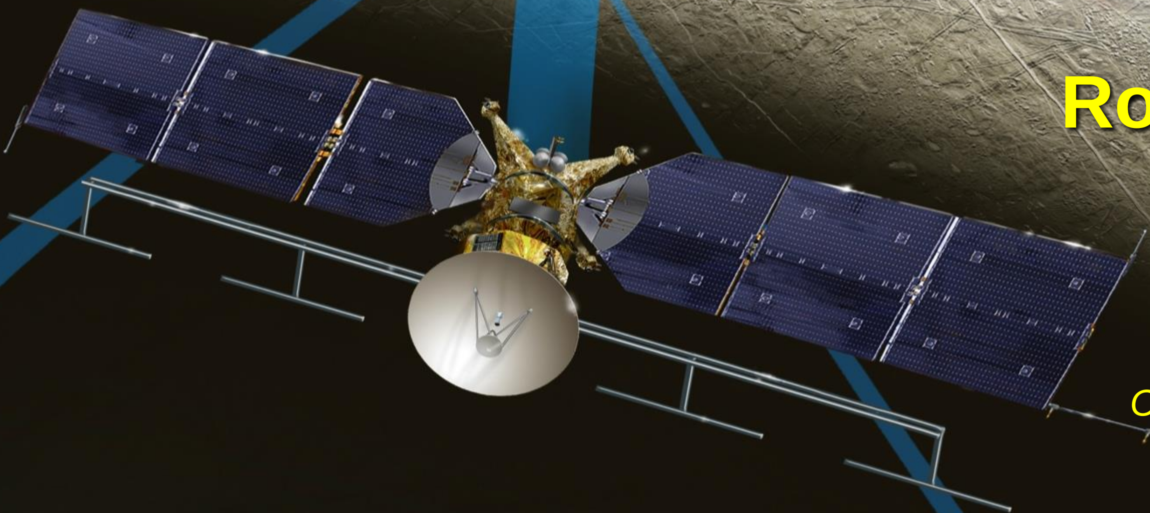
Europa Update



Barry Goldstein

Project Manager

Robert Pappalardo

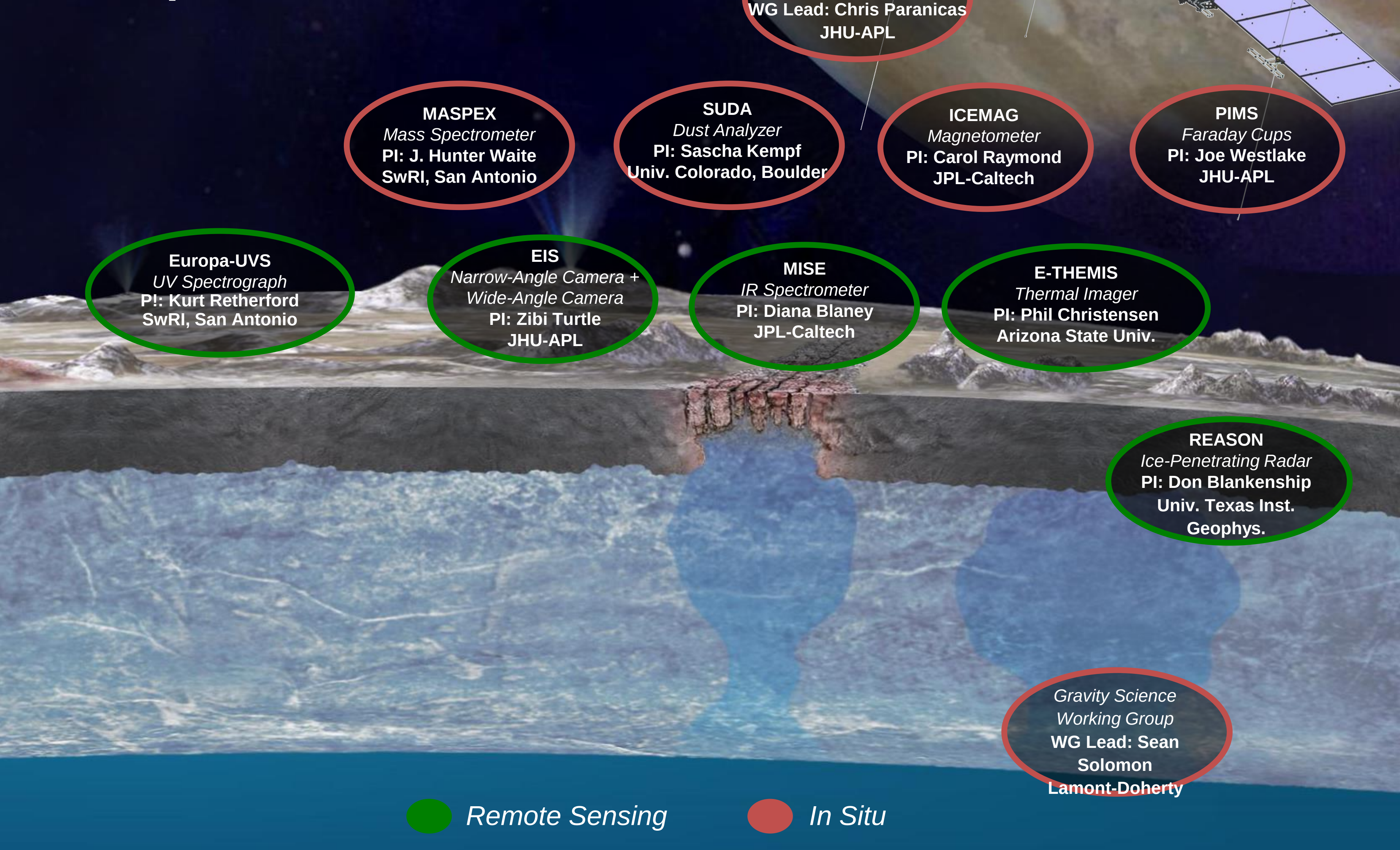
Project Scientist

Jet Propulsion Laboratory,

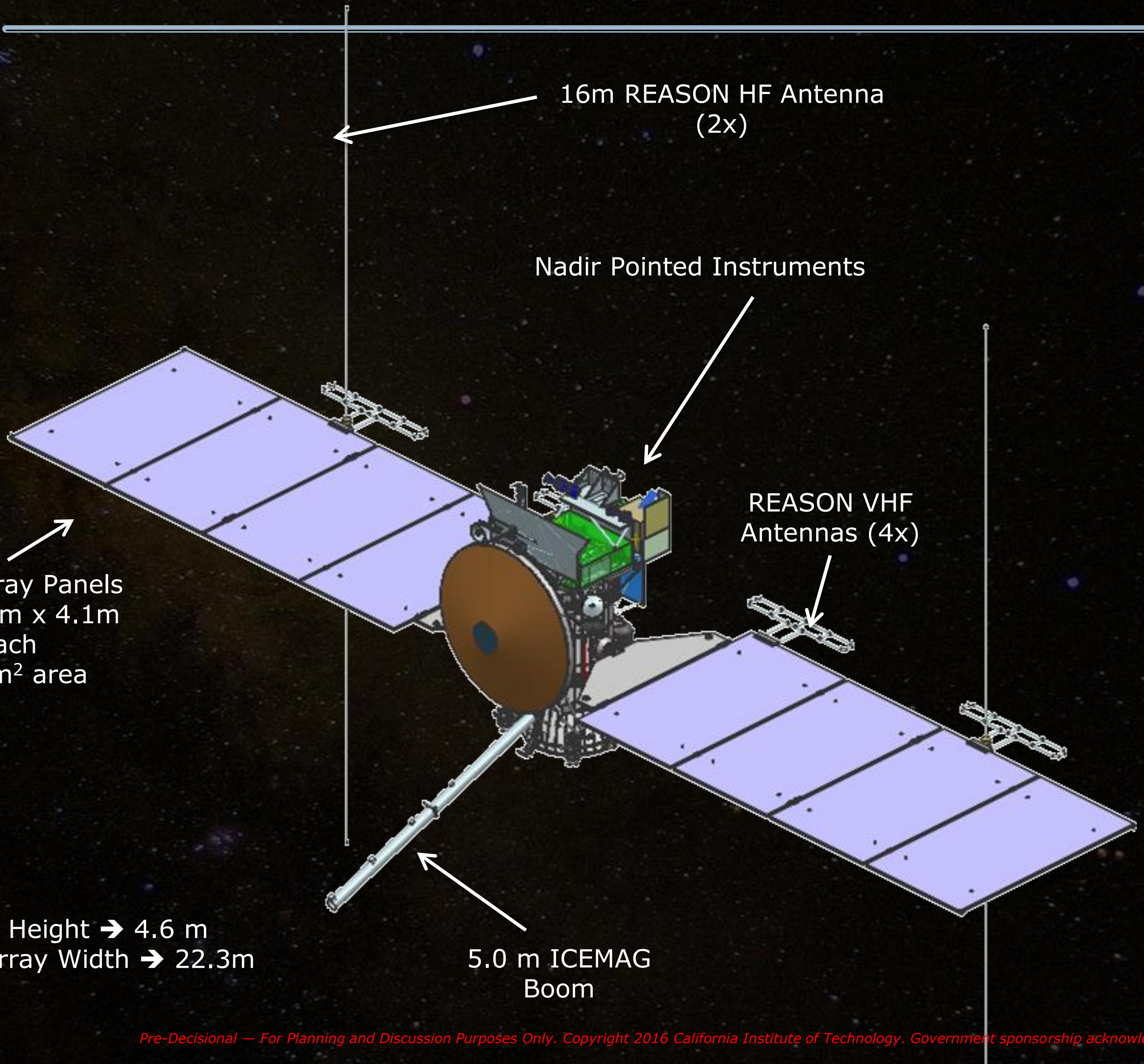
California Institute of Technology

March 30, 2016

NASA-Selected Europa Instruments

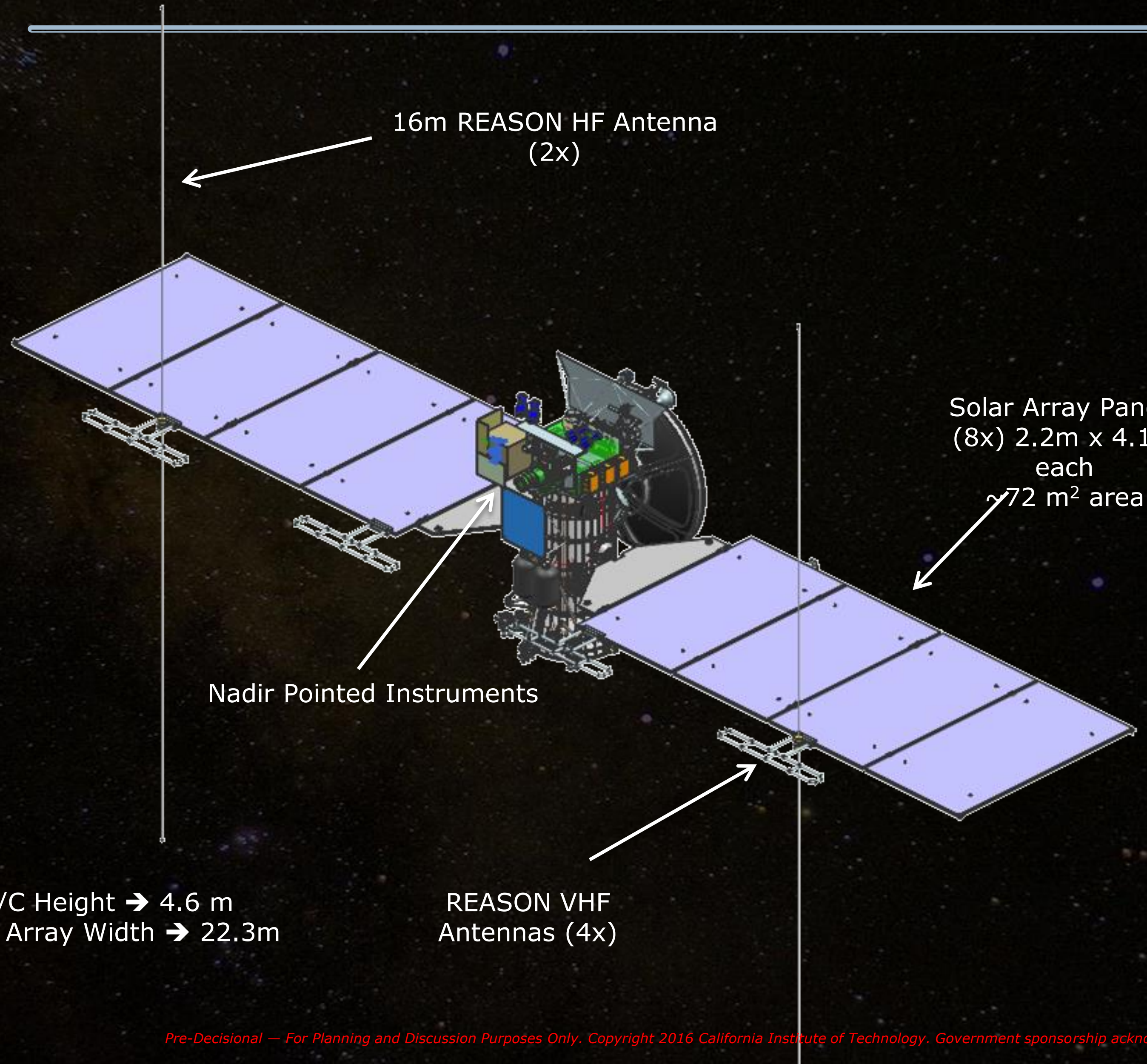


Proposed Flight System Configuration



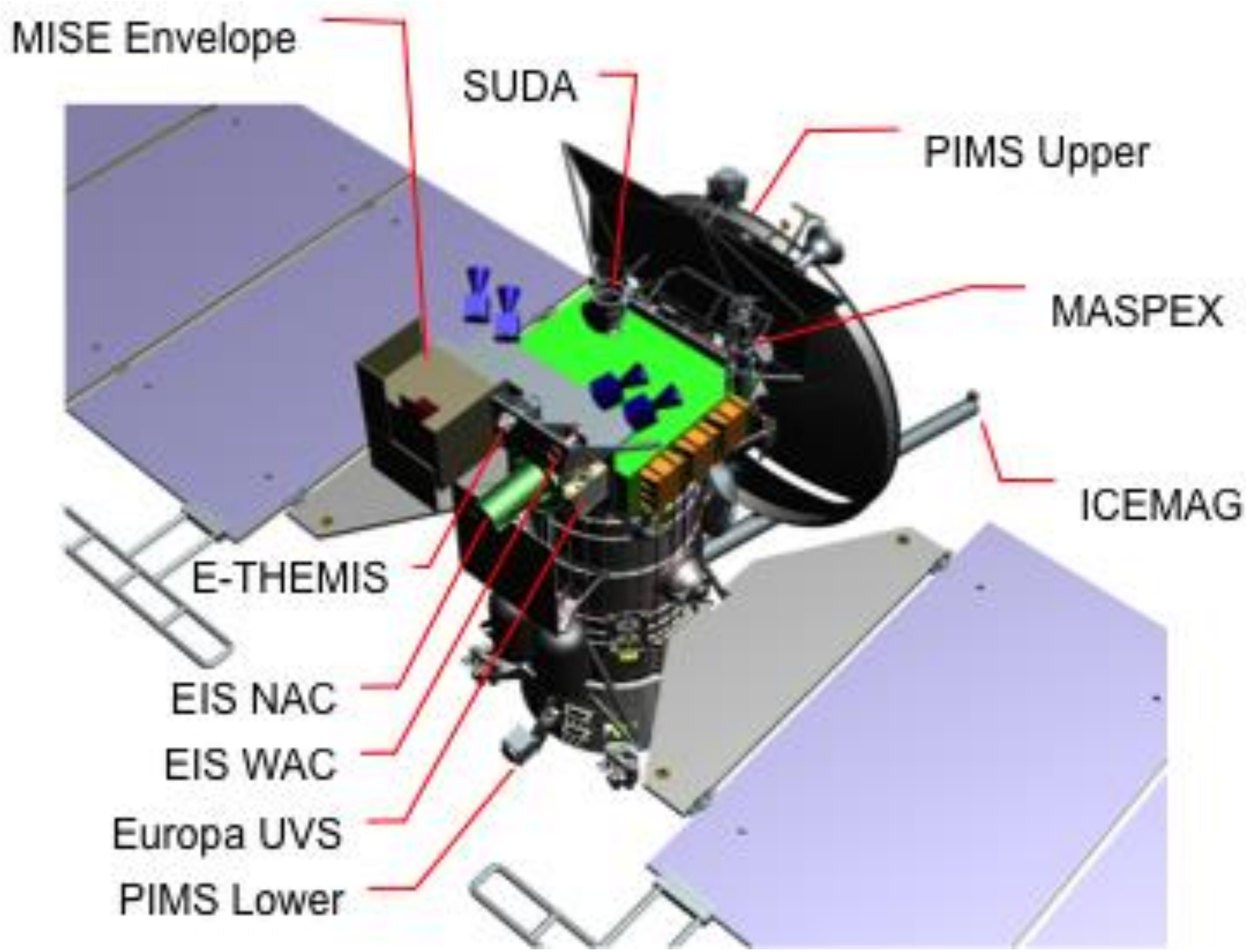
S/C Height ➔ 4.6 m
Solar Array Width ➔ 22.3m

Proposed Flight System Configuration



S/C Height ➔ 4.6 m
Solar Array Width ➔ 22.3m

Payload Accommodation



Mission Enhancements?

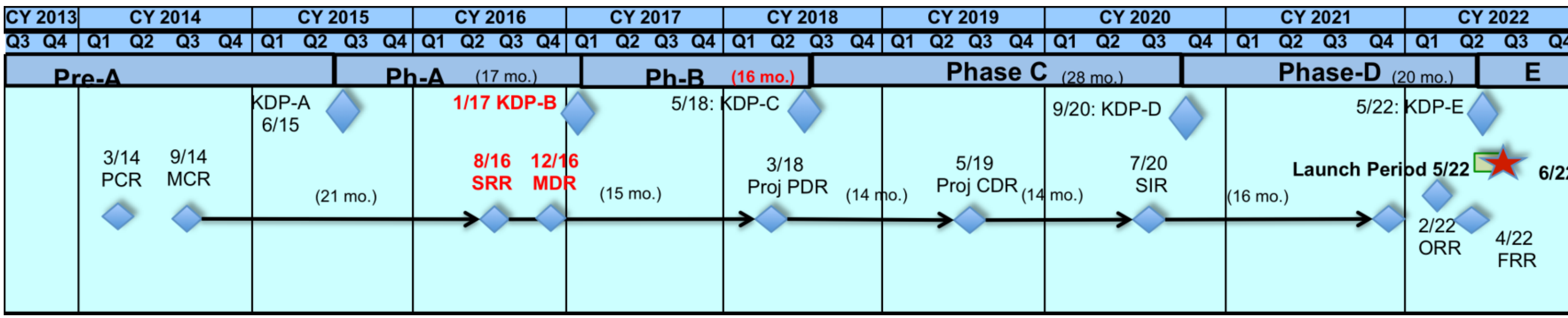
- Several options for mission enhancements have been under study
  - Plume Free Flyers
  - Landed Element
  - Gravity Science Working Group (GSWG)

- Direction received in February
  - Keep Clipper on 2022 launch path
  - Extend lander study as a Pre-Project
    - Only as a separate S/C launched either co-manifest (SLS only possible LV) or separate launch
    - Evaluate longer time on surface, greater payload capacity

- Direction received in March
  - Plume Free Flyers removed from consideration
  - In response to recommendation from GSWG, Project evaluating the accommodation impacts of a Laser Altimeter

Top Level Schedule (UPDATED)

(June 2022 Launch)

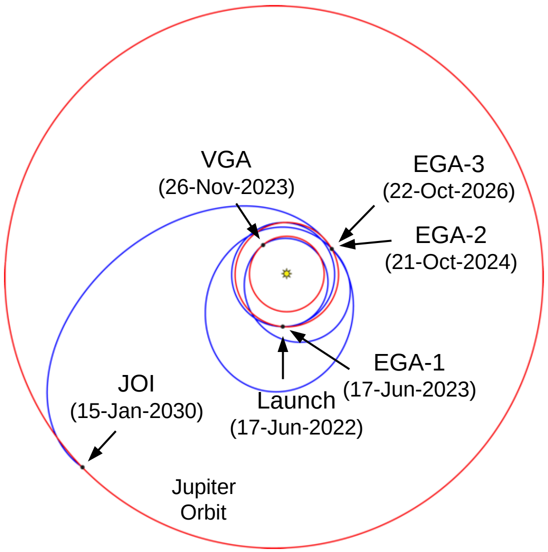


Trajectory 1 ➔ "EVEEGA"

- Earth, Venus, Earth, Earth Gravity Assist
  - Low energy trajectory that acquires energy for Jupiter transit via four planetary flybys

- **Pro's**
  - Low launch energy provides for significant launch mass (or lower capability launch vehicle)

- **Con's**
  - Long flight time (7.5 years for 2022 launch)
  - Requires inner solar system cruise
    - Venus Sun distance drives thermal design of the Spacecraft and payload

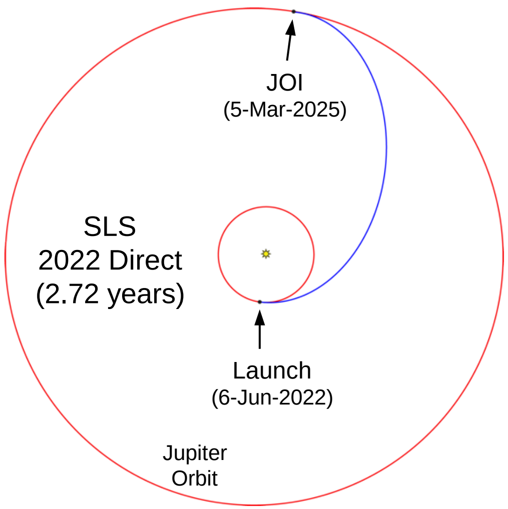


Trajectory 2 ➔ Direct

- **Launch and go directly to Jupiter**
  - Do not pass Go, do not collect …….

- **Pro's**
  - Quickest transit to Jupiter (2.7 years for 2022 launch)
  - No inner solar system cruise (thermal design advantage)

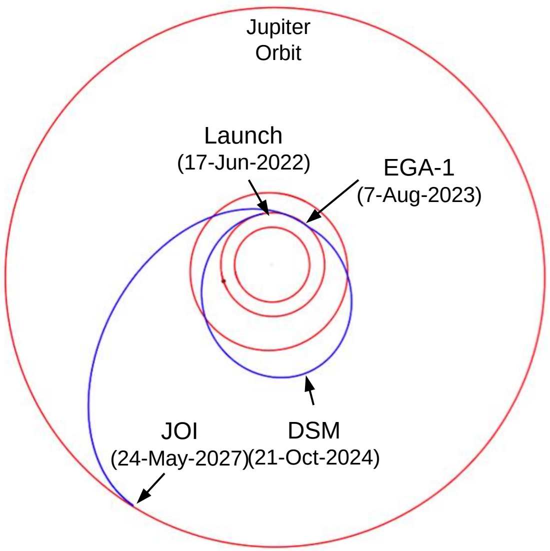
- **Con's**
  - Need very large rocket!
    - SLS only vehicle capable of this transit



Trajectory 3 ➔ Δv/EGA

- **Delta** **V**elocity, **E**arth **G**ravity **A**ssist
  - Between previous two trajectories in launch energy.
  - Requires large Deep Space Maneuver (Δv) and one earth flyby (Juno is flying this trajectory)
    - “2+” : Earth flyby is before the maneuver
    - “2-” : Earth flyby is after the maneuver

- **Pro’s**
  - Shorter transit than EVEEGA (4.9 years for 2022 launch)
  - No inner solar system cruise (thermal design advantage)

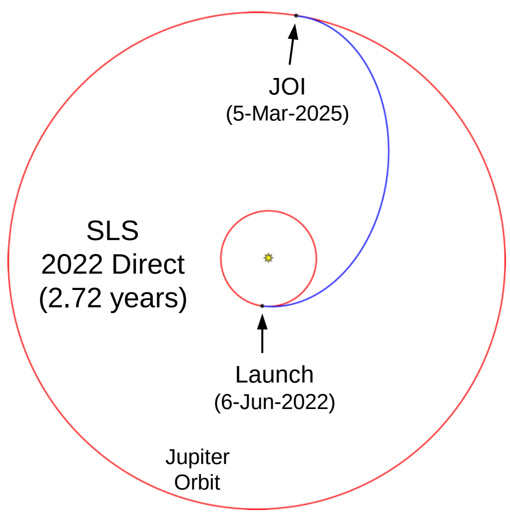


- **Con’s**
  - Deep space maneuver requires significant propellant and associated fuel tank size
    - Increased mass requires large lift capability

Current Jupiter Delivery Strategy

Baseline

Launch Vehicle: SLS Block-1
Transfer: Earth-Jupiter Direct
Time-of-flight: 2.5-2.7 yrs.

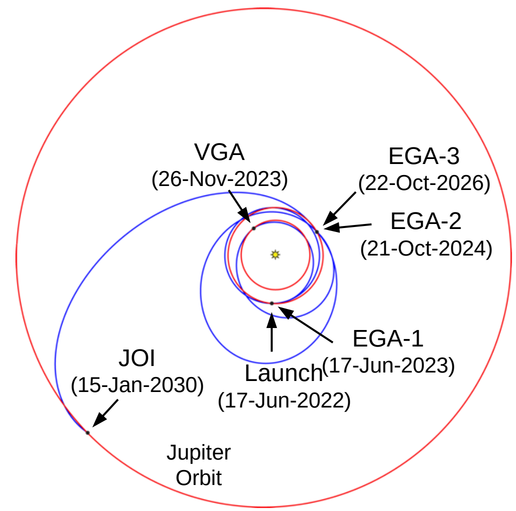


Mass Margin

35% - 2022 Launch
33% - 2023 Launch

Backup

Launch Vehicle: Atlas V 551 or Delta IV Heavy
Transfer: EVEEGA
Time-of-flight: 7.4 yrs.



Mass Margin

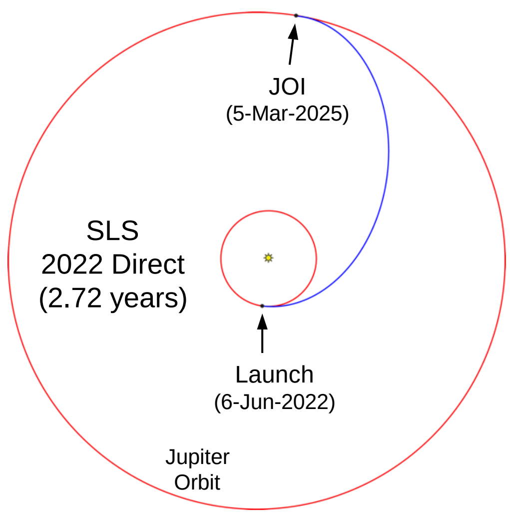
Atlas V 551		**Delta IV Heavy****
29%	**2022 Launch**	**65%**
30%	**2023 Launch**	**66%**

** **IF fully** utilize L.V. capability

Modified Jupiter Delivery Strategy
[With 250 kg ESA/NASA Asset Mass Holdback]

BASELINE

Launch Vehicle: SLS Block-1
Transfer: Earth-Jupiter Direct
Time-of-flight: 2.5-2.7 yrs.

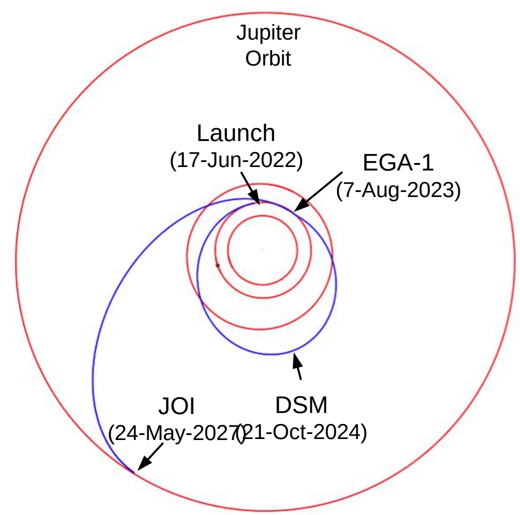


Mass Margin

27% - 2022 Launch
24% - 2023 Launch

Backup

Launch Vehicle: Delta IV Heavy
Transfer: Δv/EGA
Time-of-flight: 4.7 yrs.



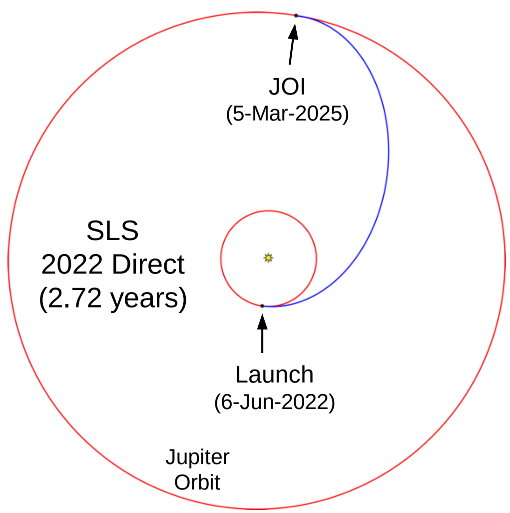
Mass Margin

26% - 2022 Launch
26% - 2023 Launch

Modified Jupiter Delivery Strategy
[Without ESA/NASA Asset Mass Holdback]

Baseline

Launch Vehicle: SLS Block-1
Transfer: Earth-Jupiter Direct
Time-of-flight: 2.5-2.7 yrs.

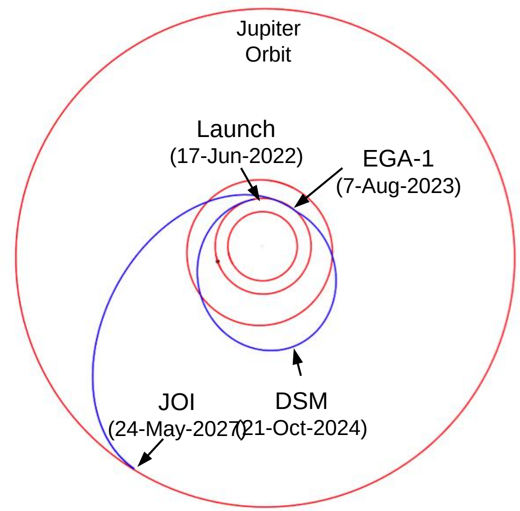


Mass Margin

35% - 2022 Launch
33% - 2023 Launch

Backup

Launch Vehicle: Delta IV Heavy
Transfer: Δv/EGA
Time-of-flight: 4.7 yrs.



Mass Margin

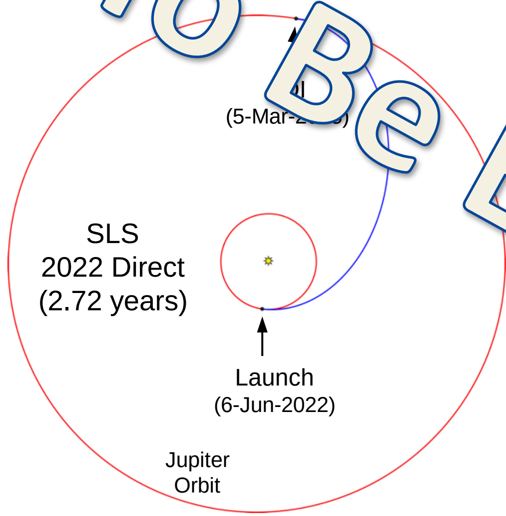
34% - 2022 Launch
34% - 2023 Launch

To be verified

Modified Jupiter Delivery Strategy
[With Laser Altimeter?]

Baseline

Launch Vehicle: SLS Block-1
Transfer: Earth-Jupiter Direct
Time-of-flight: 2.5-2.7 yrs.

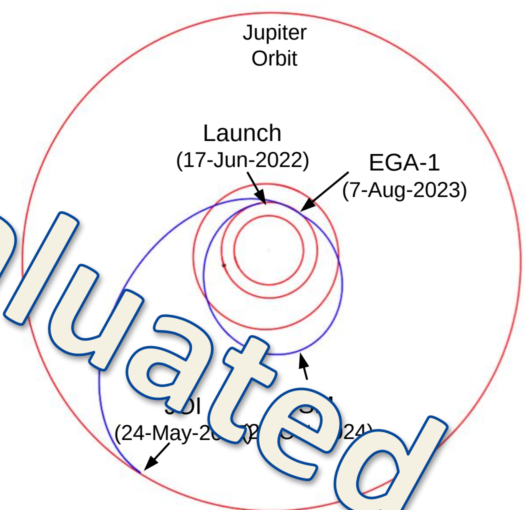


Mass Margin

35% - 2022 Launch
33% - 2023 Launch

Backup

Launch Vehicle: Delta IV Heavy
Transfer: Δv/EGA
Time-of-flight: 4.7 yrs.



Mass Margin

34% - 2022 Launch
34% - 2023 Launch

To be verified

To Be Evaluated

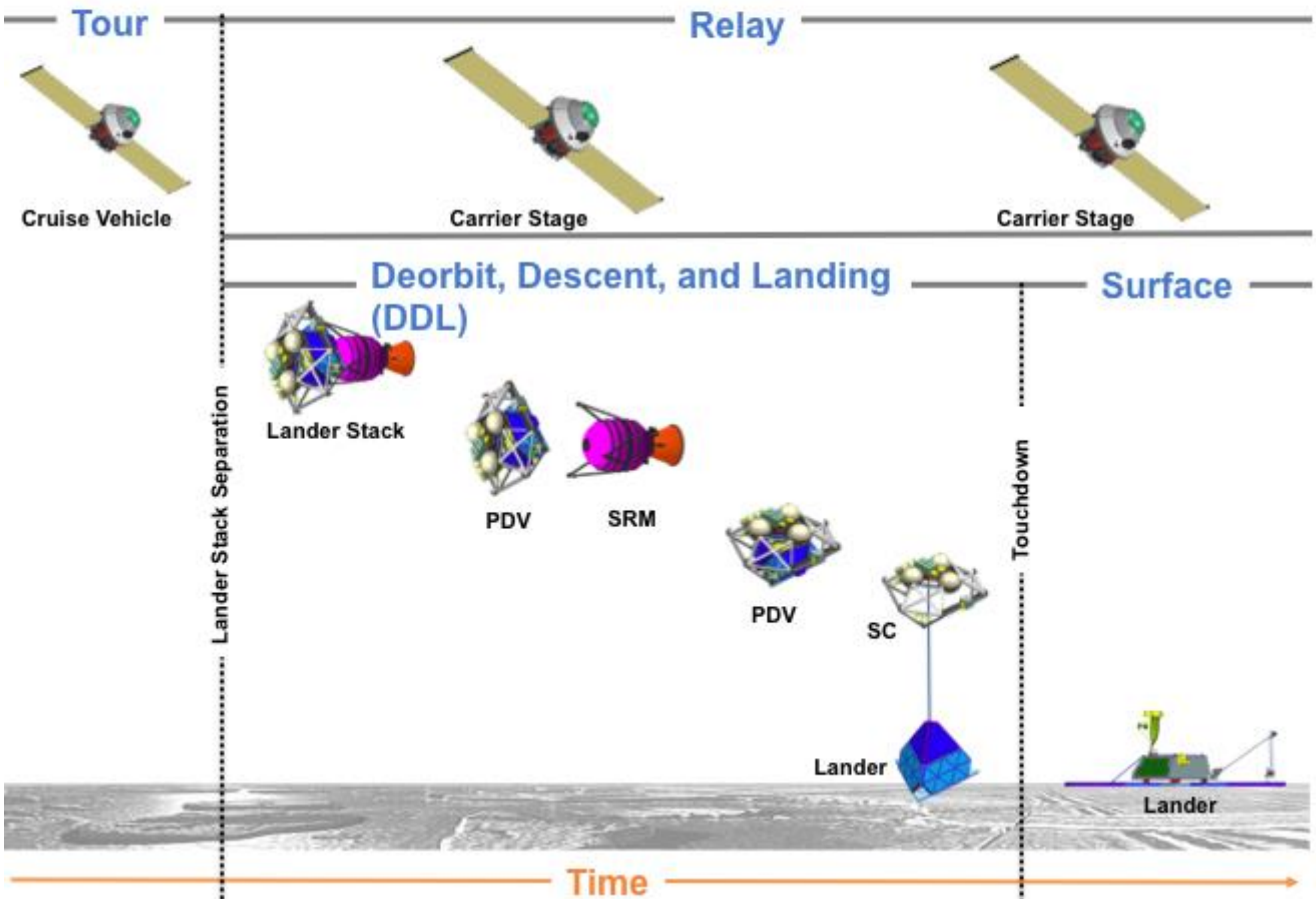
03/30/2016

Lander Concept

Concept Highlights

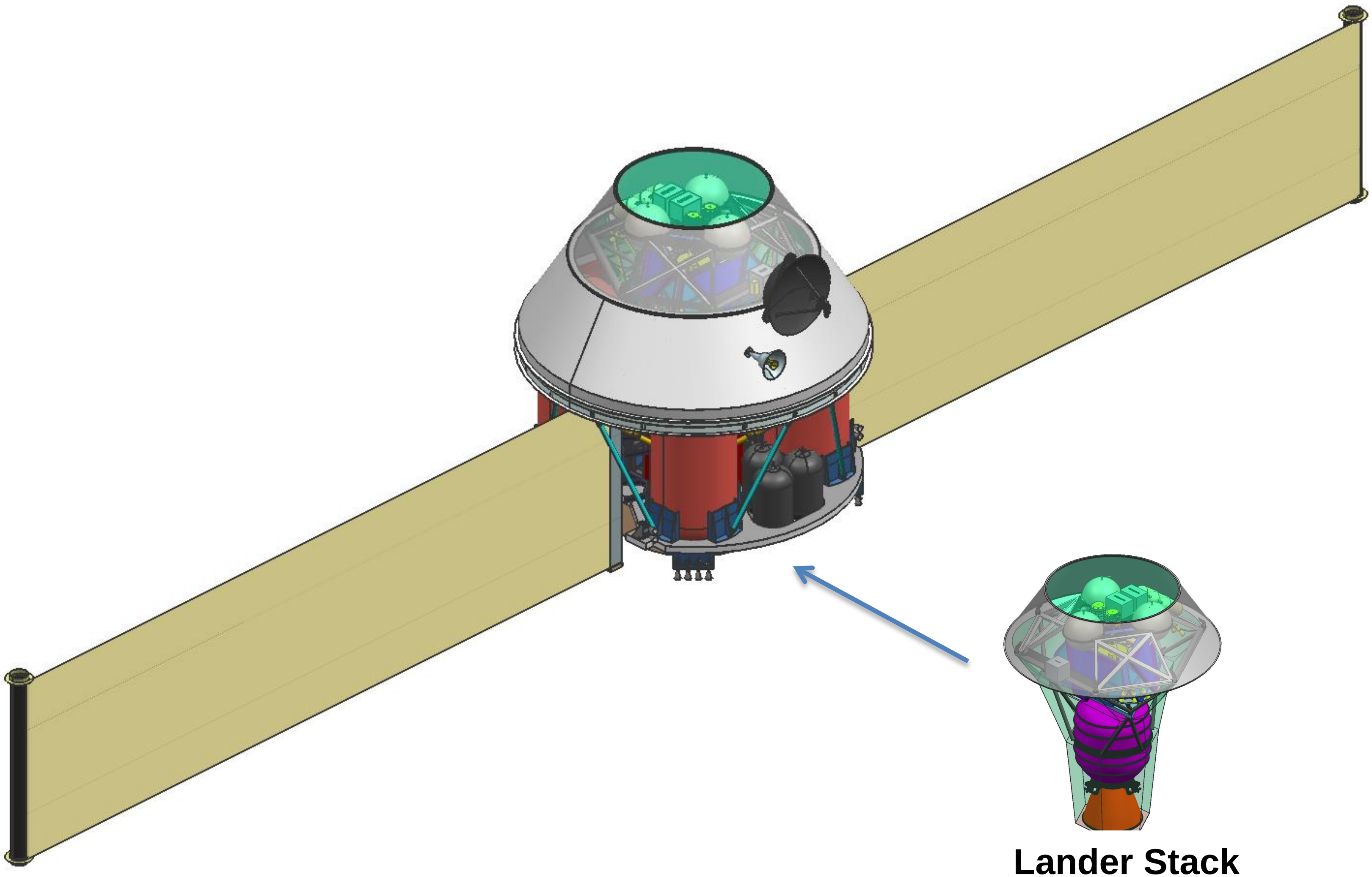
- Spacecraft physically decoupled from Clipper
- Enter Jovian system and '*park*' in a radiation safe orbit awaiting reconnaissance from Clipper to decide where to target landing
- Spacecraft components:
  - **Carrier/Orbit Stage**
    - Delivers system to Jovian system and eventually targets lander stack (everything bellow)
    - Provides relay capability (Clipper can be backup) to earth
  - **De-orbit Module**
    - Decelerates lander to capture a Europa descent trajectory
  - **Descent Module**
    - Slows down lander, terminal descent to Europa
  - **Lander**
    - Science!!!

Top-Level Mission Event Sequence

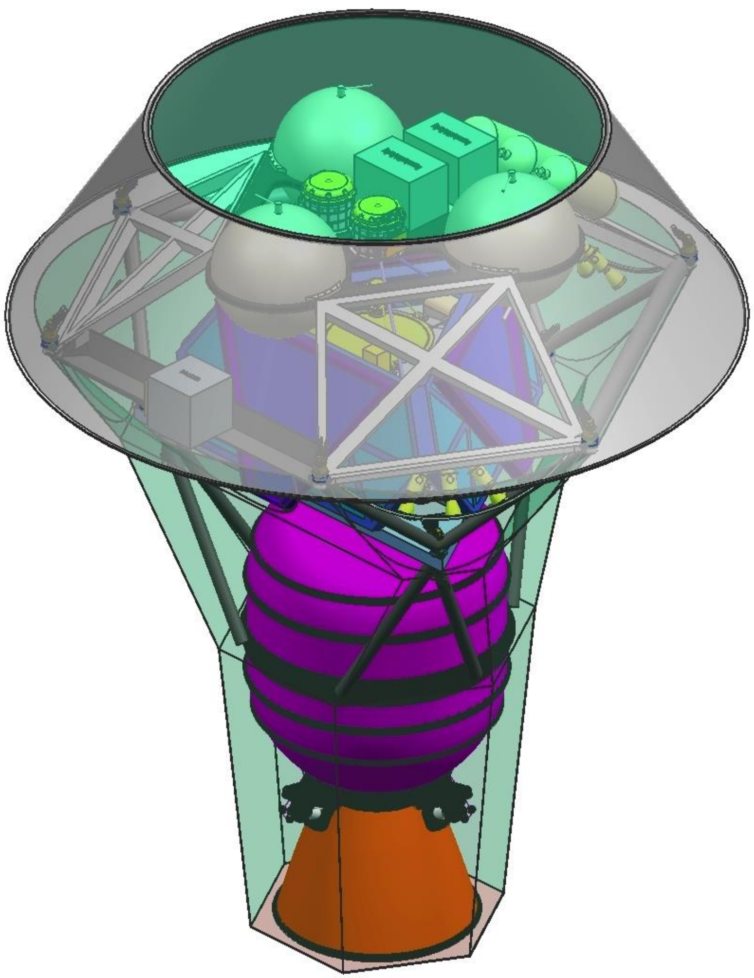


(Image source: JonLomberg.com Giclee Prints)

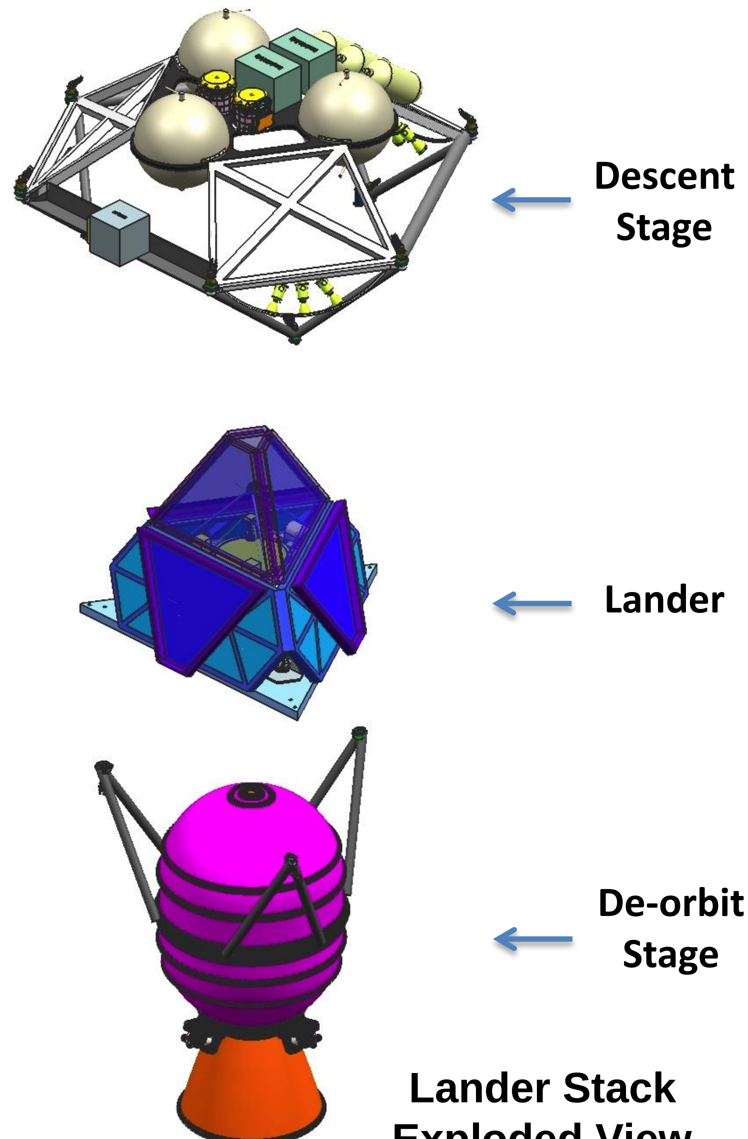
Carrier / Orbit Stage Concept



Lander Full System Concept

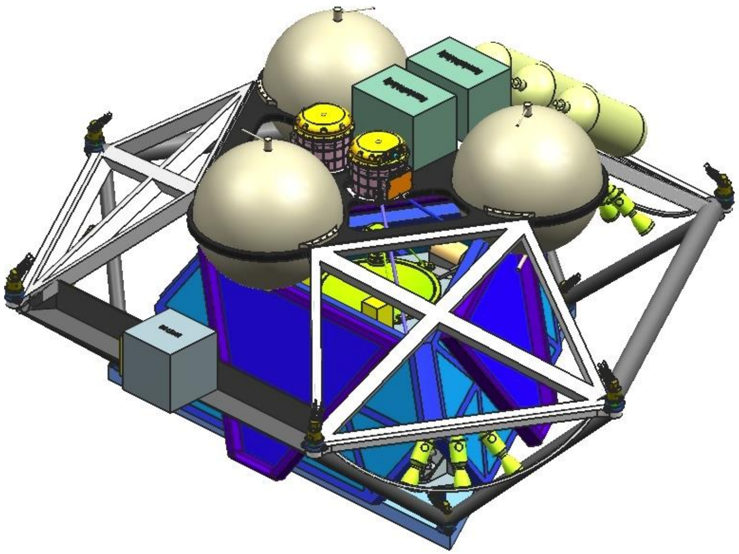


Lander Stack
at Integration

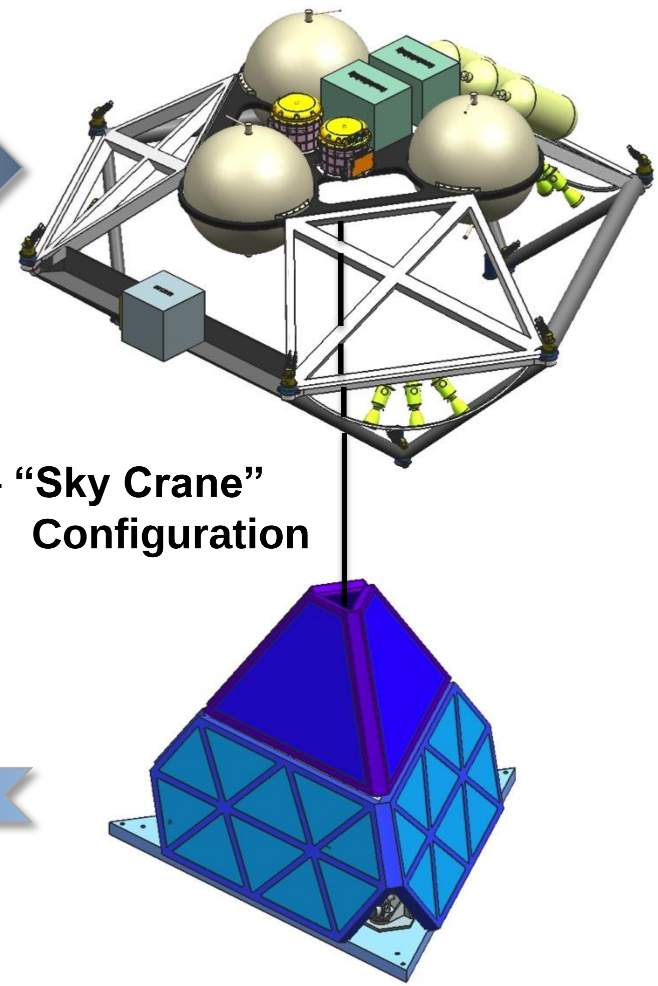


Lander Stack
Exploded View

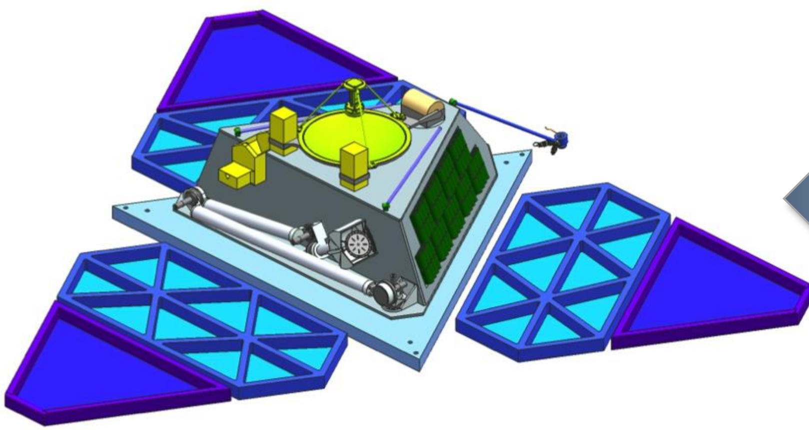
Lander Descent and Surface Concepts



1 - Descent Configuration



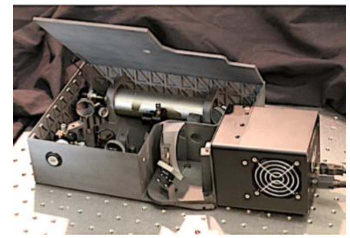
2 – "Sky Crane" Configuration

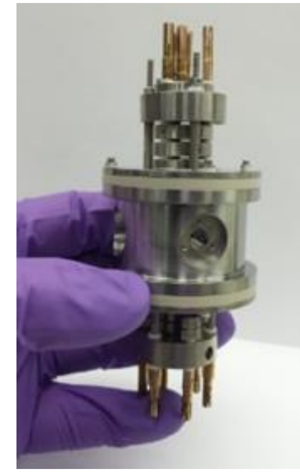


3 - Landed Deployed

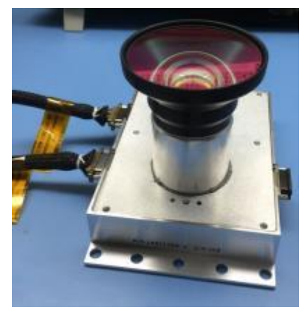
Model Payload (Total Mass: 25 kg MEV)

- Centerpiece Instruments for Astrobiology
  - **GCMS**: VCAM GC + Ion Trap MS, 8.3 kg CBE
  - **Raman**: SHERLOC 5.4 kg CBE



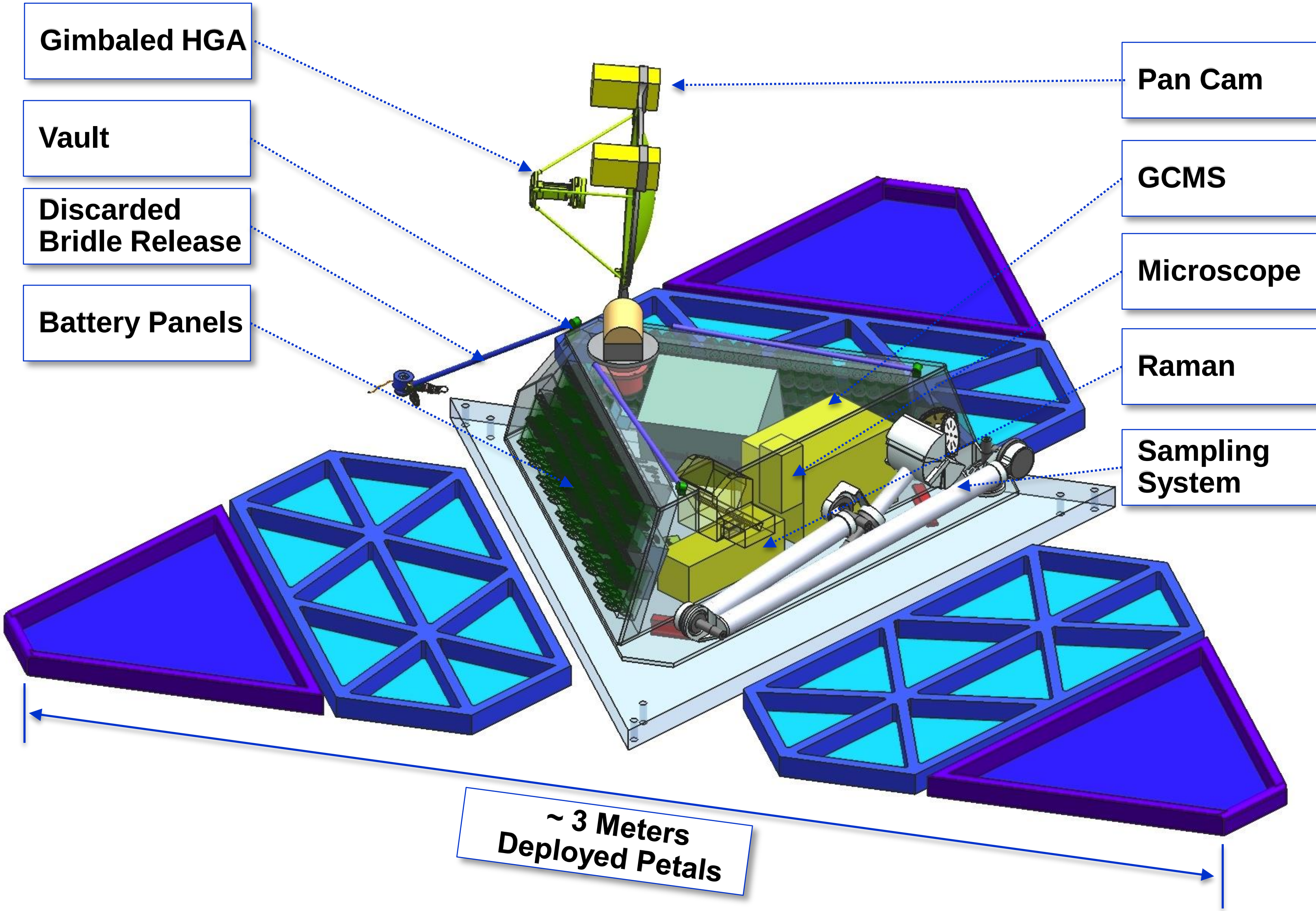


- Auxiliary Instruments
  - **Context LanderCams (x2)**, 0.5 kg each CBE
  - **Microscopic SampleCam**, 0.5 kg CBE



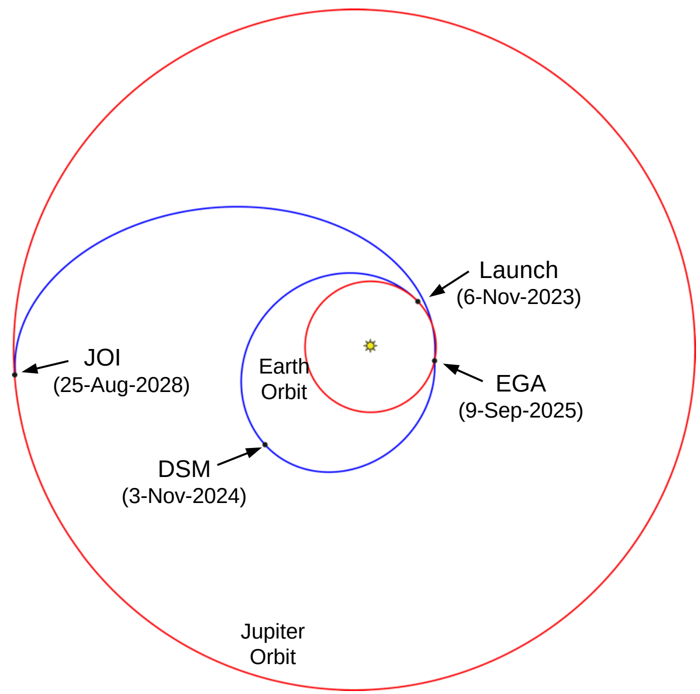
- Baseline Instrument (not included in Threshold)
  - **3-axis Geophone**, 0.8 kg

Lander Surface Concept



Lander Jupiter Trajectory

Launch Vehicle: SLS Block-1
Interplanetary Transfer: Δv/EGA $(2:1^-)$
Time-of-flight: 4.6 yrs.



Mass Margin

60+% - 2023 Launch