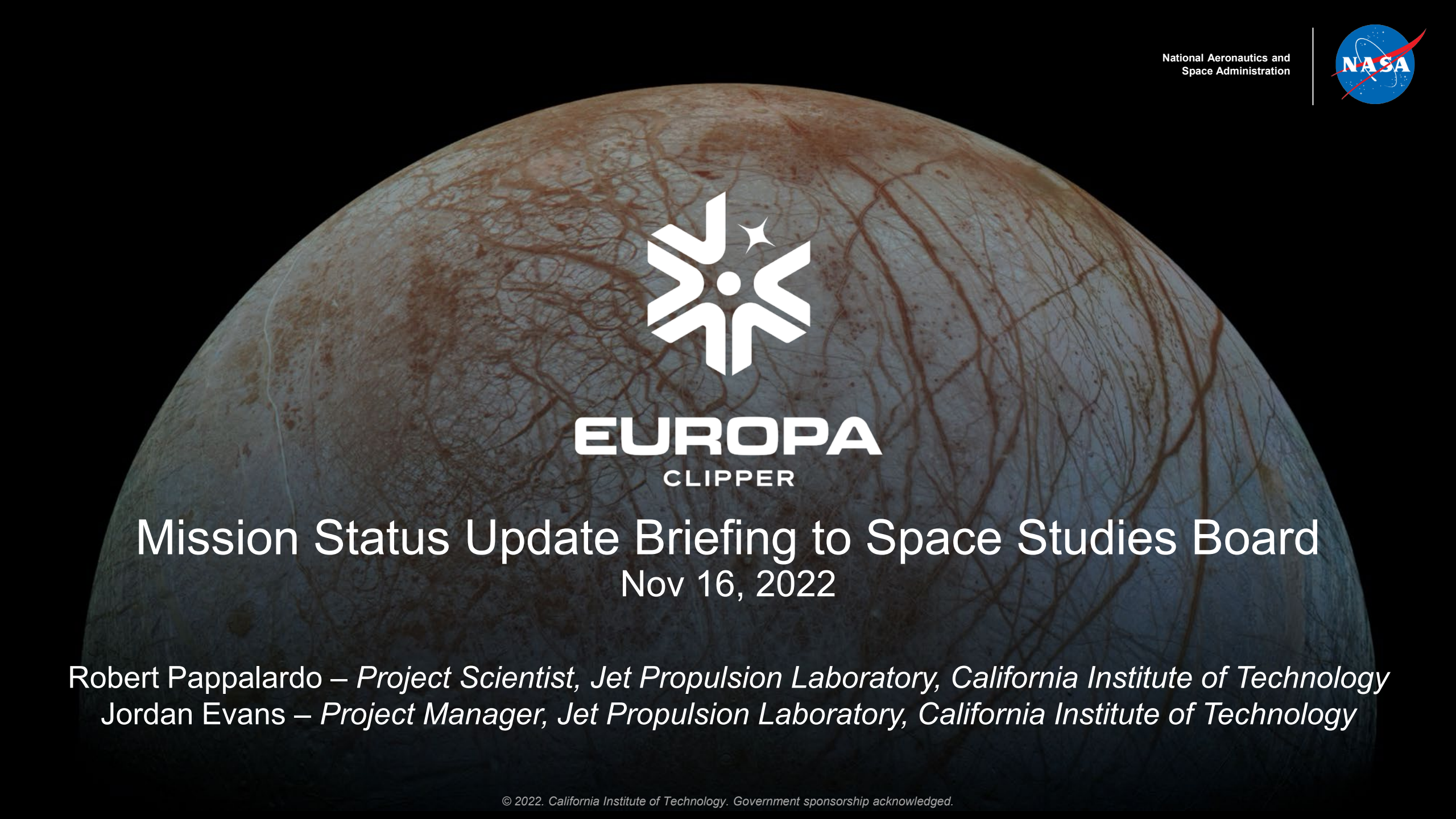
National Aeronautics and Space Administration



EUROPA CLIPPER

Mission Status Update Briefing to Space Studies Board

Nov 16, 2022

Robert Pappalardo – *Project Scientist, Jet Propulsion Laboratory, California Institute of Technology*
Jordan Evans – *Project Manager, Jet Propulsion Laboratory, California Institute of Technology*

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Exploring Europa's Habitability: Ingredients for Life

Water:

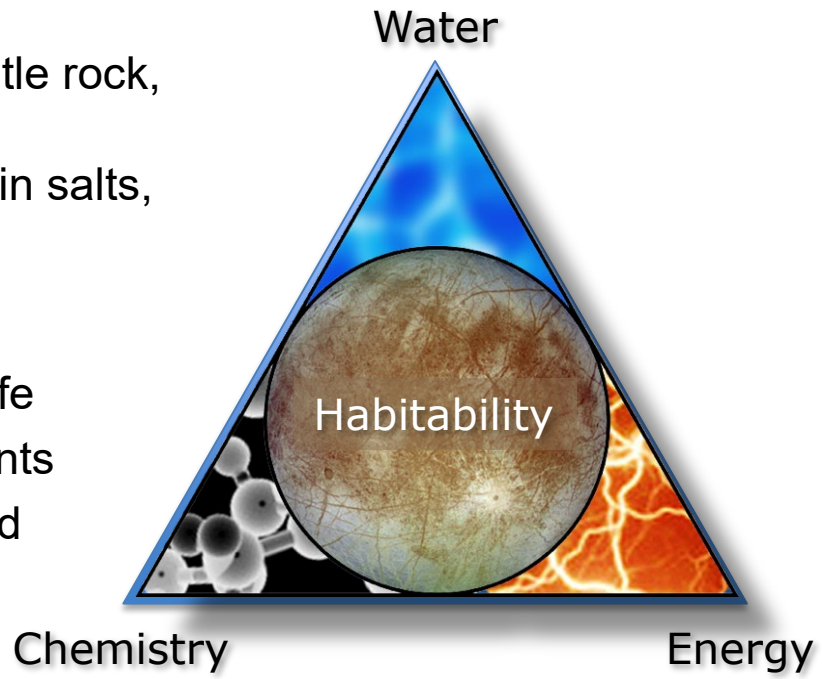
- Probable saltwater ocean, implied by surface geology and magnetic field
- Possible lakes within the ice shell, produced by local melting

Chemistry:

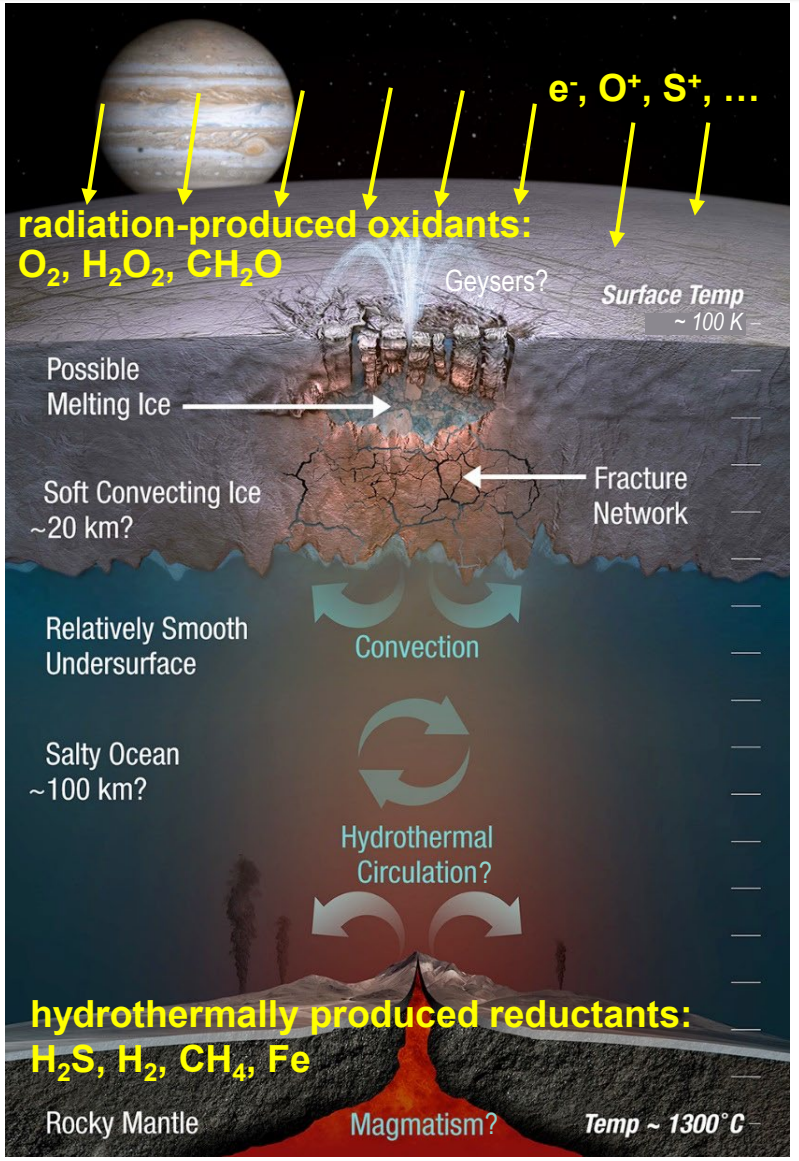
- Ocean in direct contact with mantle rock, promoting chemical leaching
- Dark red surface materials contain salts, probably from the ocean

Energy:

- Chemical energy might sustain life
- Surface irradiation creates oxidants
- Mantle rock-water reactions could create reductants (hydrothermal or serpentinization)

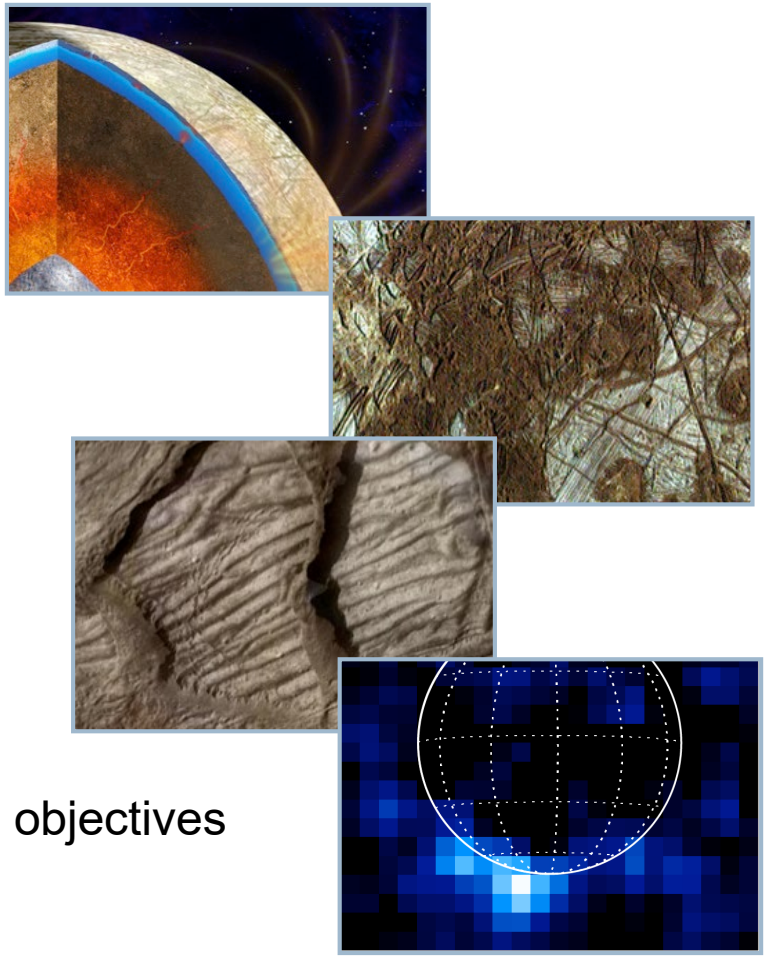


The Europa Clipper Mission will test key habitability hypotheses



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



Note: **Recent Activity** cross-cuts through all three principal science objectives

Europa Clipper Level 1 Science Requirements Post-SIR

	Baseline Level-1 Science Requirements	Threshold Level-1 Science Requirements
Ice & Ocean	**I1:** Map the vertical subsurface structure in regions of potential surface-ice-ocean exchange to >3 km depth along globally distributed ground tracks achieving a total cumulative length ≥30,000 km.	**I1:** Map the vertical subsurface structure in regions of potential surface-ice-ocean exchange to ≥3 km depth along regionally distributed ground tracks achieving a total cumulative length ≥10,000 km.
	I2: Constrain our knowledge of the average thickness of the ice shell, and the average thickness and salinity of the ocean, each to ±50%.	**I2:** Confirm the presence of a subsurface ocean, and determine whether the ice shell is in a “thin” (several km) or “thick” (10s km) regime.
Composition	**C1:** Create a compositional map at ≤10 km spatial scale, covering ≥60% of the surface, sufficient to identify non-ice materials, especially organic compounds.	**C1:** Create a compositional map at ≤10 km spatial scale, covering ≥40% of the surface, sufficient to identify non-ice materials, especially organic compounds.
	C2: Characterize the composition of ≥0.3% of the surface, globally distributed at ≤300 m spatial scale, sufficient to identify non-ice materials, especially organic compounds.	**C2:** Characterize the composition of ≥0.15% of the surface, regionally distributed at ≤400 m spatial scale, sufficient to identify non-ice materials, especially organic compounds.
	C3: Characterize the composition and sources of volatiles, particulates, and plasma, sufficient to identify the signatures of non-ice materials, including organic compounds, in at least one of the above forms, in globally distributed regions of the atmosphere and local space environment.	**C3:** Characterize the composition and sources of volatiles or particulates, sufficient to detect the signatures of non-ice materials, including organic compounds, in at least one of the above forms, in distributed regions of the atmosphere and local space environment.
Geology	**G1:** Produce a controlled photomosaic map of ≥80% of the surface at ≤100-m spatial scale.	**G1:** Produce a controlled photomosaic map of ≥30% of the surface at ≤100-m spatial scale.
	G2: Characterize the surface at ≤25-m spatial scale across ≥5% of the surface with global distribution, including measurements of topography at ≤15-m vertical precision across ≥1% of Europa’s surface.	**G2:** Image the surface at ≤50-m spatial scale across ≥1.5% of the surface with regional distribution, including measurements of topography at ≤20-m vertical precision across ≥0.5% of Europa’s surface.
	G3: Characterize the surface at ~1-m spatial scale to determine surface properties, for ≥18 globally distributed sites.	N/A
Current Activity	**A1:** Search for and characterize any current activity, notably plumes or thermal anomalies, in regions that are globally distributed.	**A1:** Search for current activity, notably plumes or thermal anomalies.

Europa Clipper Investigations

MASPEX
Mass Spectrometer
PI: Jim Burch, SwRI
sniffing atmospheric composition

SUDA
Dust Analyzer
PI: Sascha Kempf: U. Colorado
detecting surface & plume composition

ECM
Magnetometer
TL: Margaret Kivelson, U. Michigan
revealing ocean properties

PIMS
Faraday Cups
PI: Joe Westlake, APL
measuring plasma environment

Europa-UVS
UV Spectrograph
PI: Kurt Retherford, SwRI
seeking plume glow

EIS
Narrow-angle Camera + Wide-angle Camera
PI: Zibi Turtle, APL
mapping alien landscape

MISE
IR Spectrometer
PI: Diana Blaney, JPL
detecting chemical fingerprints

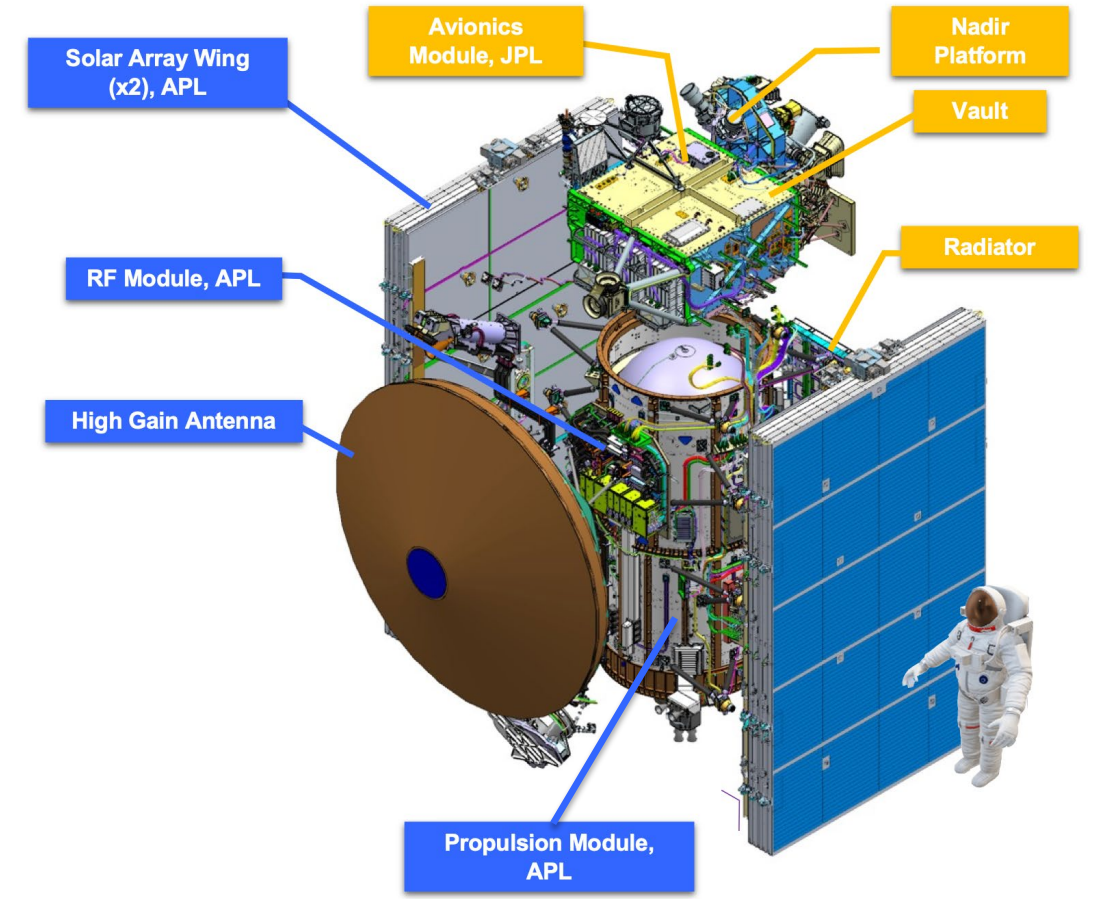
E-THEMIS
Thermal Imager
PI: Phil Christensen, ASU
searching for hot spots

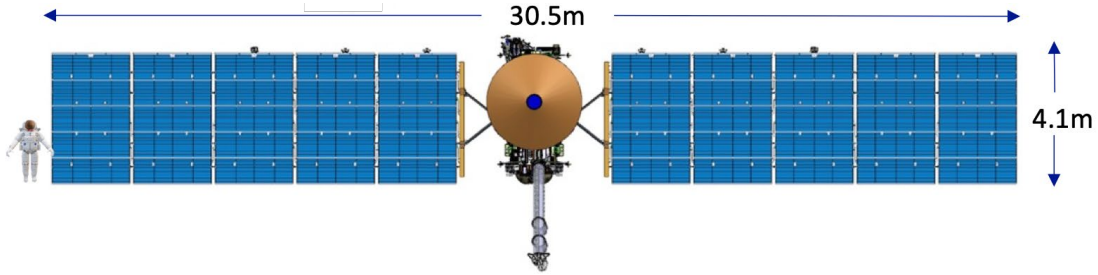
REASON
Ice-Penetrating Radar
PI: Don Blankenship, UTIG
probing the ice shell

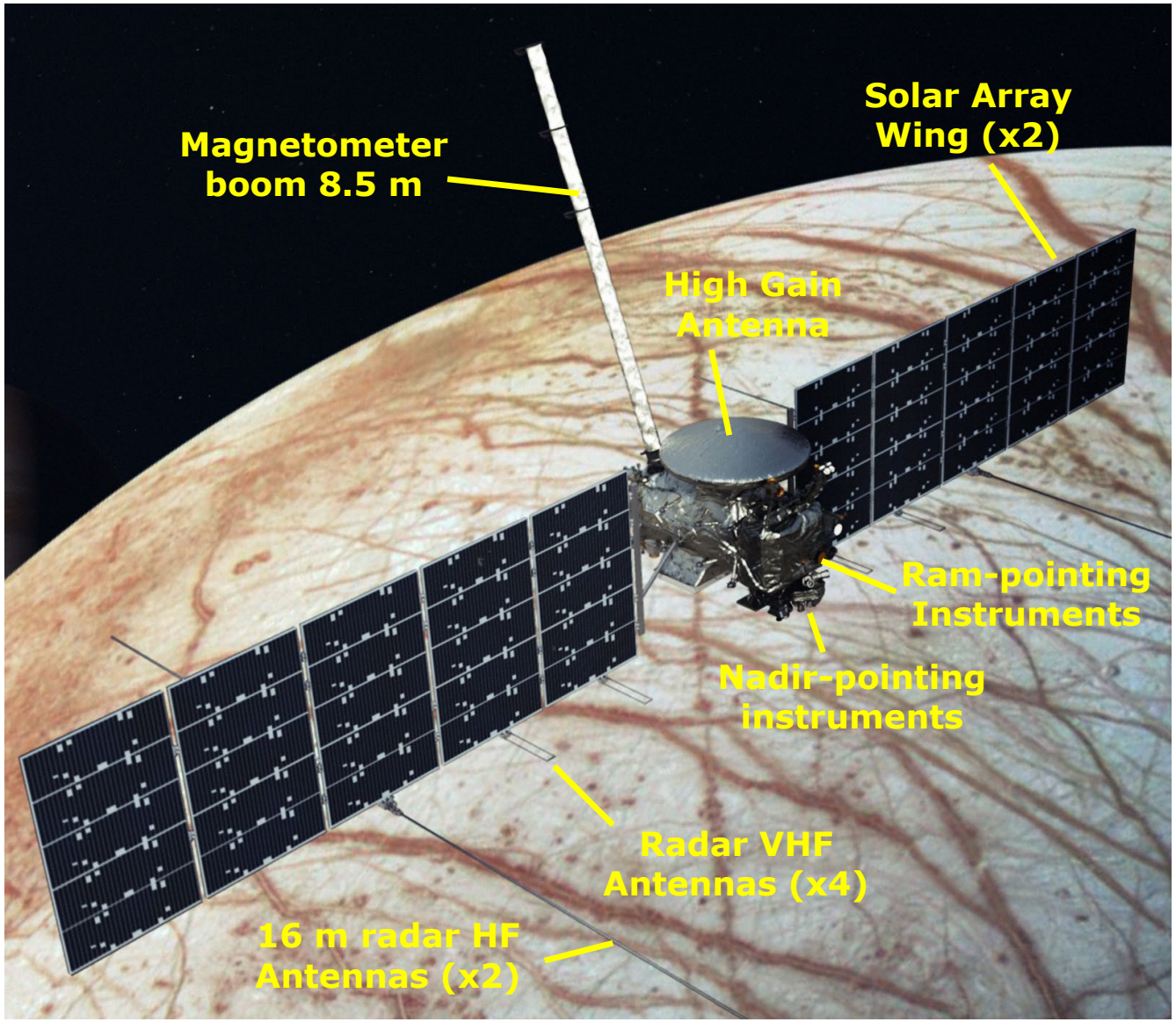
G/RS
Doppler Gravity
TL: Erwan Mazarico, GSFC
sensing interior layers

Remote Sensing In Situ

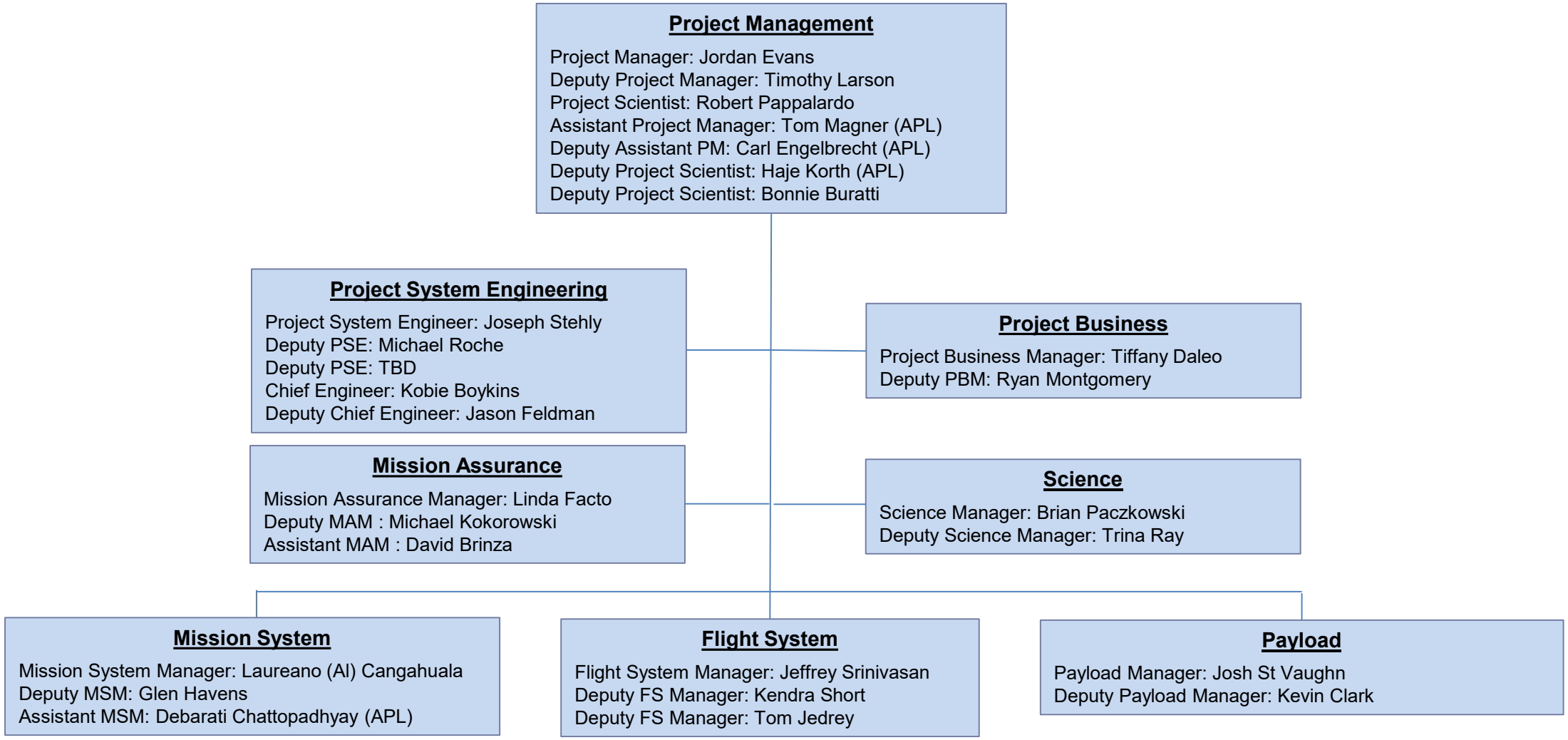
Europa Clipper Flight System







Project Organization



Current Project Status

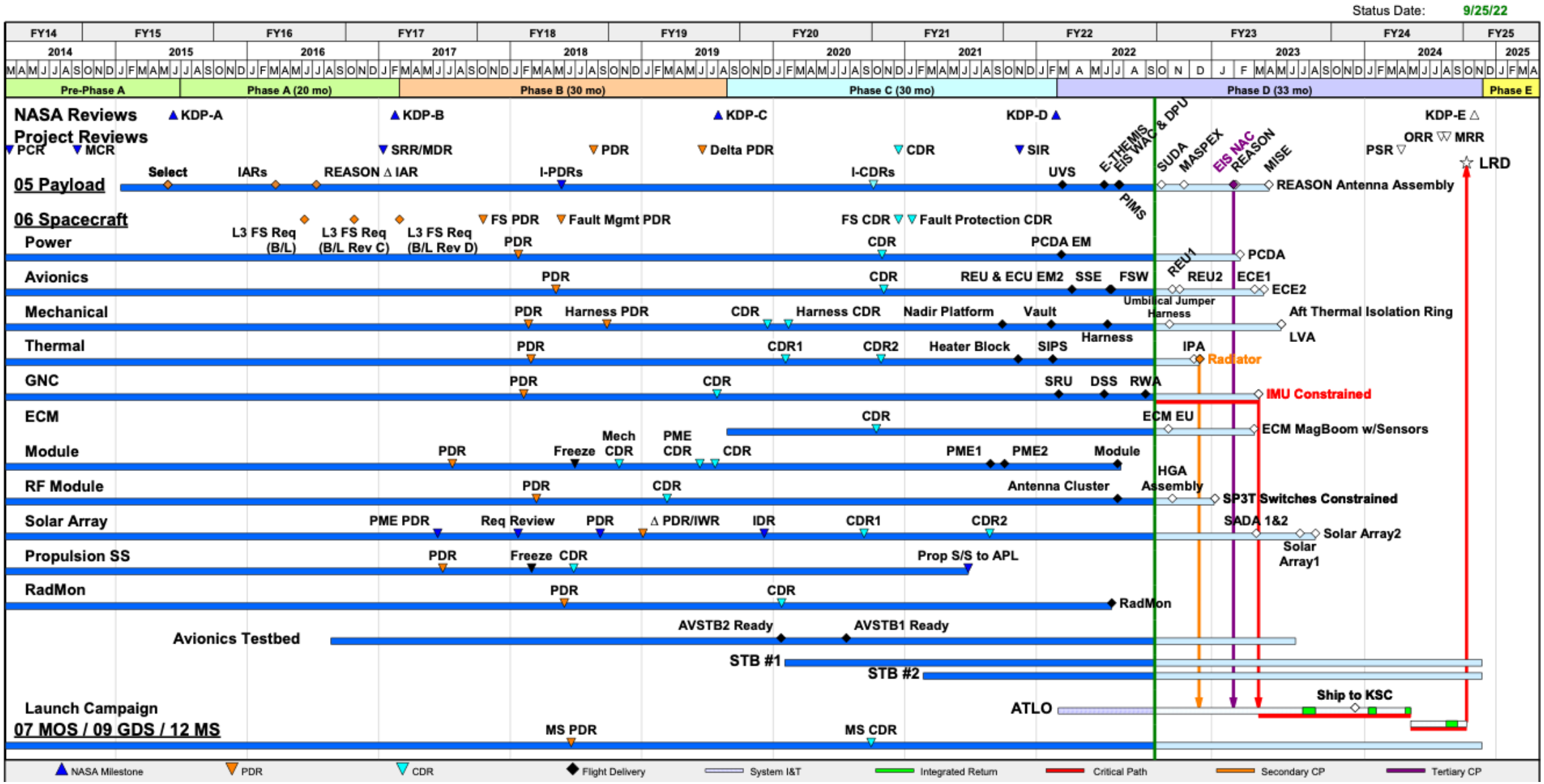
- Assembly, Test, and Launch Operations (ATLO) started on March 2, 2022 and is making great progress in integration and functional testing of Europa Clipper
- Five of ten science instruments have been delivered to JPL
  - Europa-UVS: February 22, 2022
  - E-THEMIS: May 22, 2022
  - EIS Wide-Angle Camera (WAC): June 20, 2022
  - PIMS: June 27, 2022
  - SUDA: Sept. 9, 2022
- High Gain Antenna was delivered to JPL on Oct. 6, 2022
- Key ATLO activities in the next 6 months include:
  - Integration and functional testing of remaining instruments into the Vault (MASPEX, ECM, NAC, REASON, MISE)
  - Integration and functional testing of flight avionics
- Flight Software is mature with nearly all required functionality running in the Testbeds, positioning Europa Clipper well for the Verification & Validation campaign

Status of Instruments Not Yet Delivered

- MASPEX:
  - A short occurred during TVAC; the root cause was quickly found and has delayed delivery
- ECM:
  - Decision made to replace op-amps that were exhibiting random noise and may degrade over time
- NAC:
  - Extra time spent in EMI/EMC testing, to ensure compatibility with REASON operations; beginning TVAC
- REASON:
  - After successful TVAC, now in EMI/EMC testing
- MISE:
  - Scanner experiences “soft” stoppages that can be “plowed through”—may be due to testing in Earth gravity
  - EMI/EMC testing shows violation of REASON operational requirements, and remedies are being explored
  - TVAC upcoming

Since the last OPAG/SSB, all of these instrument schedules have eroded by 2 or more months

High-Level Project Schedule

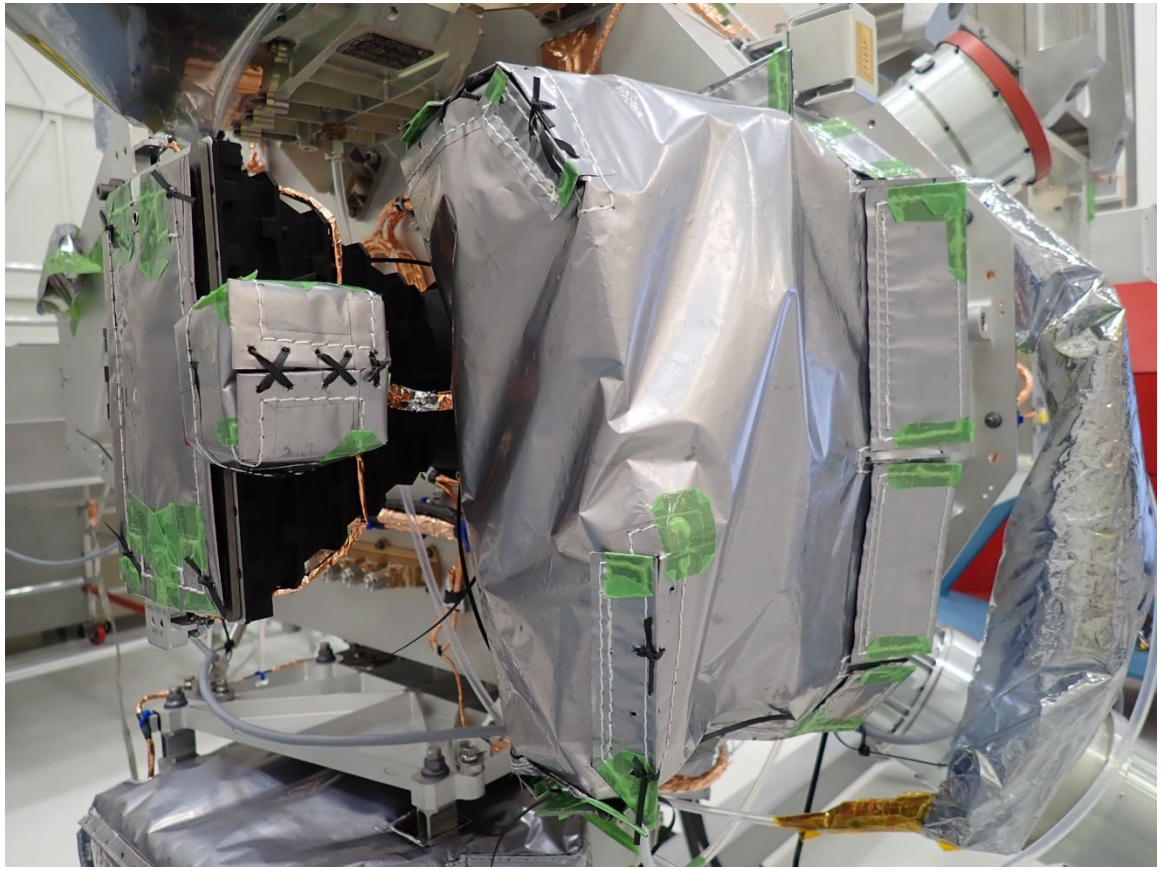


Live From the Clean Room:

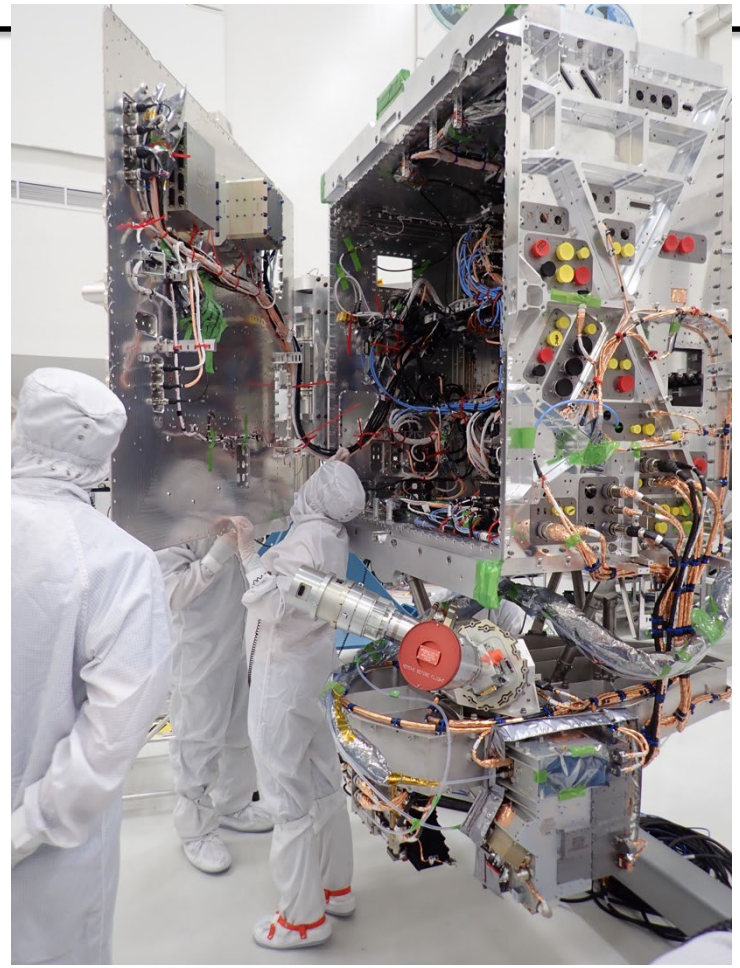
Publicly Available 24/7 Live Stream from JPL High Bay 1

https://bit.ly/clippercam

ATLO Pictures

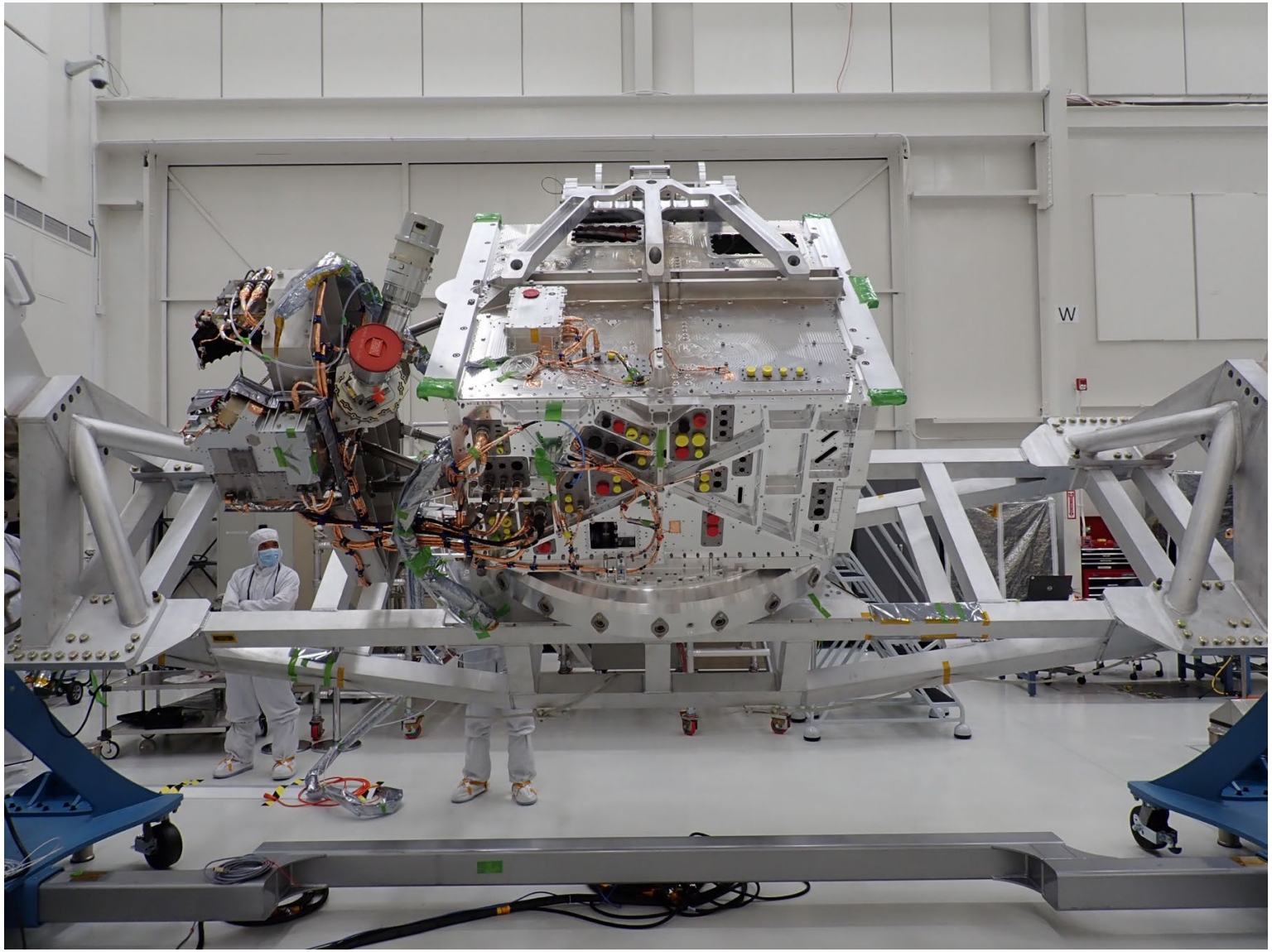


WAC Multi-Layer Insulation (MLI) Fit Check



Vault +Z Panel

ATLO Pictures



Vault Rotation

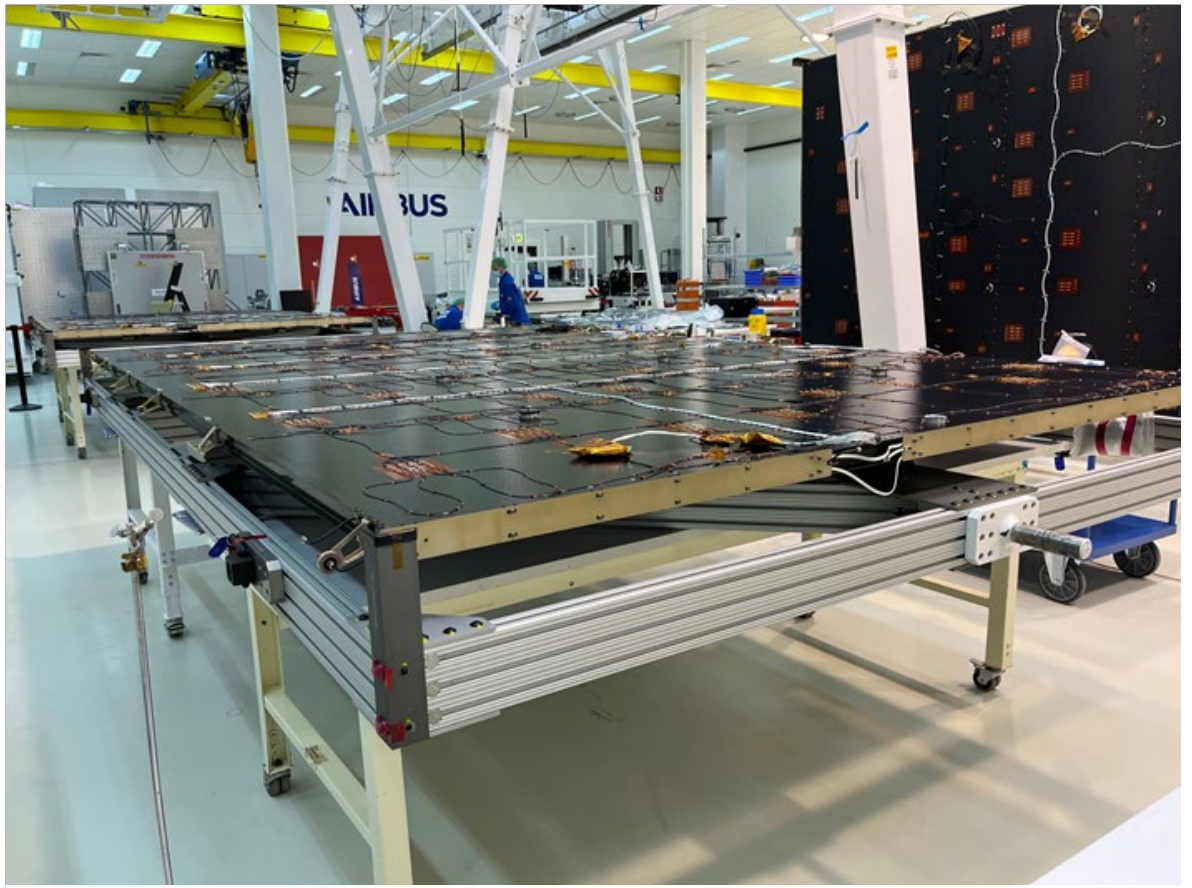
ATLO Pictures

Developmental Test Model (DTM) in High Bay 1

High-Gain Antenna (HGA) in Airlock for Delivery to High Bay 1

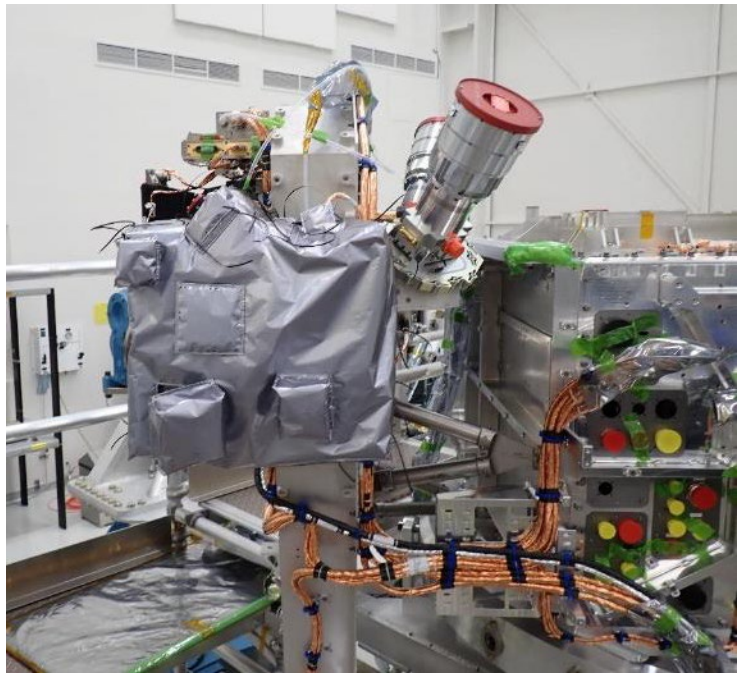
Solar Array:
Flight Model Panel Integration Progress at Airbus

Integration of Solar Panel PX P1 completed
(with exception of the REASON antenna)



Integration of Solar Panel PX P2 ongoing

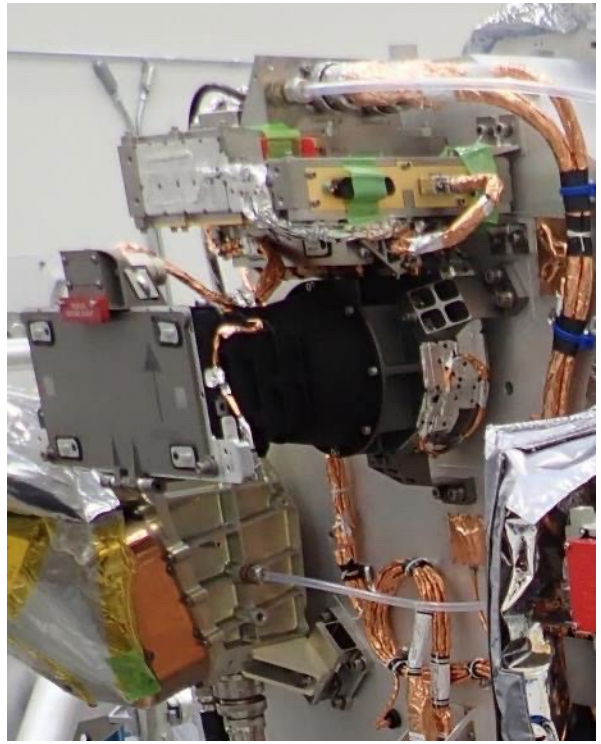
Payload Photos – 1 of 3



Europa-UVS MLI Fit Check

E-THEMIS MLI Fit Check

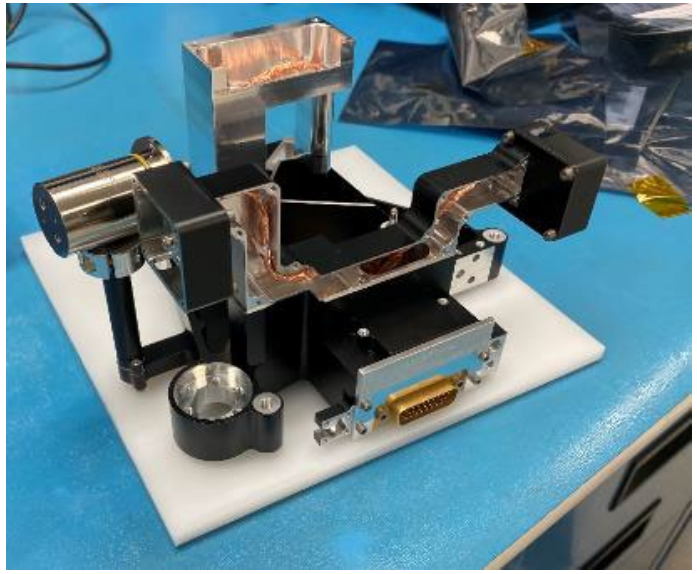
PIMS Upper Temporarily Installed for MLI Patterning



EIS WAC Sensor/Harness Installed on Nadir Deck

Payload Photos – 2 of 3

MISE in EMI/EMC Testing

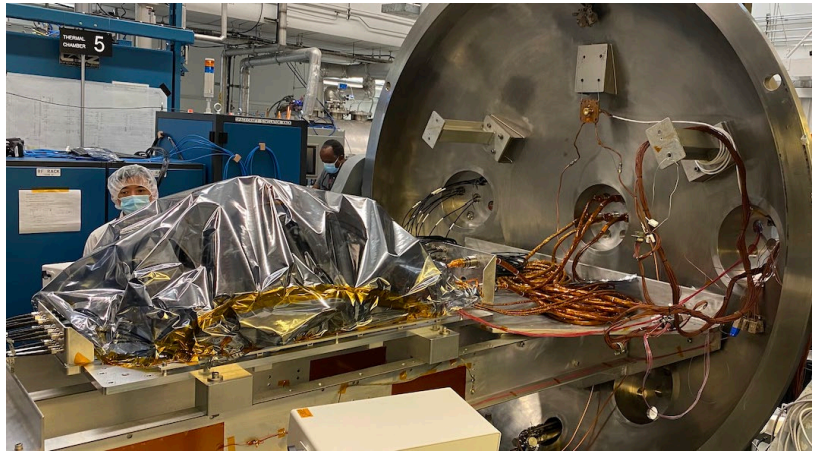


REASON VHF QM Harness Completed

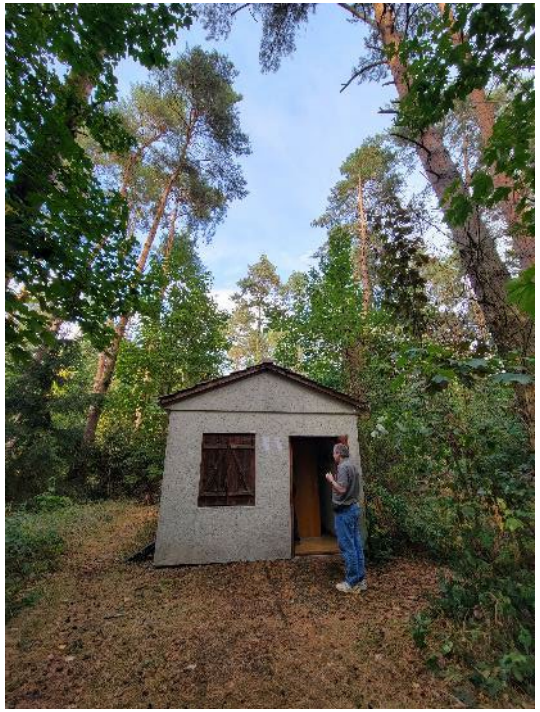
SUDA Pre-ATLO Delivery Team

Payload Photos – 3 of 3

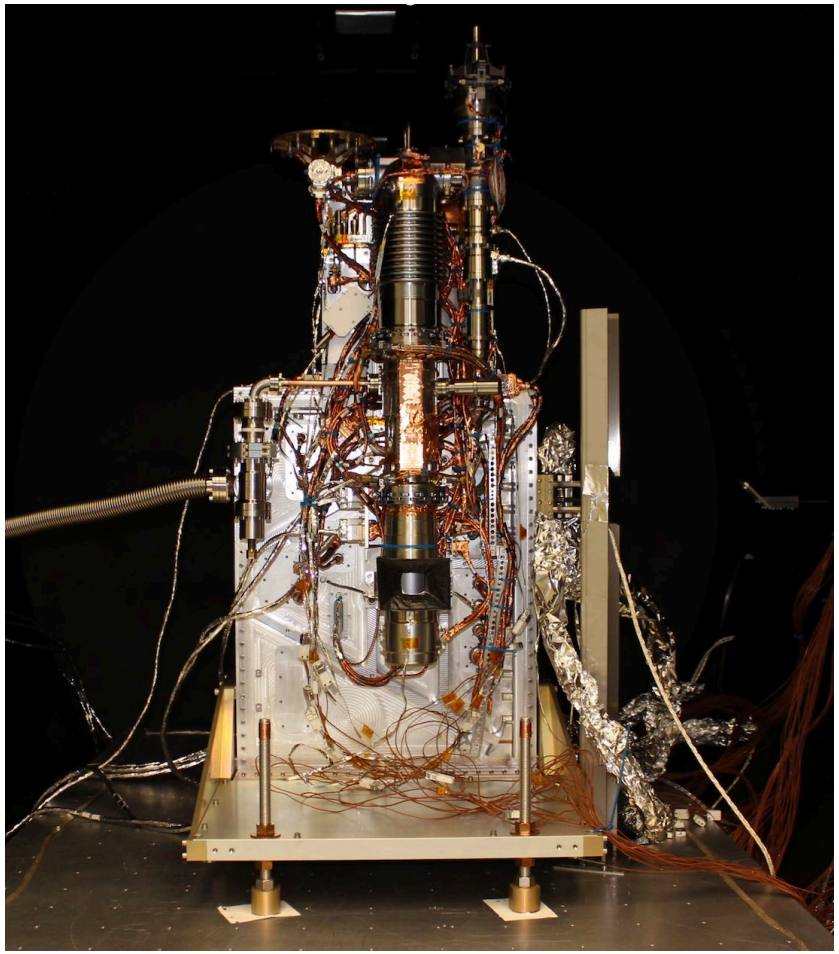
PIMS Pre-ATLO Delivery Team



REASON Electronics in TVAC

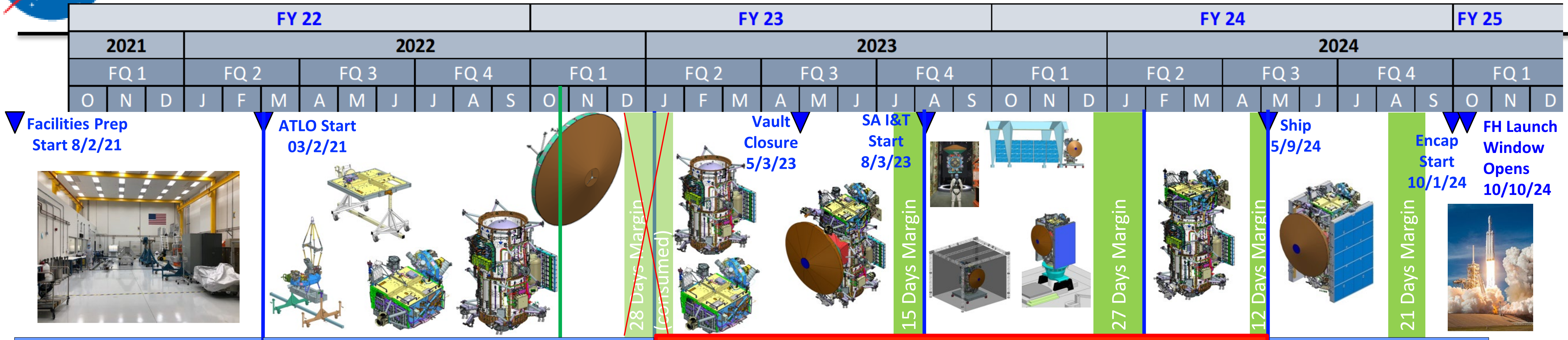


ECM Mag Cal Testing Location:
Deep in the woods in Germany



MASPEX in TVAC

ATLO High-Level Schedule



Phase 1 Facilities Prep	Phase 2 De-stacked Integration & Test	Phase 3 Stacking & System Level Tests	Phase 4 Environmental Test	Phase 5 Post-Env Activities	Phase 6 Launch Activities

B344
- Facility Set Up
- MGSE/EGSE Set Up

B344/B179 HB1
- Vault I&T
- Nadir Deck I&T
- +Z Panel I&T
- Avionics Module I&T
- PM Integration
- REU FM Swap

B179 HB2
- Prop Module I&T

TODAY

B179 HB1
- AM/PM destacked I&T
- DSN Compat
- Sys Test 1a
- SP3T swap
- SADA Install
- PCDA FM swap
- ECE FM swap
- *Vault Closure
- AM/PM Stack
- HGA Install
- ECM Install
- Sys Test 1b
- FP Test 1a

B179 HB1
- EMI/EMC/Magnetics

B150
- TVAC-Cruise

B179 HB1
- SA & REASON I&T
- Sys Test 2a
- FP Test 1b
- Sys Test 2b

B144
- Acoustics
- Random Vibe
- Clamp Band Sep Tests

~~**B150**~~
- ~~TVAC-Launch~~

B179 HB1
- Alignments
- SA Uninstall
- Sys FP 2
- Sys Test 3
- Mass Props (Spin Table)
- HGA Uninstall
- Pack & Ship FS

PHSF
- Unpack FS
- Install FM Batteries, HGA & SA
- Sys Test 4
- MIL-71 ETE Compat
- Final Alignments
- RBF/IBF Closeouts
- Propellant Loading
- Final Mass Prop
- Install FS onto PAF & Encapsulate

Hangar 39A/Pad 39A
- Chkout/Batt Charge
- Integrate to LV
- Chkout/Batt Charge
- Config for Launch
- Launch

Two shift operations

* May be impacted by MISE delivery

Project Manager's Top Concerns

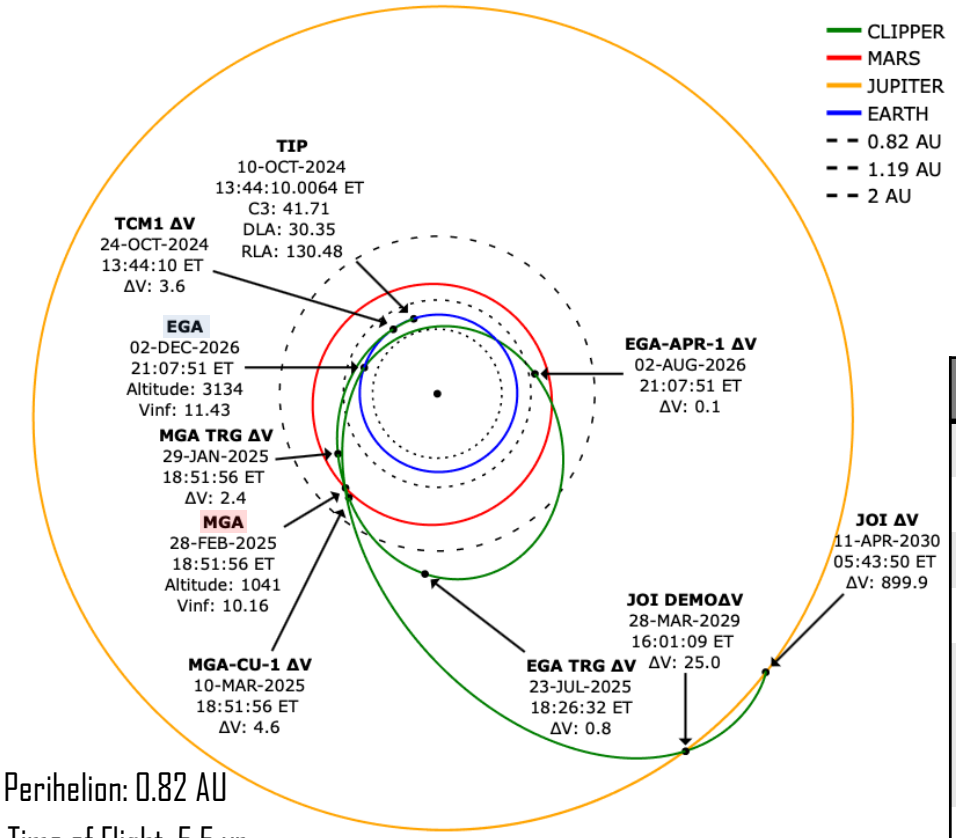
- Schedule erosion due to technical challenges consistent with a Flagship mission at this point in the Project lifecycle
  - Several deliveries are in their "end game," after overcoming technical issues:
    - Power Control and Distribution Assembly (PCDA)
    - Narrow Angle Camera (NAC)
    - MASPEX Instrument
    - REASON Electronics
  - Several deliveries remain open, due to either technical issues in work or due to the risk of additional technical issues, given the amount of testing remaining:
    - MISE Instrument: In environmental test and needs EMI/EMC retest to verify mitigations that are currently in work
    - Europa Compute Element (ECE): In box-level test and still have the full test campaign ahead of them before Spring 2023 delivery
- Solving technical issues and the associated schedule slips expend budget reserves (Unallocated Future Expenditures [UFE])
- Ensuring Europa Clipper is staffed appropriately remains a top concern

While challenged by current and expected future issues,
Europa Clipper remains on track for our October 2024 launch

Europa Clipper Reference Trajectory

21F31_v5: Includes Ephemeris updates and Minor Tour Tweaks

Mars-Earth Gravity Assist (MEGA) Trajectory



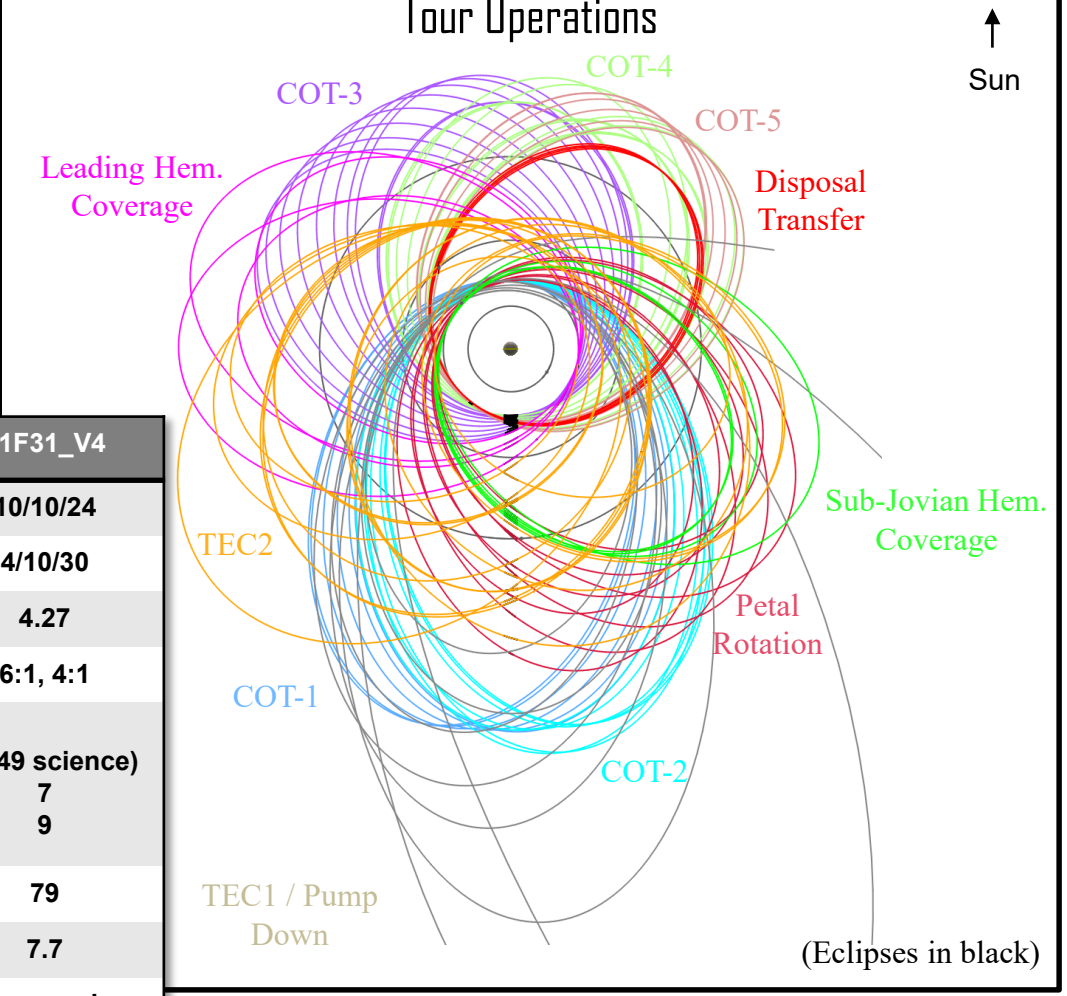
Perihelion: 0.82 AU

Time of Flight: 5.5 yr

Launch Period: 10/10-10/30, 2024 (21 days)

Tour Parameter	21F31_V4
Launch Date	**10/10/24**
Arrival Date	**4/10/30**
Tour Duration (yr)	**4.27**
Europa Resonance	**6:1, 4:1**
Number of Flybys Europa Ganymede Callisto	 **53 (49 science)** **7** **9**
Jupiter Orbits	**79**
Max. Incl. (deg)	**7.7**
Disposal Body	**Ganymede**

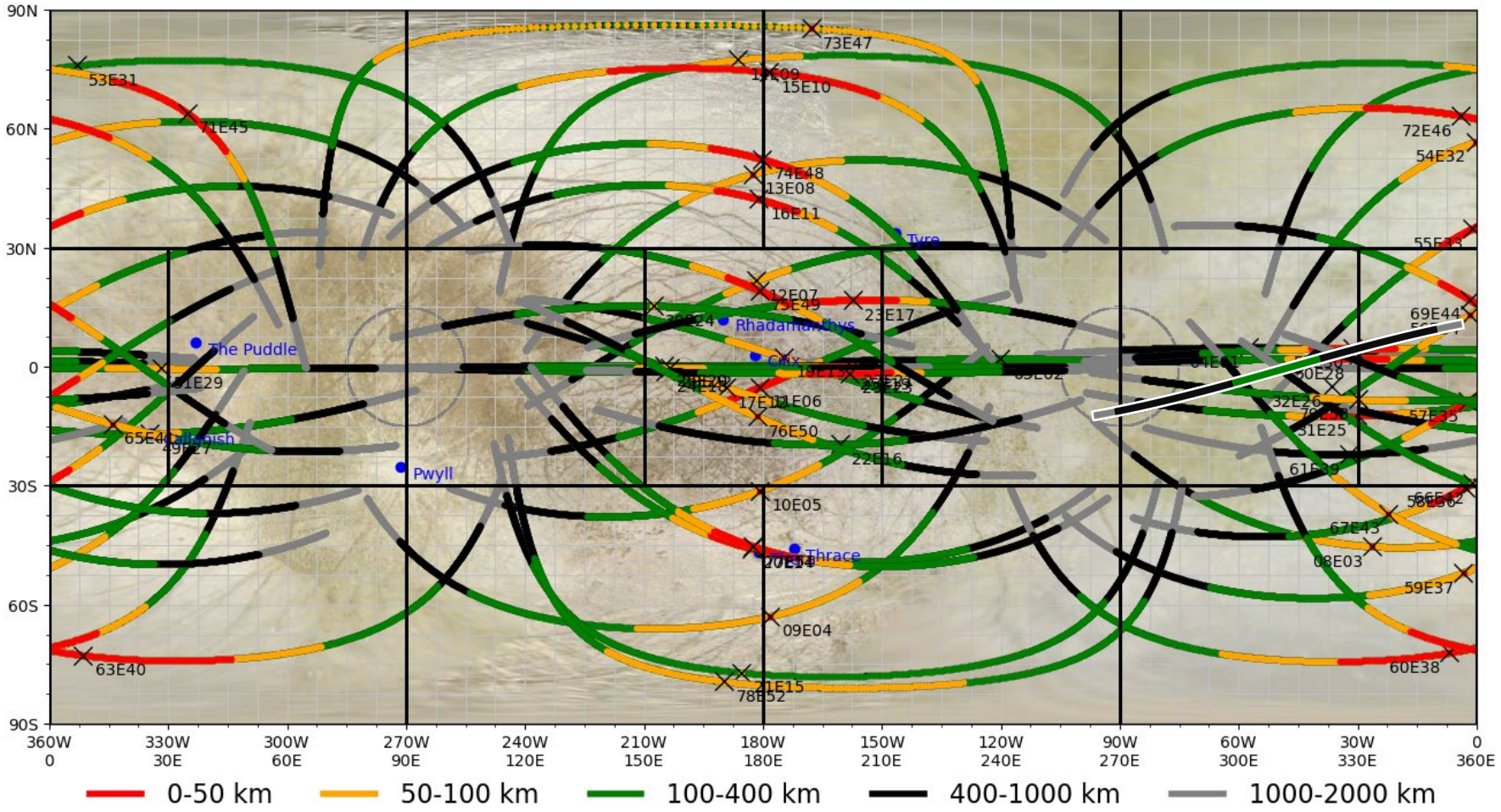
Tour Operations



Europa Clipper Reference Trajectory

21F31_v5

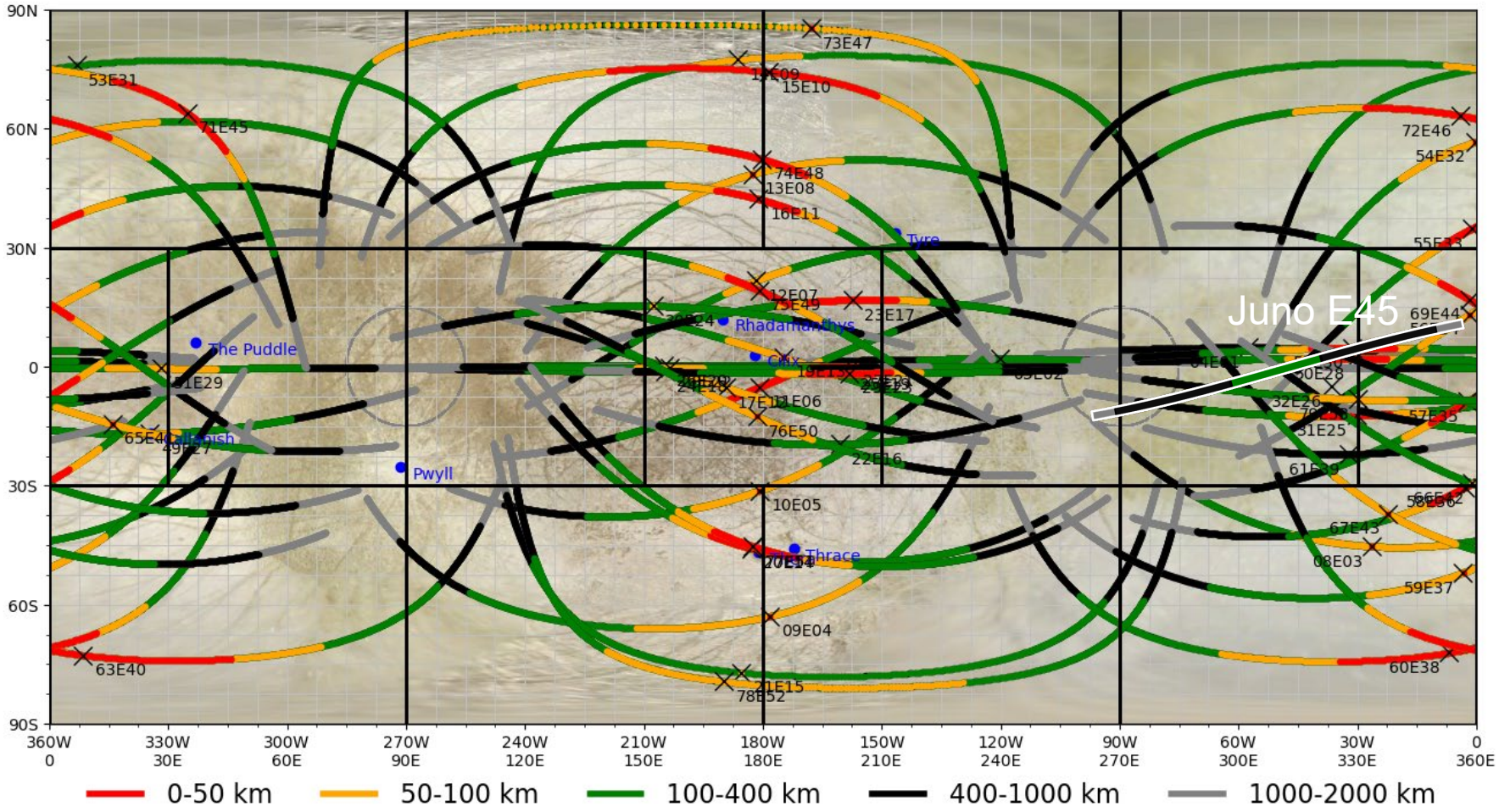
- Trajectory has been slightly updated (v5), given Juno-related ephemeris updates
- Options for tweaked tours are being evaluated this winter



Europa Clipper Reference Trajectory

21F31_v5

- Trajectory has been slightly updated (v5), given Juno-related ephemeris updates
- Options for tweaked tours are being evaluated this winter
- New Juno results at Europa potentially could influence the final selected Europa Clipper tour

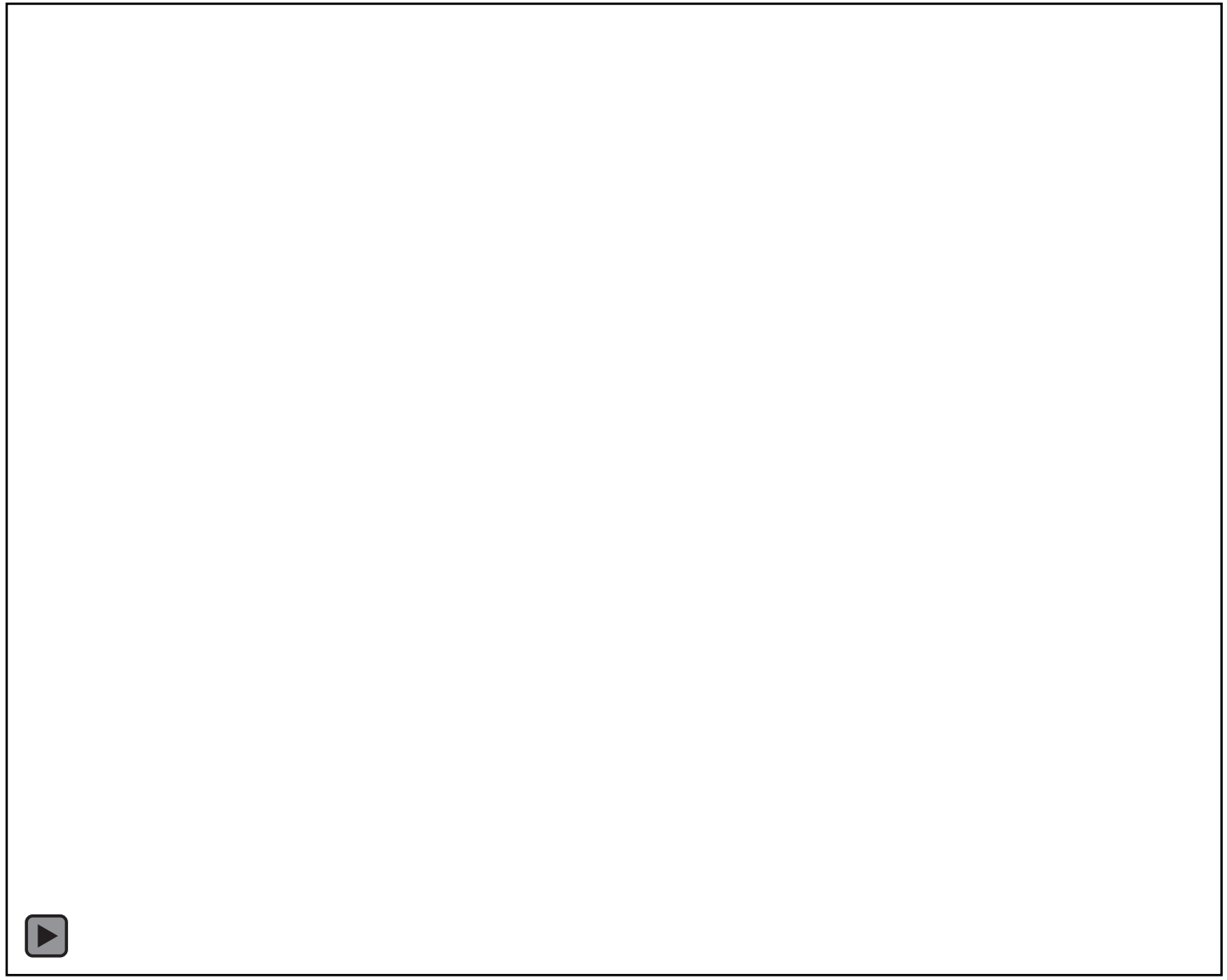


Toward a Science Strategic Planning Guide

- At PSG-12 (Feb. 2022), we will begin to develop a Strategic Science Planning Guide, ahead of the initial (early 2024) Reference Activity Plan (RAP v0) for tour operations
- To date, timelines have been driven by instrument inputs; this will be the first formal opportunity for Thematic Working Groups to provide science guidance for RAP v0
- The items of highest impact to tour RAP v0 development
  - Science priorities that could affect spacecraft pointing, or items that could have impactful downstream effects
  - Science discipline-focused objectives and priorities across flybys and orbits
- The Thematic Working Groups will concentrate on:
  - Science priorities for non-nadir tour periods (s/c pointing: e.g. joint scans, plume search)
  - Per-encounter prioritized observation objectives for the nadir period

Potential Synergistic Science Opportunities with JUICE

- Europa Clipper and JUICE now have launch dates and near-final trajectories, expected to be in the Jupiter system simultaneously
- For example, JUICE E2 and Clipper E23 flybys are nominally <4 hr apart, potentially offering insights into rapid temporal phenomena
- Informal joint Clipper-JUICE workshop held (Feb. 2) to discuss possible synergies, and many interesting opportunities identified for consideration
- A joint JUICE-Clipper Science Steering Group has been formed, co-chaired by Emma Bunce (Univ. Leicester) and Louise Prockter (APL), to cull and prioritize synergistic science opportunities

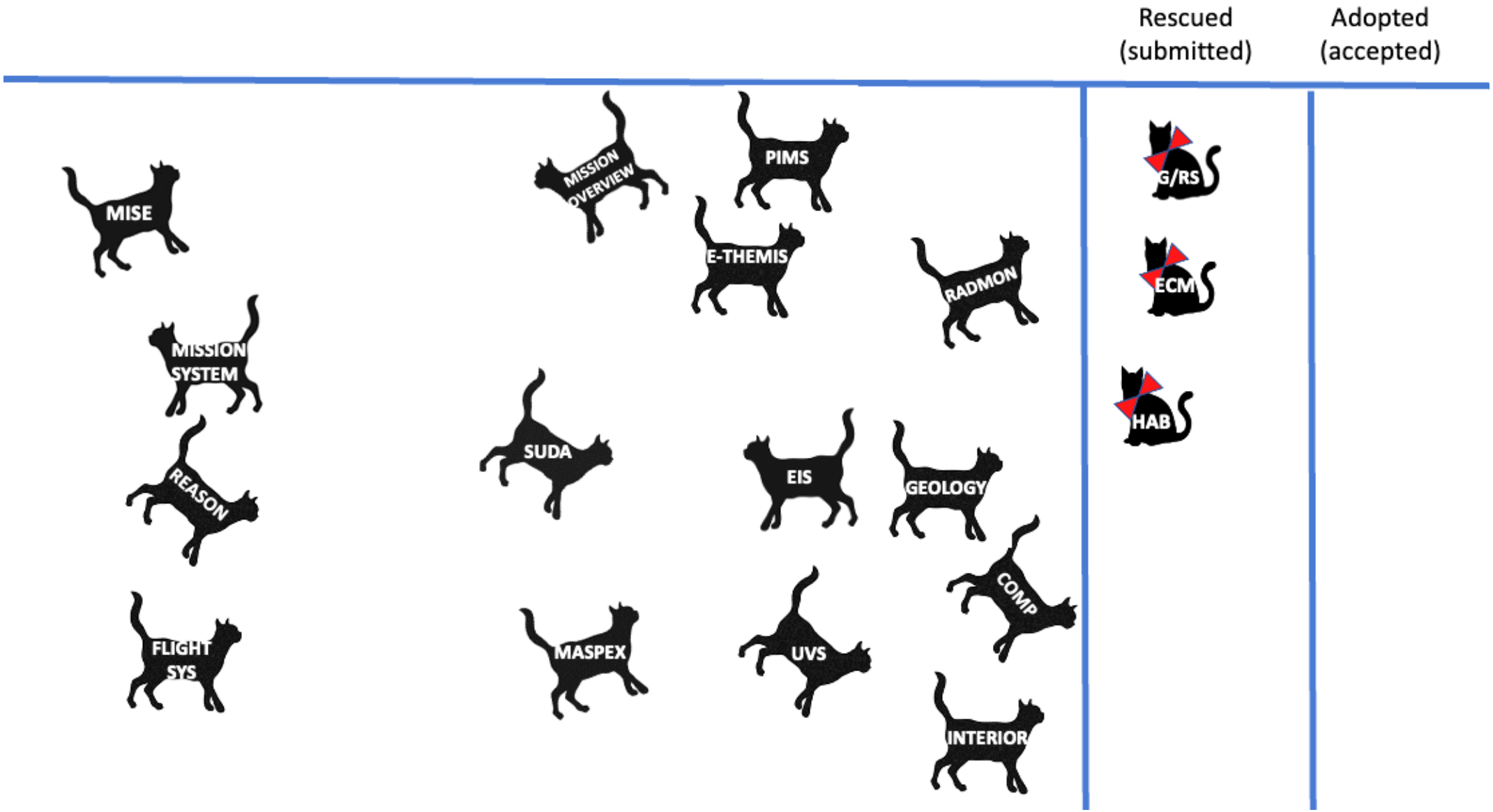


Observers' Support Group: Purpose

- Why? To enhance the scientific return of the mission at no additional cost
  - Temporal coverage; additional wavelengths and geometries; spatial context; monitoring; follow-up; historical data
  - Calibration of instruments
- Project will coordinate, hold workshops, have a website, and advocate with TACs
- Observers fund themselves
- Community-wide invitation in DPS Newsletter and PEN (Planetary Exploration Newsletter) went out in October 2022
- Is there any role for amateurs?
- Group will be respectful of competitive sensitivities
- Contact: Bonnie.Buratti@Jpl.nasa.gov

Space Science Reviews Topical Collection: Status

All papers to be submitted by March 2023



Europa Clipper Science Team Efforts Toward Equity, Diversity, Inclusion, and Accessibility (EDIA)

- EDIA Efforts are a high priority to Europa Clipper leadership and team, as reflected in Science Team Rules of the Road and Code of Conduct
- Long mission duration permit team demographics to evolve
  - Team onramps and offramps defined, with diversity expected
  - Mentoring of Graduate Student and Postdoc Affiliates
  - Professional Affiliates added where specific needs are identified
  - Co-I Emeritus role recently created for less active team members, opening Co-I onramps
- Proactive efforts by the Science Team
  - Bystander Intervention Training opportunities and EDI special topics at science team meetings
  - Grassroots EDI group, which addresses specific EDI topics that arise
  - Grassroots Sunrise group, for those identifying with being in the “Sunrise” part of their career
- Working Group / Focus Group Leadership and Meetings
  - Co-Chair roles rotate, providing leadership opportunities and diversity
  - Consensus-based decision-making aims for diversity of voices and opinions
- Accessibility needs are being recognized and addressed
  - Hybrid team meetings, masking, closed captioning, color vision deficiency
- NASA is implementing the Clipper Next Gen Initiative “to grow a science community that reflects the diversity of the country as a whole and is prepared to join and lead the Clipper extended mission”
  - Here to Observe (H2O) Program: Europa Clipper is partnered with Univ. Puerto Rico
  - Preparatory Science Investigations for Europa (PSI-E) Program
  - Participating Scientists expected around time of Jupiter Orbit Insertion

Europa Clipper Project Science Group

PIs/TLs, Co-Is, Project Science (Currently 134 total)

Oleg Abramov
Nicolas Altobelli
Amy Barr Mlinar
Jordana Blacksberg
Diana Blaney
Don Blankenship
Scott Bolton
Christelle Briois
Tim Brockwell
Shawn Brooks
Lorenzo Bruzzone
Dustin Buccino
Bonnie Buratti
Jim Burch
Bruce Campbell
Lynn Carter
Tony Case

Julie Castillo
Mathieu Choukroun
Phil Christensen
Roger Clark
Corey Cochrane
Geoff Collins
Kate Craft
Brad Dalton
Ingrid Daubar
Ashley Davies
Serina Diniega
Andrew Dombard
Charles Elachi
Catherine Elder
Carolyn Ernst
Paul Feldman
Leigh Fletcher

Antonio Genova
Yonggyu Gim
Randy Gladstone
Thomas Greathouse
Robert Green
Cyril Grima
Eberhard Gruen
Murthy Gudipati
Kevin Hand
Candy Hansen
Alex Hayes
Paul Hayne
Matt Hedman
Alain Herique
Karl Hibbitts
Mihaly Horanyi
Sam Howell

Howett, Carly
Terry Hurford
Hauke Hussmann
Xianzhe Jia
Steven Joy
Justin Kasper
Sascha Kempf
Walter Kiefer
Krishan Khurana
Randy Kirk
Margaret Kivelson
Rachel Klima
Wlodek Kofman
Haje Korth
William Kurth
Yves Langevin
Jonathan Lunine

Adrienn Luspay-Kuti
Marco Mastrogiuseppe
Erwan Mazarico
Tom McCord
Alfred McEwen
Melissa McGrath
Bill McKinnon
Ralph McNutt
Mike Mellon
Jeff Moore
Olivier Mousis
Alina Moussessian
Scott Murchie
Neil Murphy
Francis Nimmo
Bob Pappalardo
Ryan Park

Chris Paranicas
Wes Patterson
Carol Paty
Cynthia Phillips
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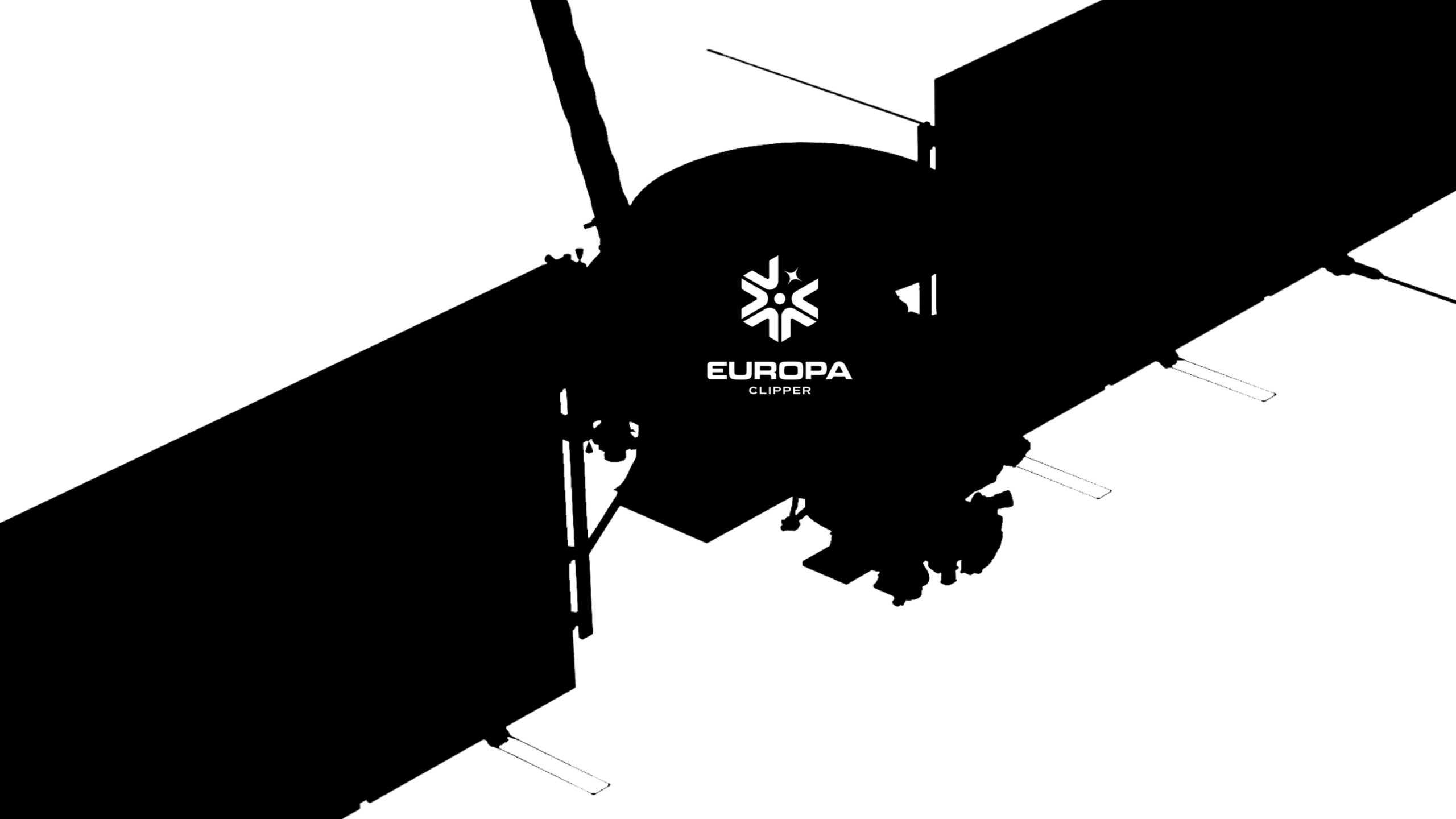
Dirk Plettemeier
Frank Postberg
Louise Prockter
Lynnae Quick
Julie Rathbun
Trina Ray
Carol Raymond
Kurt Retherford
Ingo Richter
James Roberts
Lorenz Roth

Chris Russell
Abigail Rymer
Joachim Saur
Juergen Schmidt
Britney Schmidt
Dustin Schroeder
Frank Seelos
Mark Sephton
Everett Shock
Jim Slavin
Todd Smith
Jason Soderblom
Krista Soderlund
John Spencer
Ralf Srama
Andrew Steffl
Gregor Steinbrügge

Alan Stern
Michael Stevens
Robert Strangeway
Ben Teolis
Nick Thomas
Gabriel Tobie
Paolo Tortora
Zibi Turtle
Hunter Waite
Ben Weiss
Joe Westlake
Paul Withers
Danielle Wyrick
Duncan Young
Mikhail Zolotov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