Icy moons in the Solar System

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Selected chapters on astrophysics (NAST021)
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room TAU, 14:50–16:20

Course overview

1. Motivation - why do we study icy moons.
   History of exploration - telescope observations, spacecraft missions.
   Surface characteristics - composition, age, and morphology.

2. Interior structure - layered models: from gravity, shape, composition.
   Hydrosphere structure - H_2O phase diagram, presence of oceans.
   Preferred models for selected satellites.

3. Thermal evolution - heat sources, heat transfer.
   Dynamics of the different planetary layers.
   Melting/crystallization, anti-freezers.
   Implications for the long-term stability of subsurface oceans.

4. Overview of future missions.
   Selected applications.

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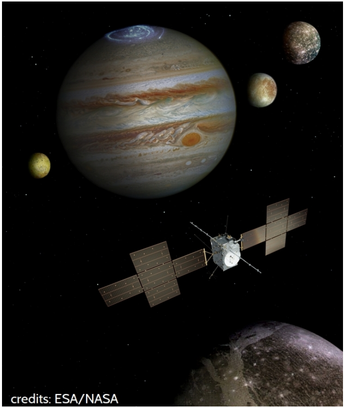
first large-class ESA mission

2022	planned launch
~7.6 yr	cruise phase
EVEME	gravity assist



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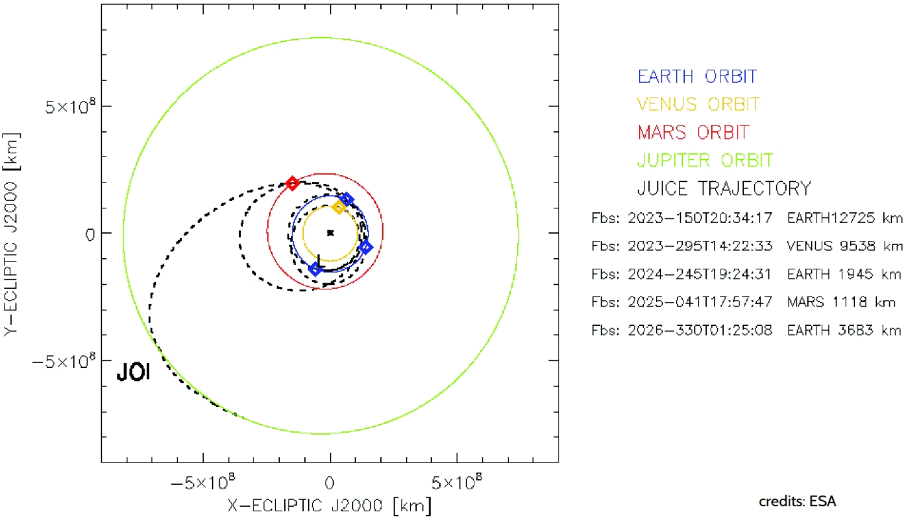
- cruise phase



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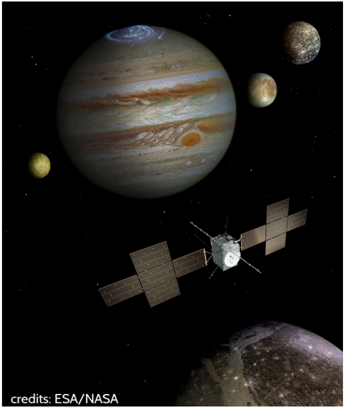
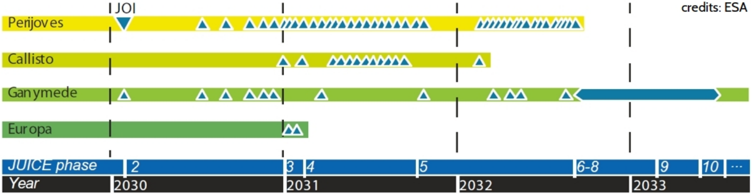
EVEME	gravity assist
2030	Jupiter Orbit Insertion
~2.5 yr	Jupiter tour
~8 m	Ganymede tour



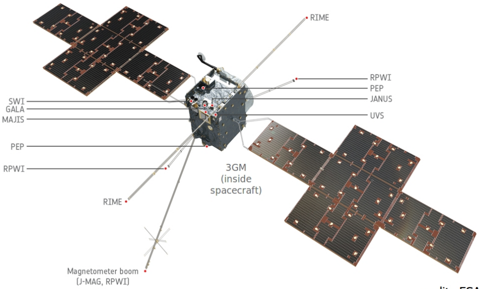


JUpiter ICy moons Explorer (JUICE)

spacecraft & science payload

~60–75 m^2 solar arrays (solar constant ~46 W m^{-2} vs. 1360 W m^{-2} @ Earth)

1h46m signal roundtrip, 3m high-gain antenna, 1.4 Gb daily downlink



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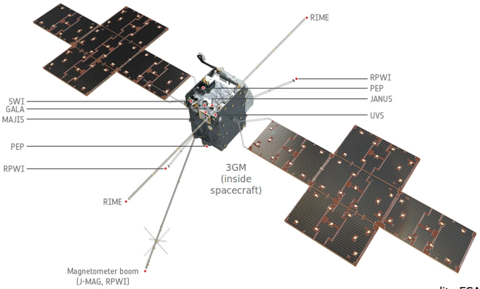

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- radar sounder (RIME)
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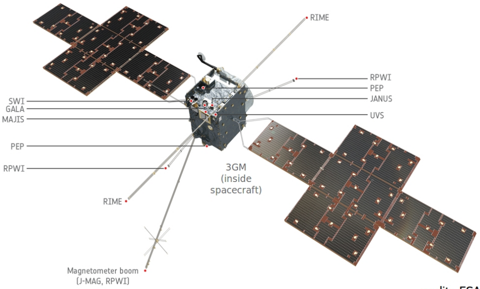

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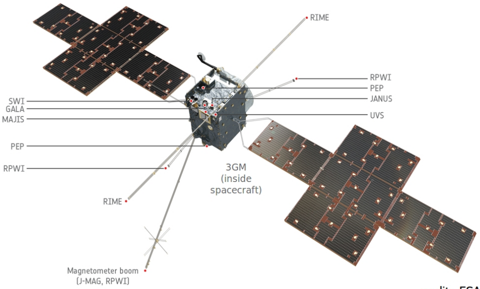
  - magnetometer (J-MAG)



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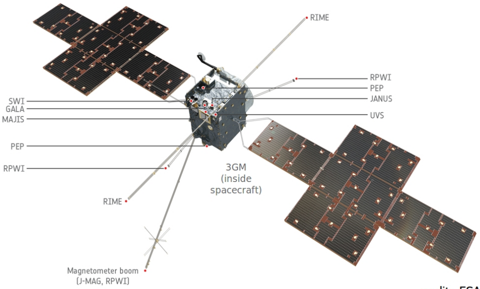
- spacecraft position+velocity (PRIDE)



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science objectives

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- Ganymede (in orbit) & Callisto (12 flybys):
  - characterisation of ocean layers
  - surface mapping (topography, geology, composition)
  - physical properties of icy crusts
  - internal mass distribution, interior dynamics & evolution
  - Ganymede's intrinsic mg field, interactions with J. magnetosphere

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- magnetosphere

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  - atmosphere (structure, dynamics & composition)
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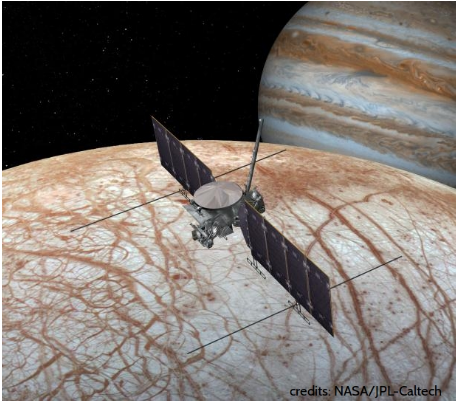
- Jupiter system:
  - moons' interactions with magnetosphere
  - gravitational coupling
  - long-term tidal evolution of Galilean satellites

Europa Clipper

NASA flagship mission

2022-25	planned launch
3–6 yr	cruise phase
trajectory	- direct (SLS) - with gravity assists (Delta IV / Falcon)



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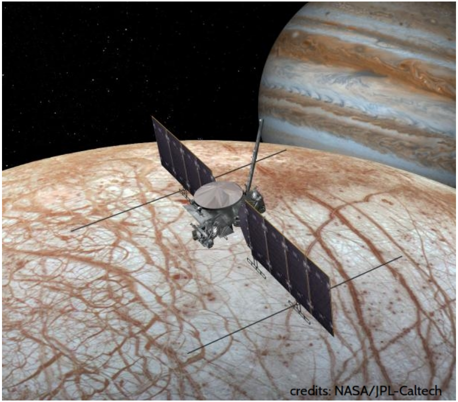
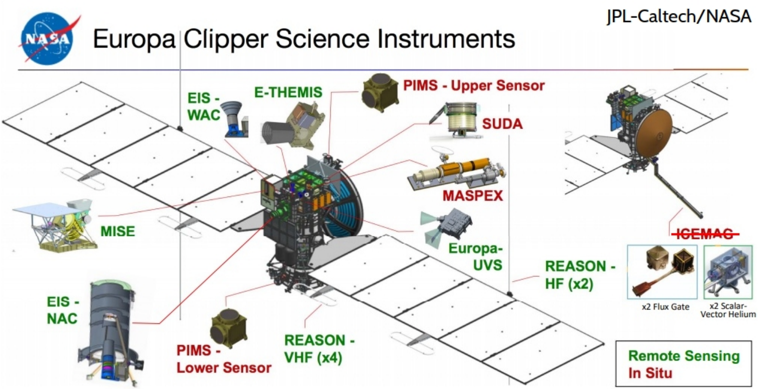
- Multiple Flyby Orbiter (around Jupiter)
- nominal mission:
  - 45 Europa flybys
  - closest-approach altitudes ~25–2700 km above surface





remote Europa Imaging System (EIS) - Narrow/Wide Angle Cameras
Mapping Imaging Spectrometer for Europa (MISE)
Ultraviolet Spectrograph/Europa (UVS)
Europa THermal EMission Imaging System (E-THEMIS)
Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)

in situ Plasma Instrument for Magnetic Sounding (PIMS)
Europa Clipper Magnetometer (?)
MAss Spectrometer for Planetary EXploration/Europa (MASPEX)
SUrface Dust mass Analyzer (SUDA)

Europa Clipper

science goal

Explore Europa to investigate its habitability

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science objectives

Ice Shell & Ocean

Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange

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Composition

Understand the habitability of Europa's ocean through composition and chemistry

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Ice Shell & Ocean

Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange

Composition

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Geology

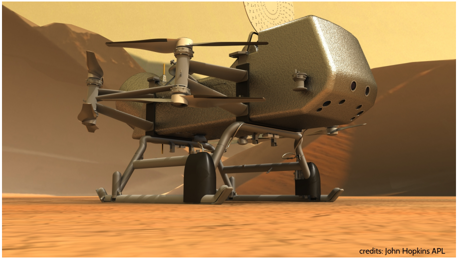
Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities

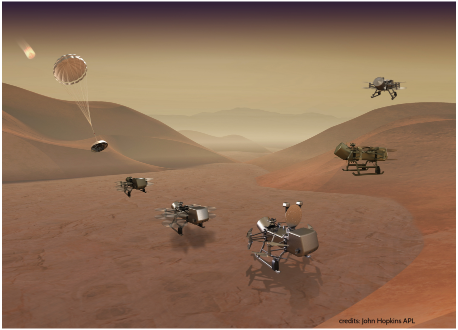
Dragonfly

NASA New Frontiers mission

- rotorcraft lander mission

2026	planned launch
2034	landing on Titan
~2 yr	baseline mission





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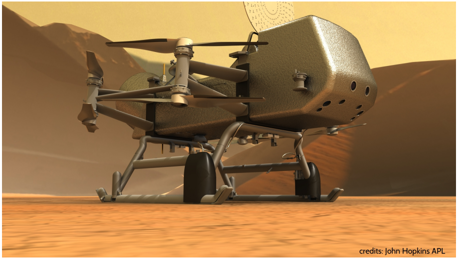
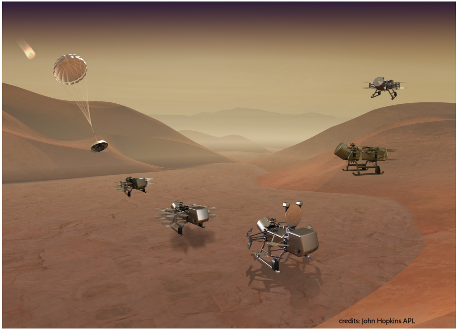
  ~2 yr baseline mission
- dense atmosphere & low gravity
  → flying is an ideal way to travel to different areas





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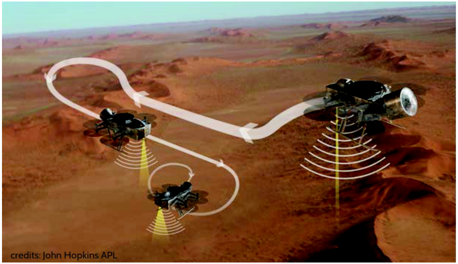
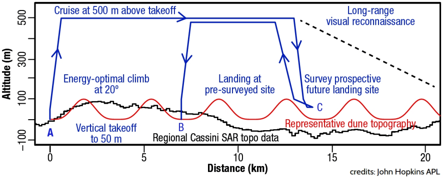
- rotorcraft lander mission
  - 2026 planned launch
  - 2034 landing on Titan
  - ~2 yr baseline mission
- dense atmosphere & low gravity → flying is an ideal way to travel to different areas
- most measurements on ground
- flight used to:
  - explore different sites
  - provide context measurements of surroundings





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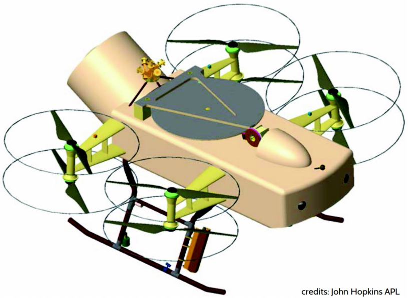
science objectives

- analyze chem. components & processes to produce biologically relevant compounds
- measure atmospheric conditions, identify CH_4 reservoirs, determine transport rates
- constrain processes to mix organics w liquid water reservoirs (past surface / ocean)
- search for chemical evidence of water-based or hydrocarbon-based life



credits: John Hopkins APL

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science payload

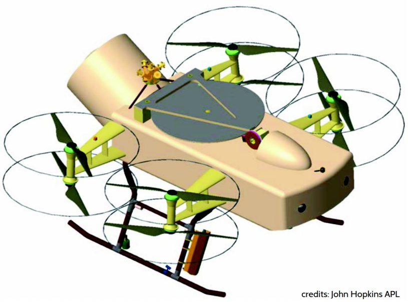
- mass spectrometer:

  - material sampling, chemical analysis
- gamma-ray and neutron spectrometer:

  - surface composition; minor elements
- meteorology, seismic + geophys. sensors:

  - monitor atmosphere & surface conditions
  - seismic monitoring - subsurface activity?
- camera suite:

  - char. geologic features, provide context



credits: John Hopkins APL

Notes on the homework

idea **reconstruction of interior structure of synthetic satellites**

- data provided will include:
  - mass M, radius R
  - reduced moment of inertia MoI
  - information on the presence of ocean
  - limited information on composition
  - range of admissible densities / EoS