gordon 1996).

- HEEET (a 3-D woven, dual-layered material) layers were sized to the aerothermal environments generated by TRAJ using **FIAT** (Chen and Milos 1999; Milos and Chen 2013), a 1-D ablation and thermal analysis simulation developed at NASA Ames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Thank you!
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