Jet Propulsion Laboratory
California Institute of Technology

Europa Clipper Mission Update to CAPS

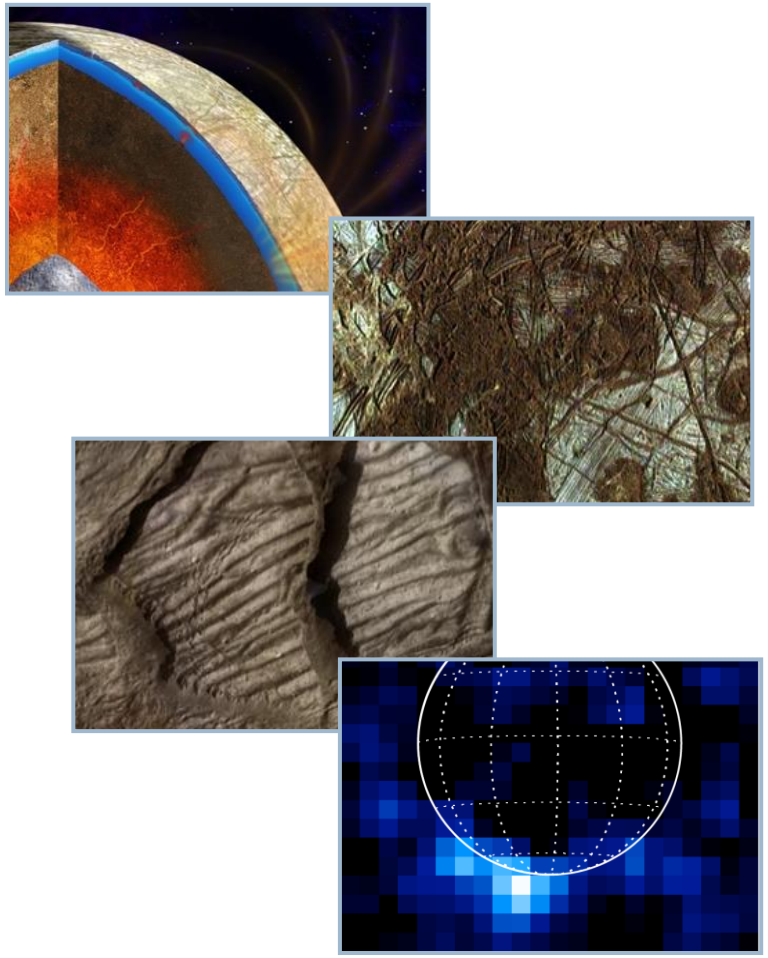
Oct. 21, 2024

Robert Pappalardo, Project Scientist (Jet Propulsion Laboratory, California Institute of Technology)
Tim Larson, Deputy Project Manager (Jet Propulsion Laboratory, California Institute of Technology)

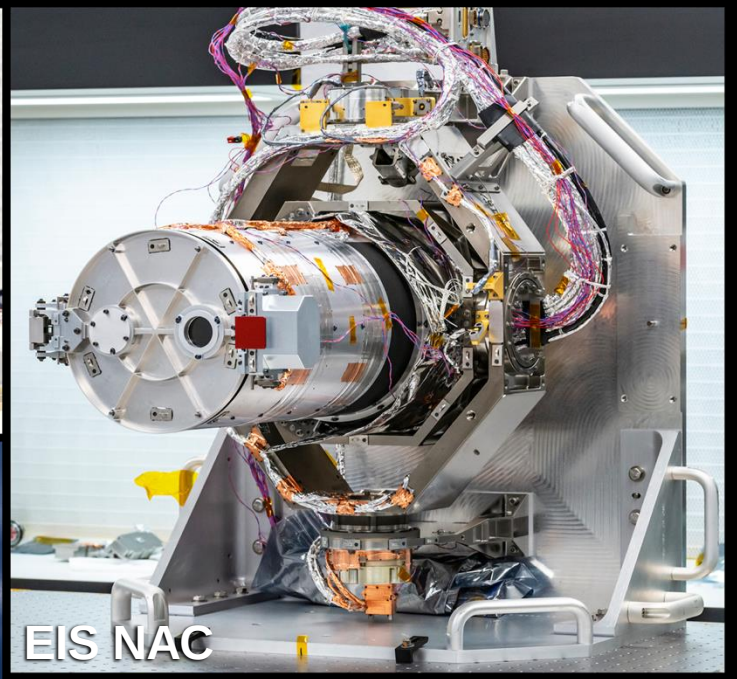
Europa Clipper Science Goal and Objectives

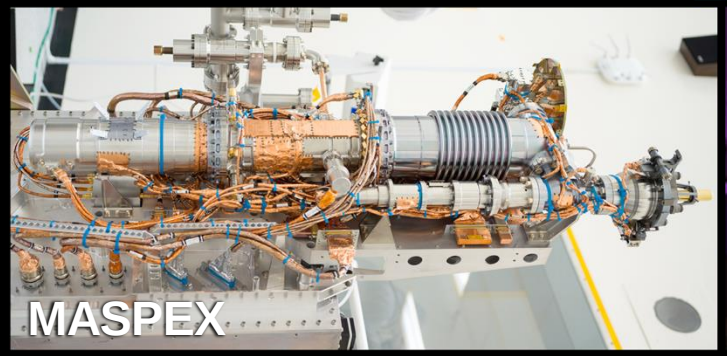
- *Science Goal:* **Explore Europa to investigate its habitability**
- *Science Objectives:*
  - **Ice Shell & Ocean:** Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange
  - **Composition:** Understand the habitability of Europa's ocean through composition and chemistry
  - **Geology:** Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities

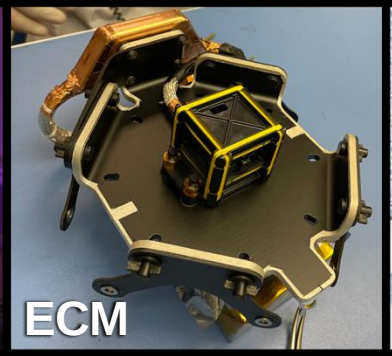
  Current Activity cross-cuts all three principal science objectives



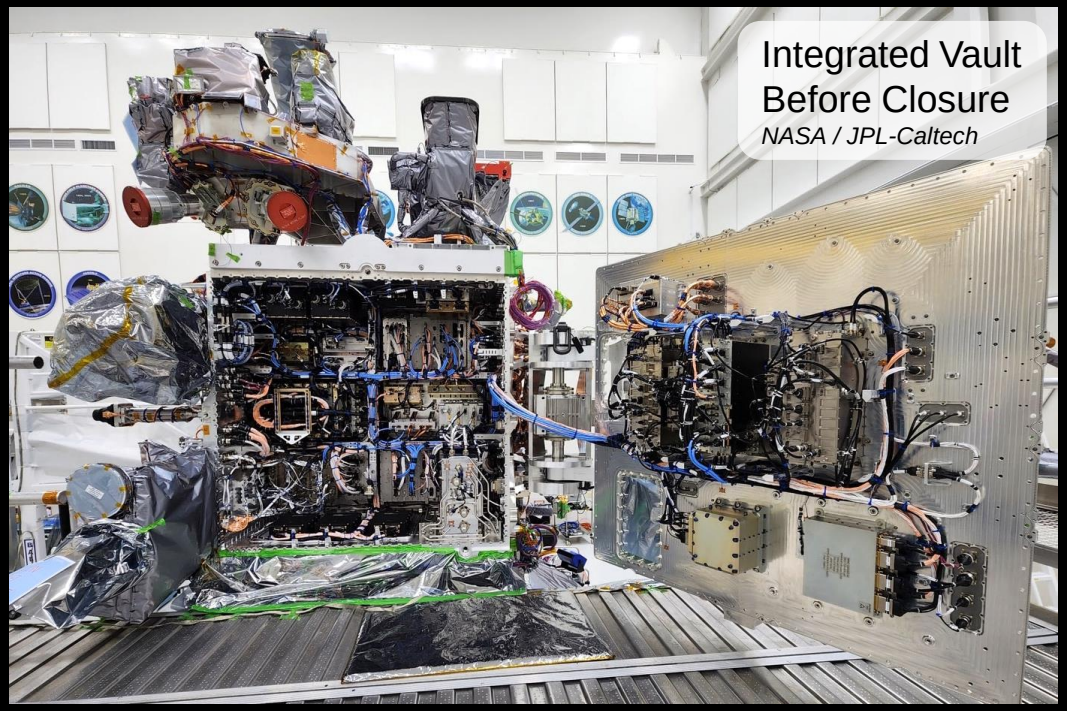
Europa Clipper's Instrument Suite





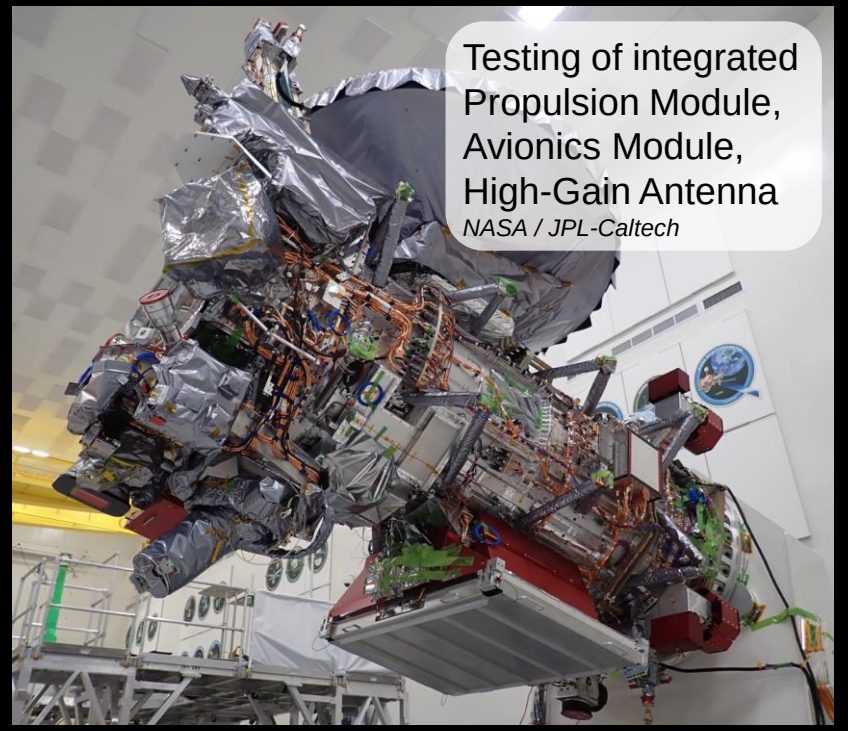


Spacecraft Integration



Integrated Vault Before Closure
NASA / JPL-Caltech

Clipper with Solar Array Mass Simulators
NASA / JPL-Caltech

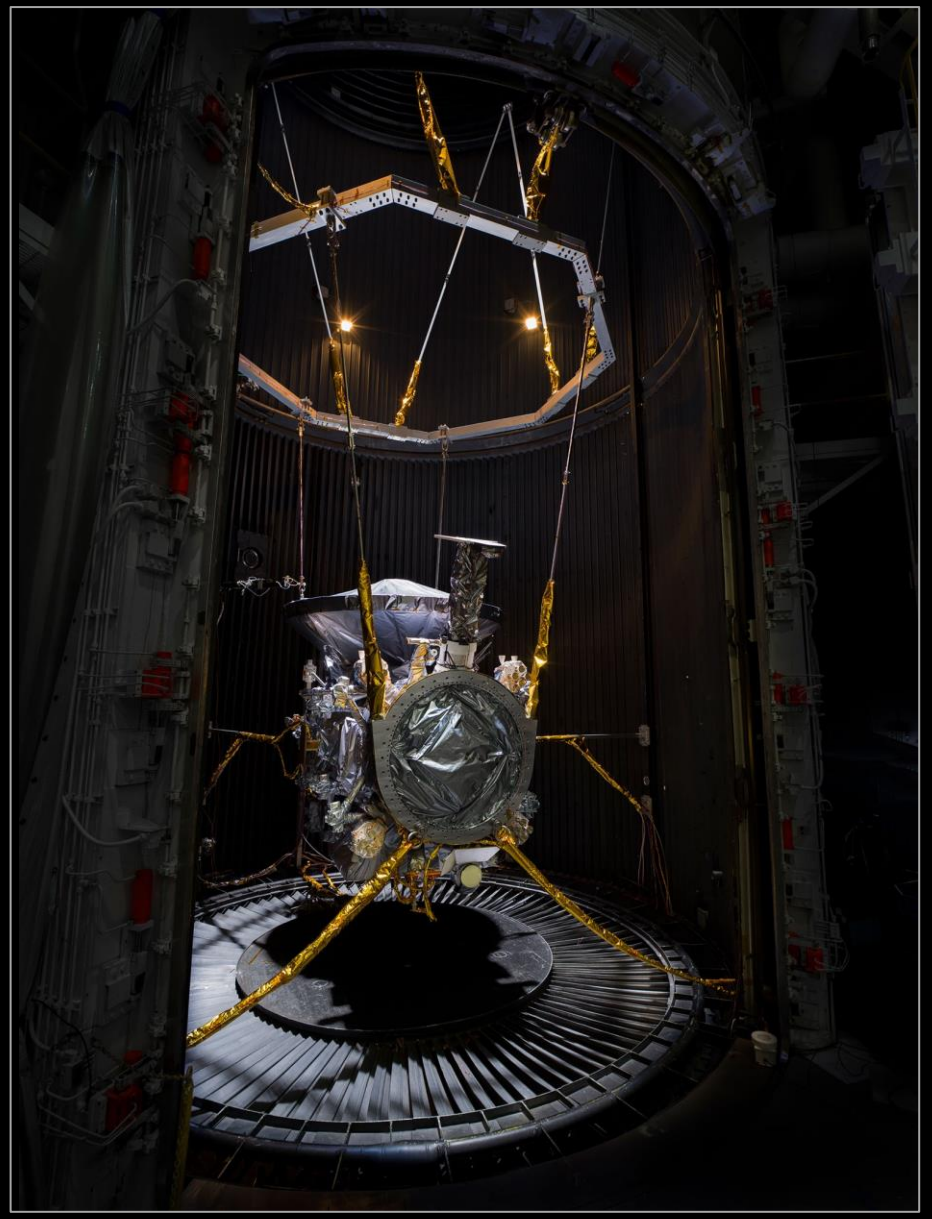


Testing of integrated Propulsion Module, Avionics Module, High-Gain Antenna
NASA / JPL-Caltech

Mag Boom Deployment Test
NASA / JPL-Caltech

Solar Arrays
Airbus, Netherlands

Thermal-Vacuum Testing in the JPL Space Simulator



Europa Clipper Solar Arrays at Kennedy Space Center

Europa Clipper from JPL to Kennedy Space Center

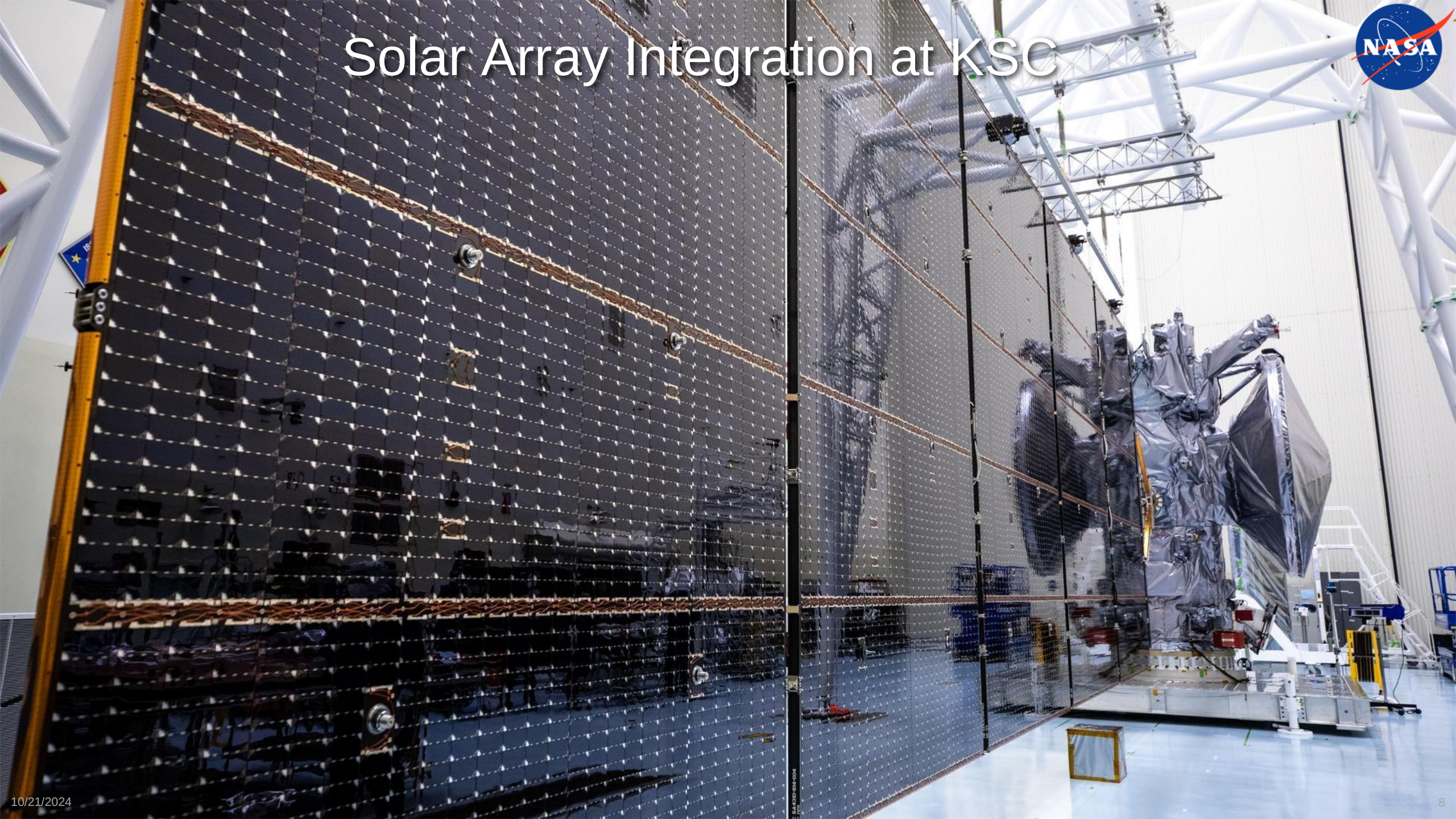
Clipper departs JPL
NASA / JPL-Caltech / Bob Pappalardo

Offloading Clipper at KSC
NASA / Isaac Watson

Clipper arrival at KSC Payload Servicing Facility
NASA / Isaac Watson

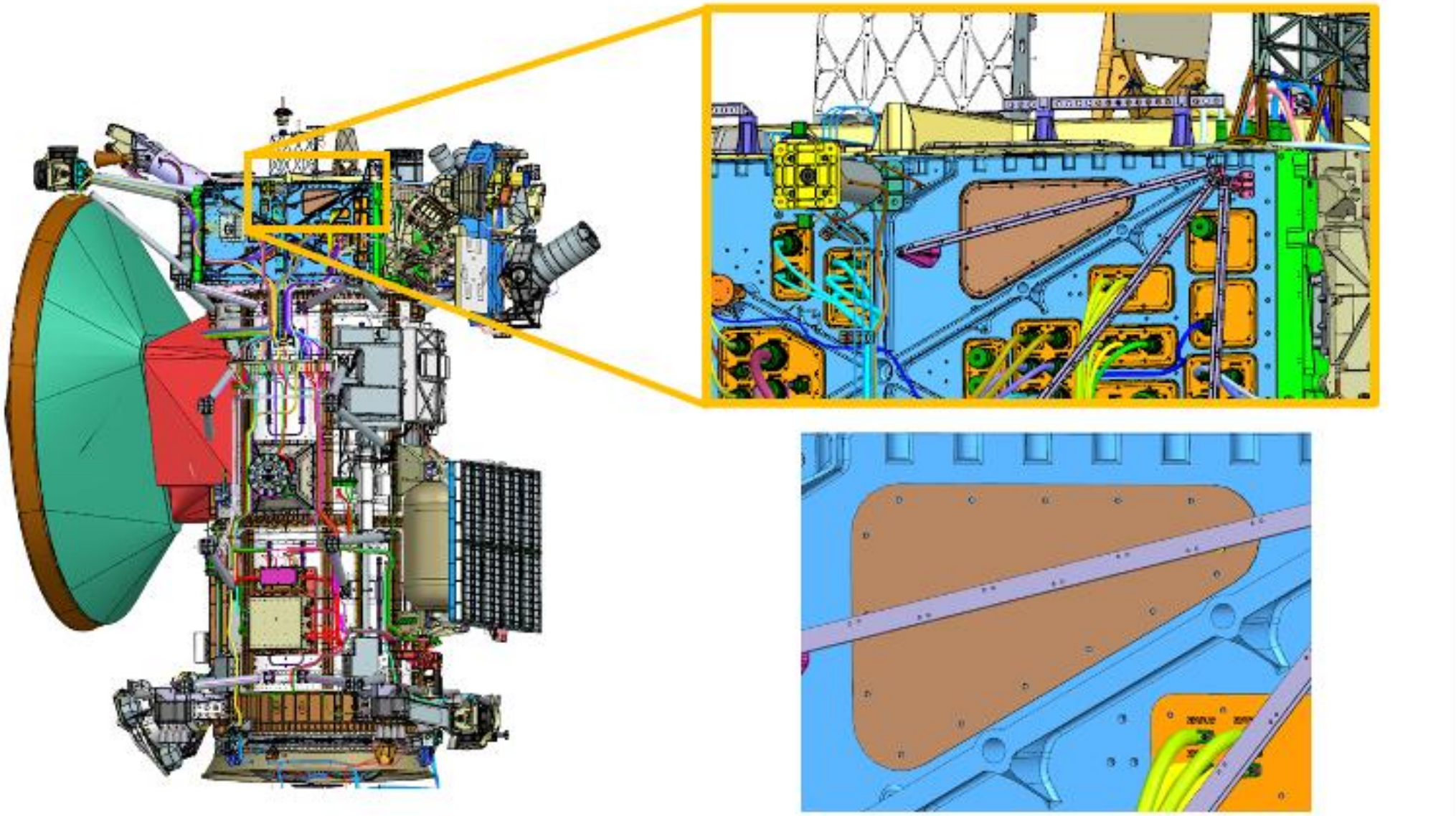
C-17 flight to KSC
NASA / Isaac Watson

Solar Array Integration at KSC



Europa Clipper Encapsulated and Transported to Hangar 39A

Europa Clipper “Vault Plate”



- A tantalum metal plate seals an opening (8.5 in x 11in) to Europa Clipper’s vault

Europa Clipper “Poem Plate” Installation

Europa Clipper “Poem Plate”

Outward-facing side:

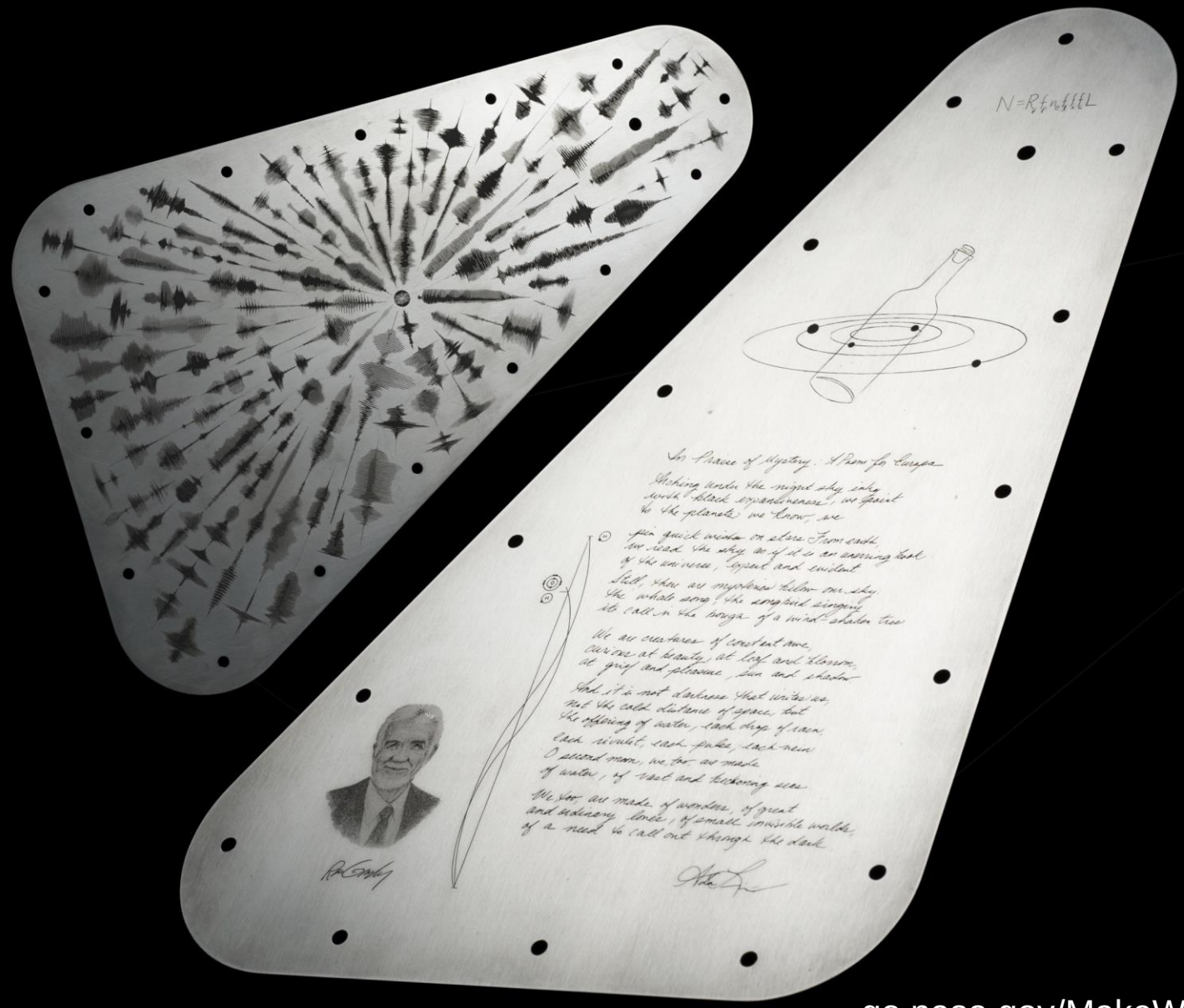
- Spoken words for water in 103 languages from across the globe, shown as waveforms
- Center representation of American Sign Language sign for water

Inward-facing side:

- *In Praise of Mystery: A Poem for Europa* by U.S. Poet Laureate Ada Limón, in her own handwriting
- Hand-drawn portrait of planetary scientist Ron Greeley
- Drake Equation, in Frank Drake’s handwriting
- OH and H radio waves (“water hole”)

The engraved designs on the vault plate represent human connections:

- Between each of us on Earth, between Earth and Europa, and between humankind and the cosmos, as we seek to learn about the possibilities of life beyond Earth
- Each element is derived from human voices or drawn by hand



go.nasa.gov/MakeWaves

ATLO Phase 6 High-Level Activities (Road Map)

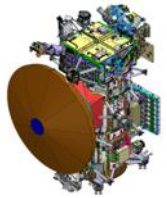
2024

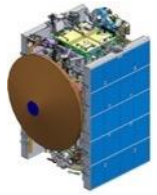
FY 2024 | FY 2025

FQ 3 | FQ 4 | FQ 1

May | June | July | August | September | October | November | December

Ship 5/23/24





Prop Load 9/13/24

2 days (Labor Day)

2 days of Margin

1 day of Margin

LV Handover 9/26/24

Launch 10/14/24

as of 10/11

Solar Array Integration

Prop Load

S/C Pwrd

Phase 5 Post-Env

Phase 6 Launch Activities

PHSF
- G-Neg set up
- PX Wing/REASON
- MX Wing/REASON
- Unpack GSE & S/C

B179 HB1
- Remove SATS
- Remove TTM ECM
- Prop Leak Check
- Sys FP 2
- Alignments
- GNC Phasing
- ~~ECM boom install~~
- Sys Test 3
- HGA Uninstall
- Install FM Batt
- Pack & Ship GSE & S/C

PHSF
- FM Battery EIP
- HDRM Install
- Pre-Launch Func (V)
- ECM Boom Install
- ECM Functional
- ECM Pop-and-Catch
- HGA Re-Install
- Pre-Launch Alignments
- Prop Leak Test

PHSF
- MIL-71
- Pre-Launch Func (H)
- Load 10.4.0 FSW & HRC
- System Test 4
- SHPC Removal
- HDRM Harness Install/Test
- Canary Harness Install/Test
- SA MX Integration Start
- SHPC Reinstall & EIP

PHSF
- SHPC Regression
- SA MX LED Test
- REASON Ant EIP & Checkout
- SA MX Deployment
- SA MX Stow for Flight
- SA PX Install
- SA PX LED Test
- REASON Ant EIP & Checkout
- SA PX Deployment
- SA PX Stow for Flight

PHSF
- Load 10.4.3 FSW
- Plume Impingement
- Canary Box install
- Canary Box Regression
- Pre-Launch ABT
- REASON E2E Test
- Pre-Fuel closeouts and Prop Load prep
- Propellant Load
- RBF/IBF
- S/C Wet Mass
- S/C Handover to LV
- Pre-Launch Inspections & Closeouts
- PLA/PAF Mate

PHSF
- Install PAF Umbilical & Deploy Harness
- Interleaved TLM Test
- Encapsulate
- Transport to Hanger 39A

Hangar 39A/Pad 39A
- Power On
- Mate to LV
- Interleaved TLM Test
- Chkout/Batt Charge
- Integrate to LV
- Rollout to PAD 39A
- Power On
- Interleaved TLM
- Config for Launch
- Launch

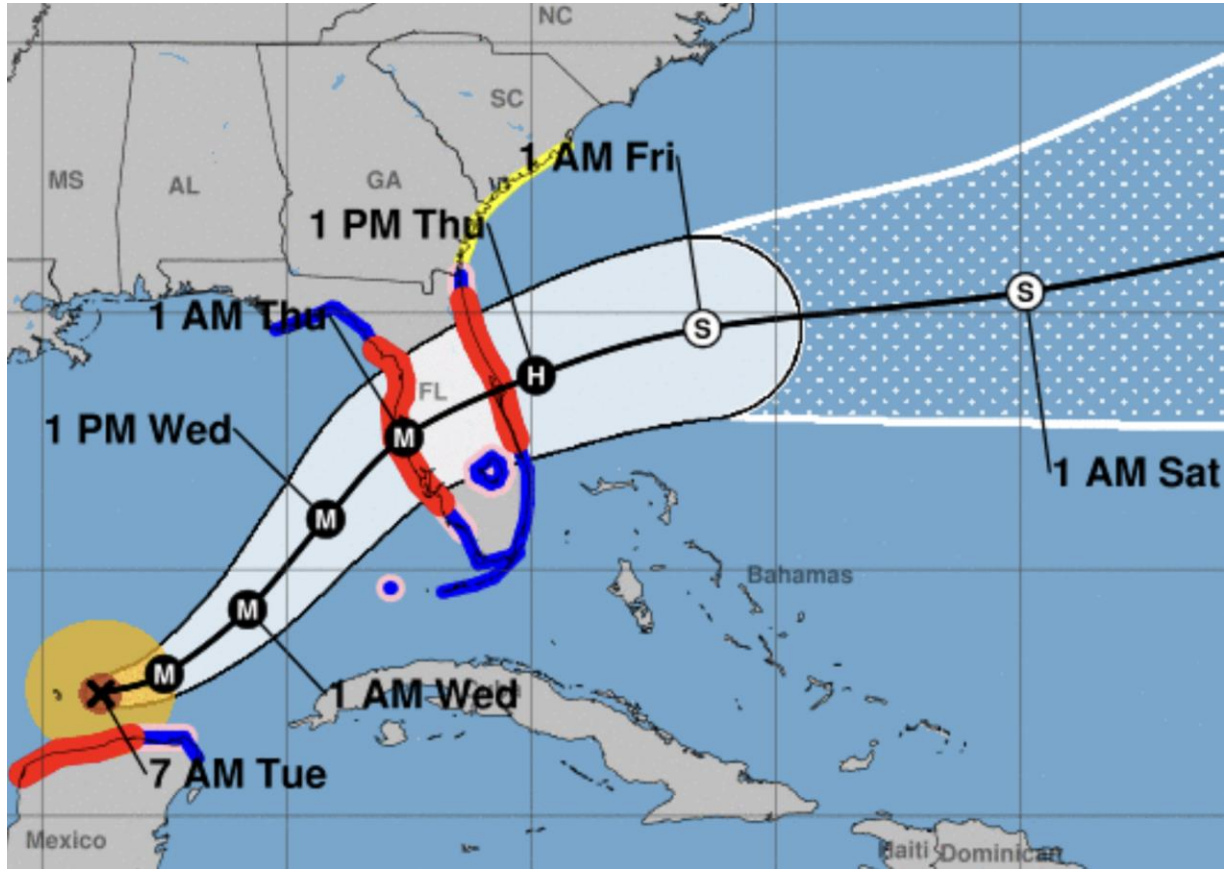
Legend
- 6 Day 1 shift
- 6 Day 2 shifts
- 24/7
- Sig Accomplishments
- New scope since arrival at KSC

Project Status (1 of 2)

- The project concluded its assessment of the MOSFET radiation hardness risk in August 2024
  - On May 1 the project was notified that MOSFETs similar to those used on Europa Clipper had failed high dose rate radiation testing despite having earlier passed testing at the vendor
  - The project initiated a Tiger Team to understand the problem and to identify and implement mitigations
    - The team identified ~1500 n-channel MOSFETs used in 200 unique applications or ‘assessments’
    - After extensive testing at High, Medium, and Low Dose rates, and multiple rounds of circuit application reviews of the 200 unique assessments, the Tiger Team was able to assign high/medium/low likelihood of failure for each assessment relative to the planned baseline mission and assessed the benefit of mitigation options
  - Based on the risk assessments, the Tiger Team recommended two sets of targeted mitigations to achieve high confidence in meeting the planned baseline mission – 1) use available heaters to warm UVS and PIMs electronics to room temperature after Europa flybys to enhance the annealing and 2) reduce the total on-time of the radios near closest approach to limit dose related damage. Both mitigations are feasible and will be implemented
  - The Project, Tiger Team leadership and JPL leadership met with SMD and NASA leadership on August 27, 2024 to review the results of the Tiger Team work and unanimously agreed that the risk to the planned science is acceptably low and supported the recommendation to proceed with the remaining launch preparations
- Held combined KDP-E APMC/DPMC on September 9, 2024

Project Status (2 of 2)

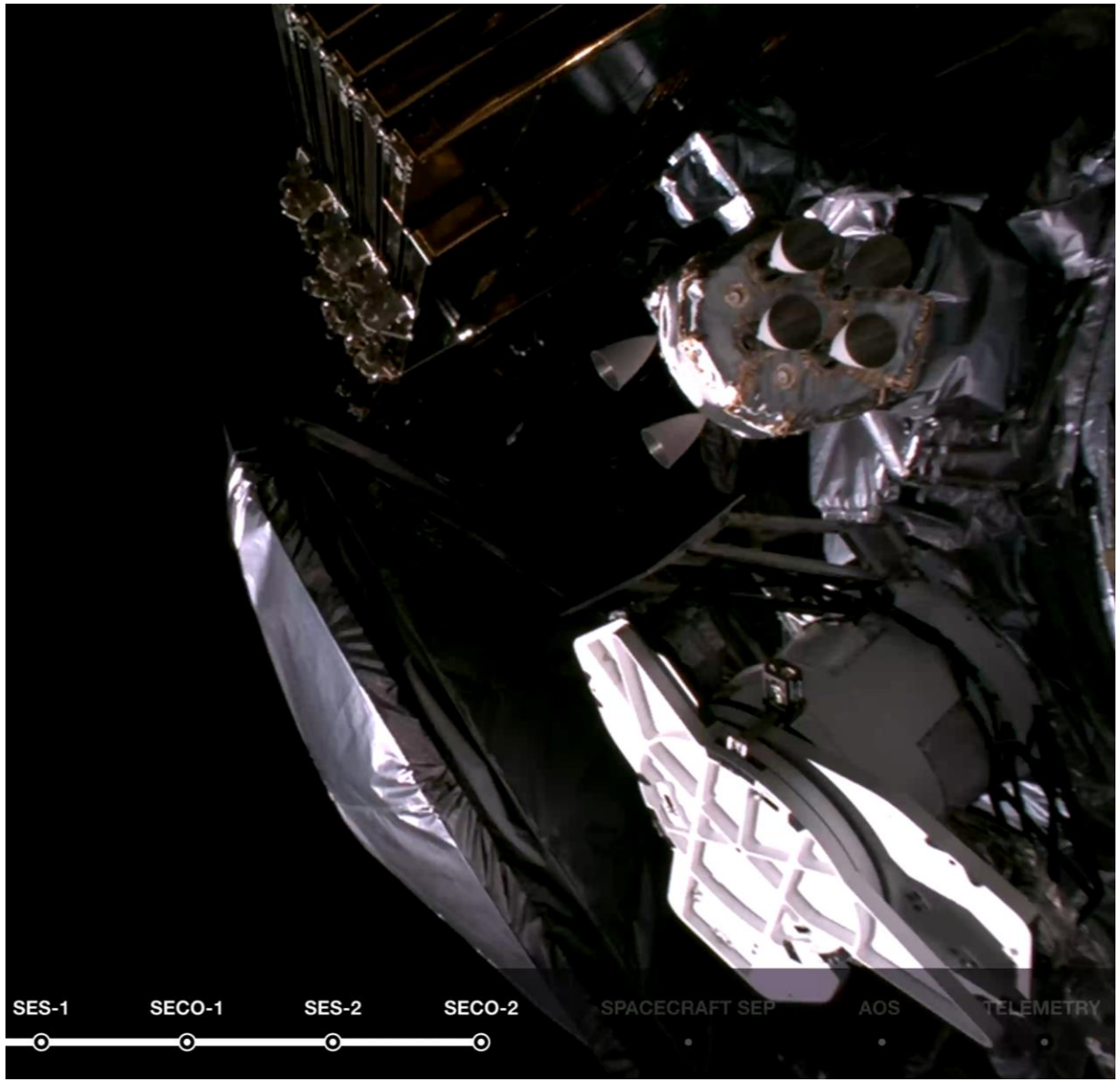
- Several technical challenges were addressed over the Summer as the team completed assembly and test of the spacecraft – each time the team addressed each issue thoroughly and expeditiously to stay on track for the LRD
- The last major obstacle to launch was a tropical storm that within a day formed into a Hurricane and quickly strengthened from a Cat 1 to Cat 5 with its predicted path heading directly toward central Florida; Hurricane Milton passed directly over KSC on the morning of Thursday, October 10, the opening day of the Europa Clipper launch period
- Launched Monday, October 14, 2024



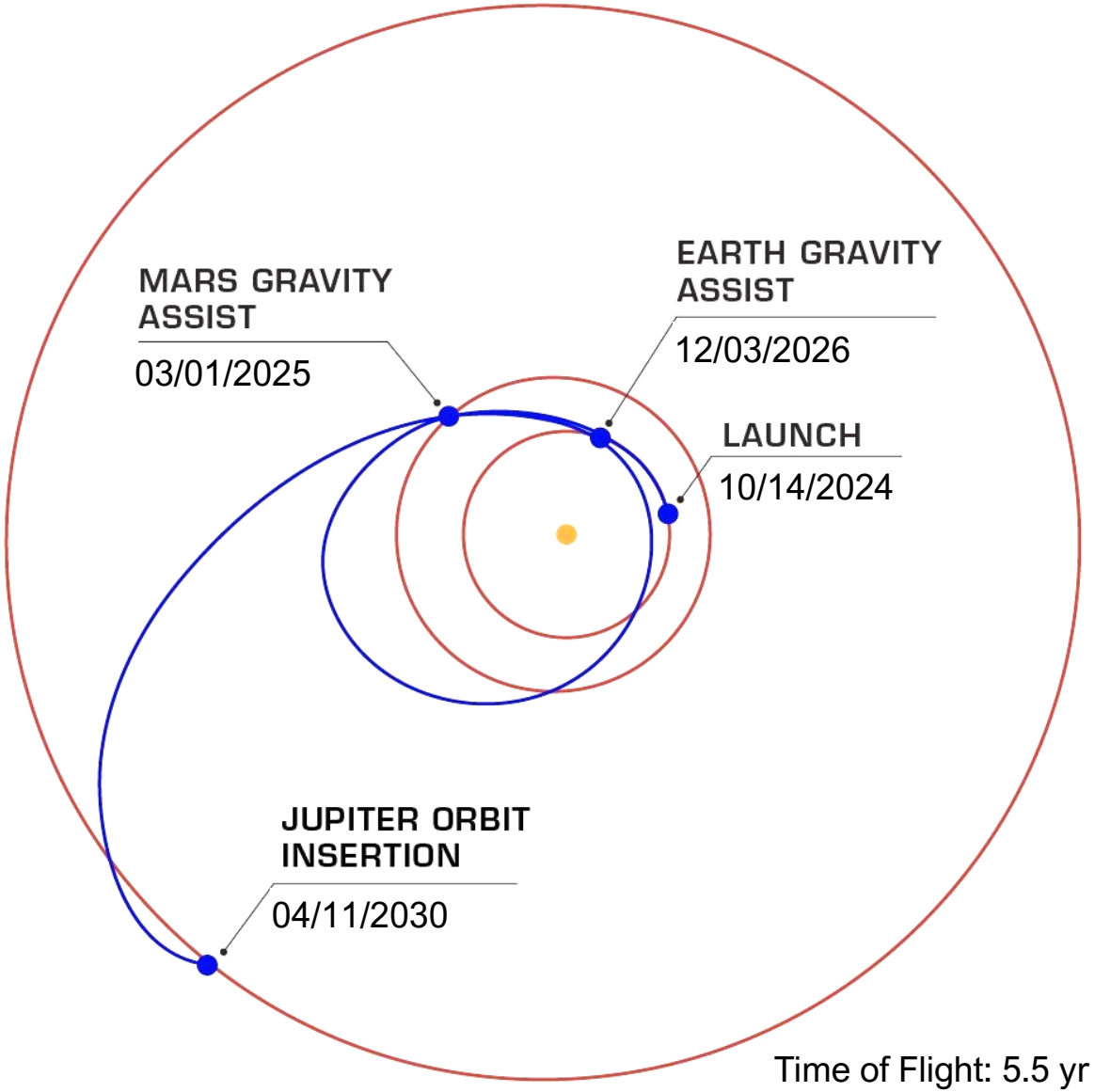
NOAA/National Weather Service
Oct. 8, 2024

State of the Spacecraft

- The spacecraft is currently on its way to Mars for a March 1, 2025 gravity assist
- All subsystems are healthy and functioning as expected
- The spacecraft is power positive with the batteries at 100% state of charge
- The GNC subsystem is in RCS inertial control, with solar arrays on sun and one LGA continuously pointed toward Earth
- Flight system checkout will continue into January 2025 with various instrument checkouts and calibrations extending into the Summer of 2025



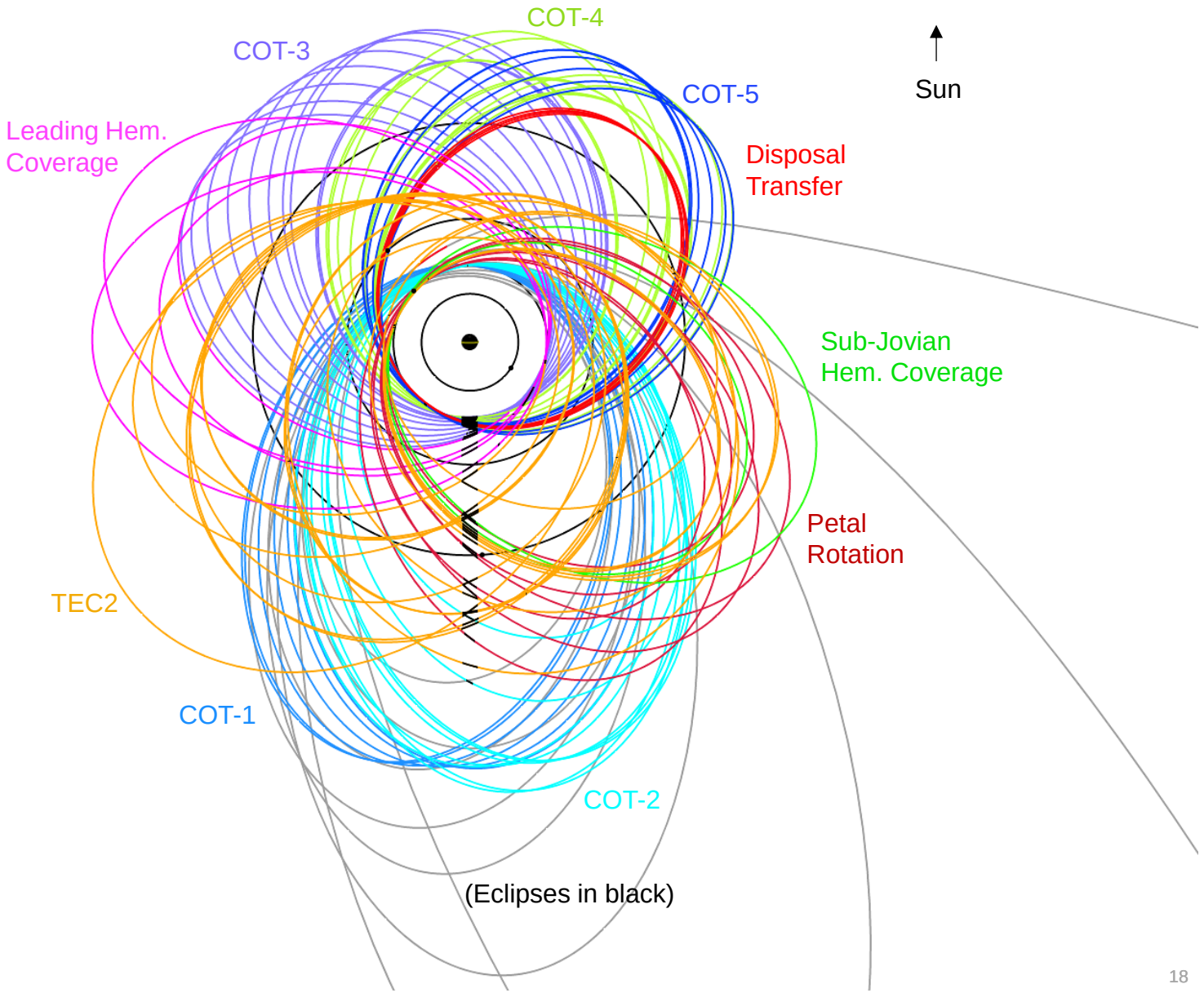
Interplanetary Trajectory: Mars-Earth Gravity Assist (MEGA)



Time of Flight: 5.5 yr

Europa Clipper Trajectory (21F31_V7): Overview

Jovian Tour	21F31_V7
Launch	**10/14/24**
Mars Gravity Assist (1041 km)	**3/01/25**
Earth Gravity Assist (3134 km)	**12/3/26**
Jupiter Orbit Insertion (JOI) Date	**4/11/30**
Interplanetary Trajectory	**MEGA**
Tour Duration (years)	**4.27**
EC1 Europa Resonance	**6:1**
Number of Flybys	
Europa	**49 of 53**
Ganymede	**7**
Callisto	**9**
Number of Night Side Europa Flybys	**11**
Number of Jupiter Orbits	**79**
Time between Flybys (days)	
Maximum (not including capture orbit)	**64.4**
Minimum	**9.4**
Minimum (Europa-to-Europa)	**13.8**
Deterministic Tour ΔV, post-JOI (m/s)	**214.8**
Maximum Inclination (deg.)	**7.7**
Maximum Eclipse Duration (hours)	**7.8**
Total Ionizing Dose (Mrad)	**2.97**
Disposal – Targeted Impact Body	**Ganymede**

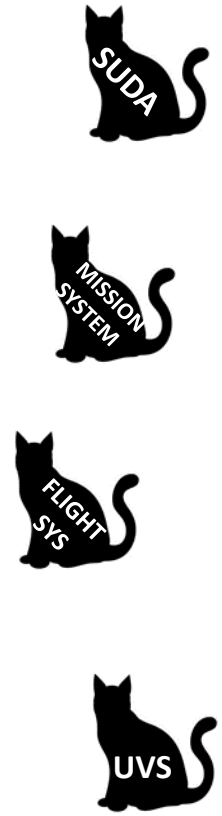


Space Science Reviews Europa Clipper Special Issue:

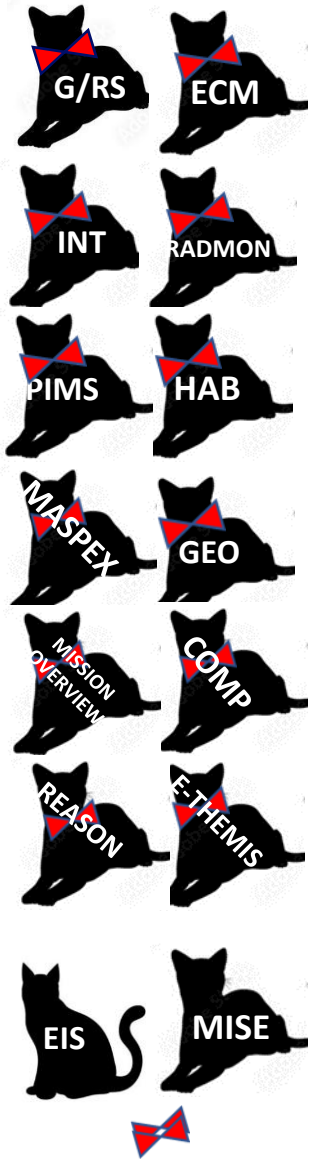
Completion Status 10/22/24

Instrument, Working Group, or Overview	Authors	Status
ECM (Magnetometer)	Kivelson et al.	Published
Gravity/Radio Science	Mazarico et al.	Published
PIMS (Faraday Cups)	Westlake et al.	Published
Radiation Monitors	Meitzler et al.	Published
Interior (Working Group)	Roberts et al.	Published
Habitability (Working Group)	Vance et al.	Published
Geology (Working Group)	Daubar et al.	Published
Composition (Working Group)	Becker et al.	Published
E-THEMIS (Thermal Imager)	Christensen et al.	Published
SUDA (Dust Analyzer)	Kempf et al.	In revision, minor revisions
MASPEX (Mass Spectrometer)	Waite et al.	Published
MISE (IR Imaging Spectrometer)	Blaney et al.	Accepted
REASON (Ice-Penetrating Radar)	Blankenship et al.	Published
Mission Overview	Pappalardo et al.	Published
EIS (NAC and WAC cameras)	Turtle et al.	Accepted
E-UVS (UV spectrograph)	Retherford et al.	In revision; minor revisions
Flight System	Srinivasan et al.	In revision; major revisions
Mission System	Cangahuala et al.	In revision; minor revisions

Rescued (under revision)

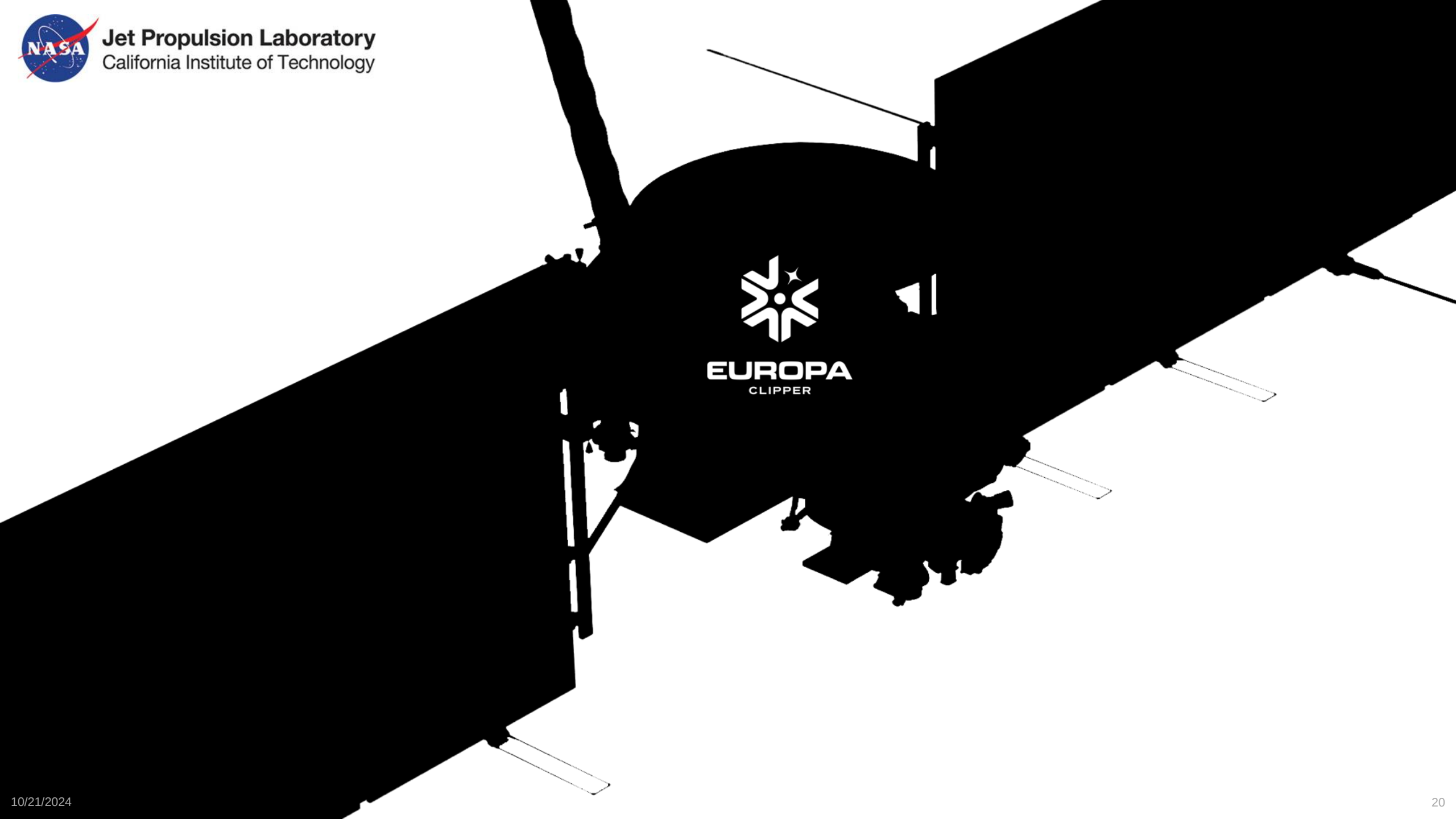


Adopted (accepted)



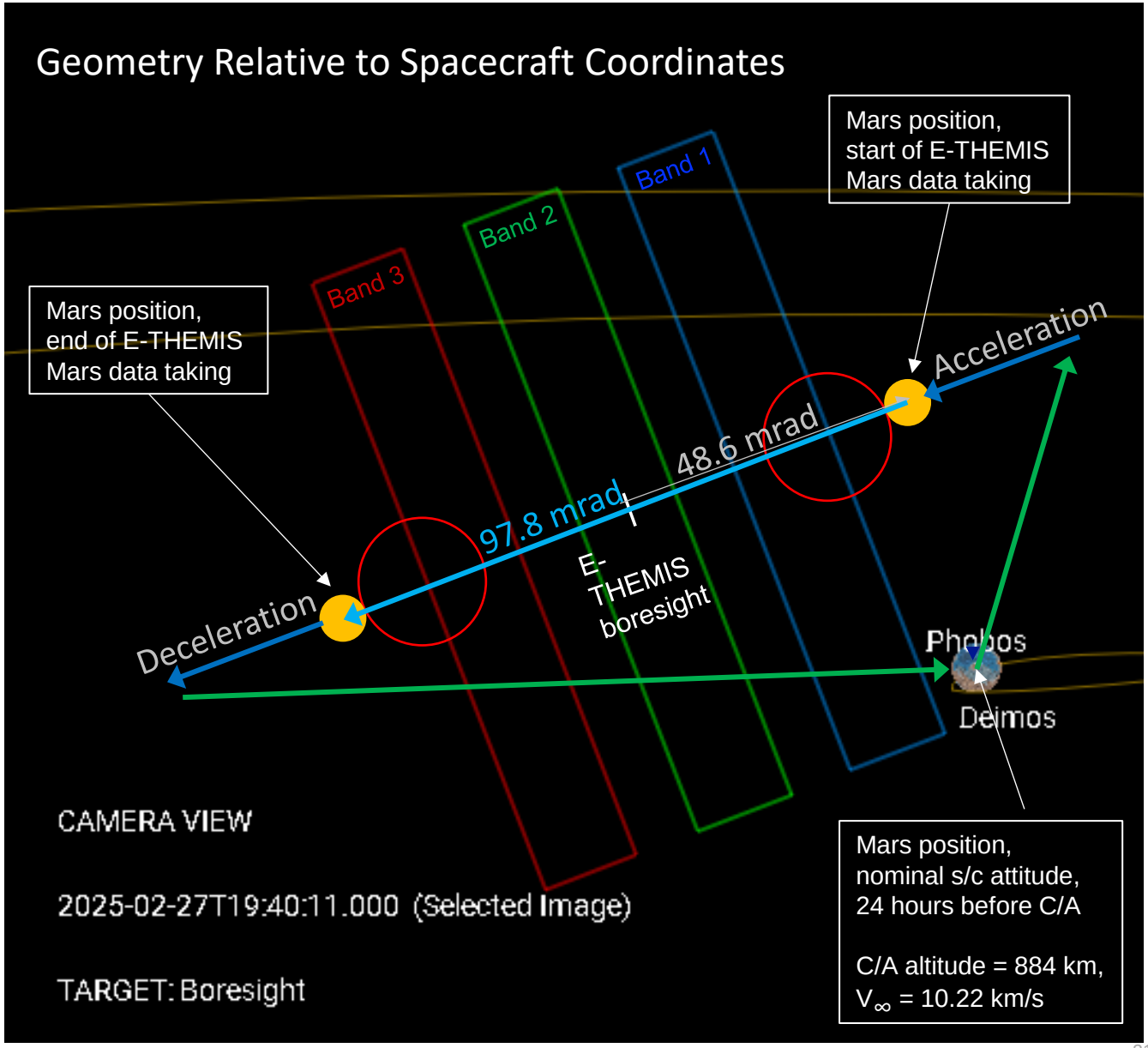
Published

Jet Propulsion Laboratory
California Institute of Technology



Mars E-THEMIS Calibration Overview

- Calibration is to test a procedure that the E-THEMIS team developed to correct a non-linearity that was discovered in spectral channels of Band 3 soon before instrument delivery to JPL
- The 10K uncertainty in Band 3 jeopardizes the measurement of blackbody temperature with insolation angle, and thus the measurement of thermal inertia
- In turn, this risks derivation of surface block abundance and measurement of thermal anomalies for plume and activity searches
- Mars is well-characterized by the THEMIS heritage-instrument on Mars Odyssey, so Mars is an ideal calibration target
- Mars diameter at -24 hours = 7.72 mrad (orange disk), and E-THEMIS pixel size is 0.114 mrad, so Mars diameter ~70 pixels during the observation
- Red circle is pointing uncertainty
- Scan duration is 16.3 minutes (plus acceleration and deceleration)



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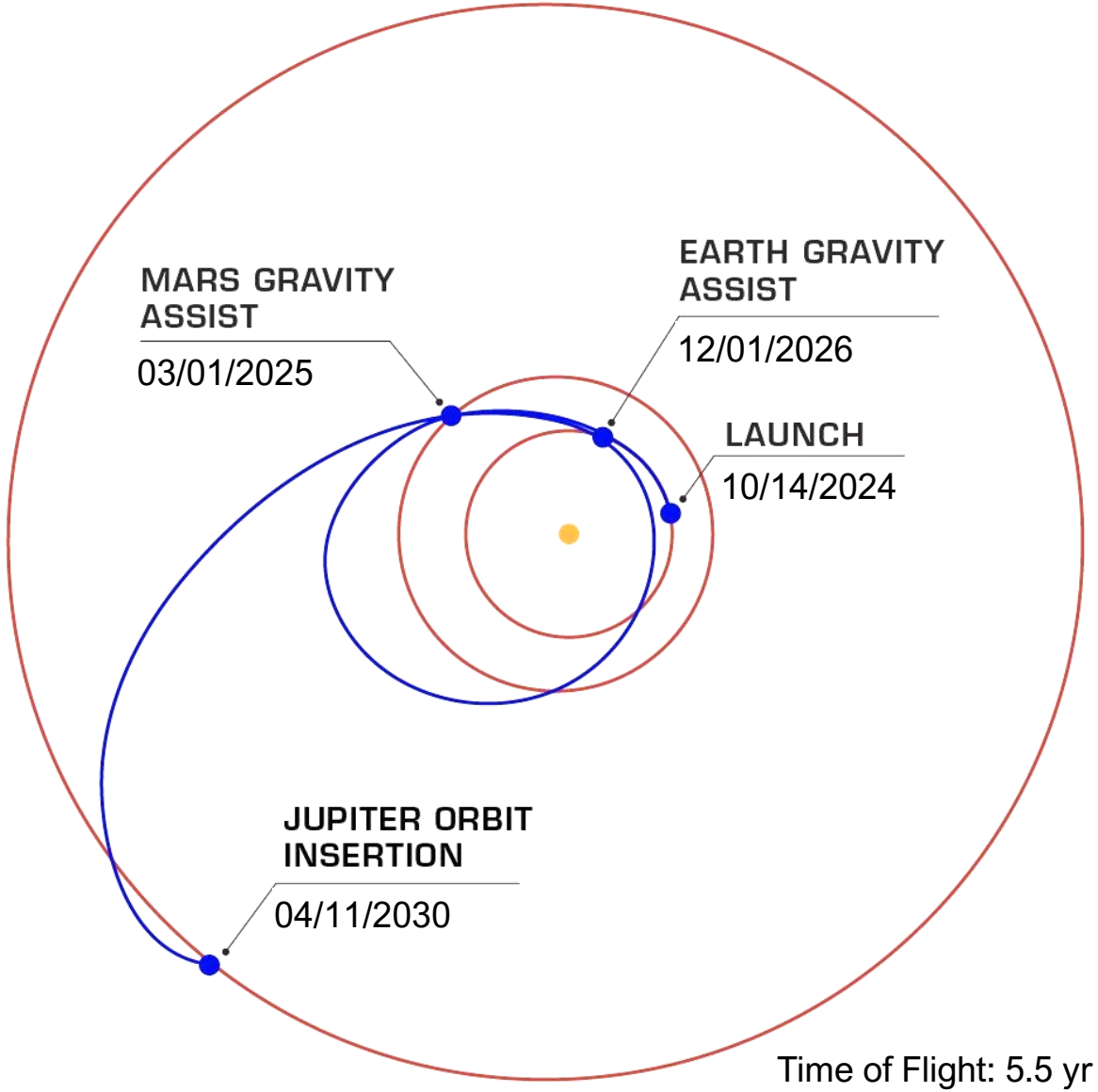
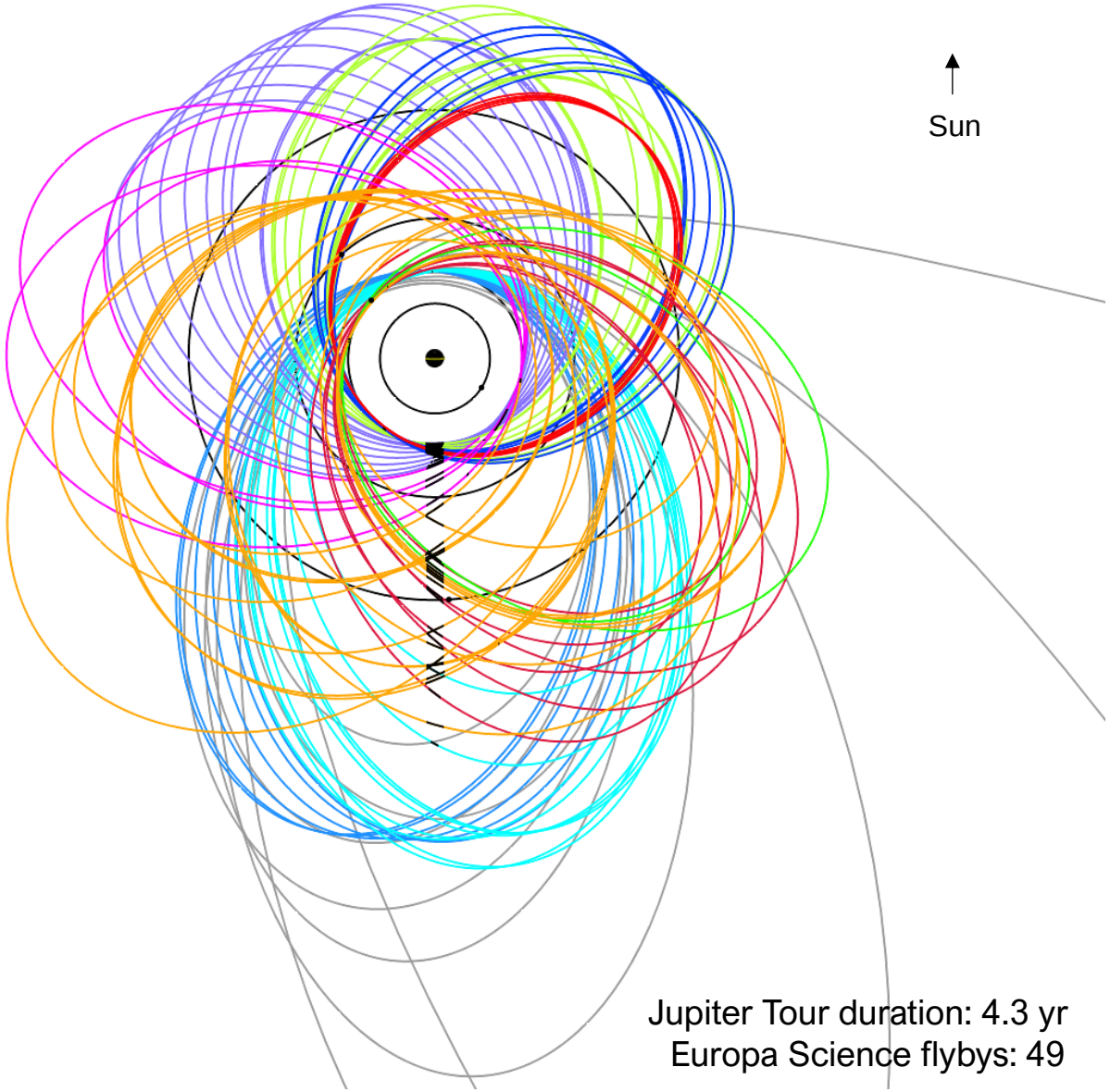


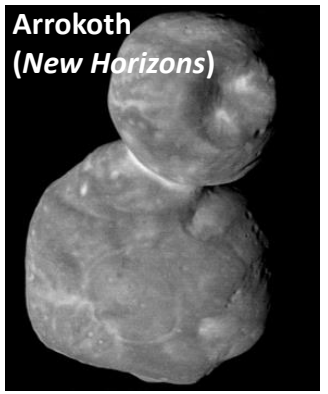
Time of Flight: 5.5 yr

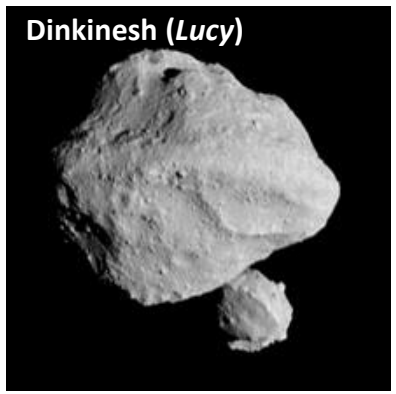


Jupiter Tour duration: 4.3 yr
Europa Science flybys: 49

Europa Clipper Astronomy Team (ECAT)

- Main objective is to provide support astronomical observations for transient events and to monitor the Europan environment
- 43 members with wide expertise (surface, atmosphere, F&P, citizen science, etc.) and covering all major assets: *HST, JWST*, full range of optical and infrared telescopes, ALMA, Goldstone, etc.
- Kick-off workshop during DPS 2023 with about 35 participants
- The main activity during cruise is to mobilize observers if activity is detected from ground-based observations
- Study activity: feasibility of an asteroid search and flyby for instrument checkout
  - An asteroid would be an excellent target for instrument check-out and calibration after covers are off, as it would be an extended source, and it could be well-characterized from ground for calibration
  - No ***known*** asteroids are currently accessible at <387,000 km, but there are almost certainly some in the right region
  - *New Horizons*-type search resulting in Arrokoth (Buie, Spencer et al., PSJ 2024) is not feasible because of greater apparent motion of Main Belt asteroids
  - The study will focus on existing archived images
  - Vera Rubin Observatory (formerly LSST) will also be investigated; first light in January 2025; survey mode in August 2025; public after 2 years
- For interest: contact Bonnie.Buratti@jpl.nasa.gov





Picture credit: Freepik/NASA/JPL/Caltech; JHU/APL

From One Ocean World to Another!

https://europa.nasa.gov

Europa Clipper Science Team Meeting
San Juan, Puerto Rico, Nov. 2023

Europa Clipper Launch, Oct. 14, 2024