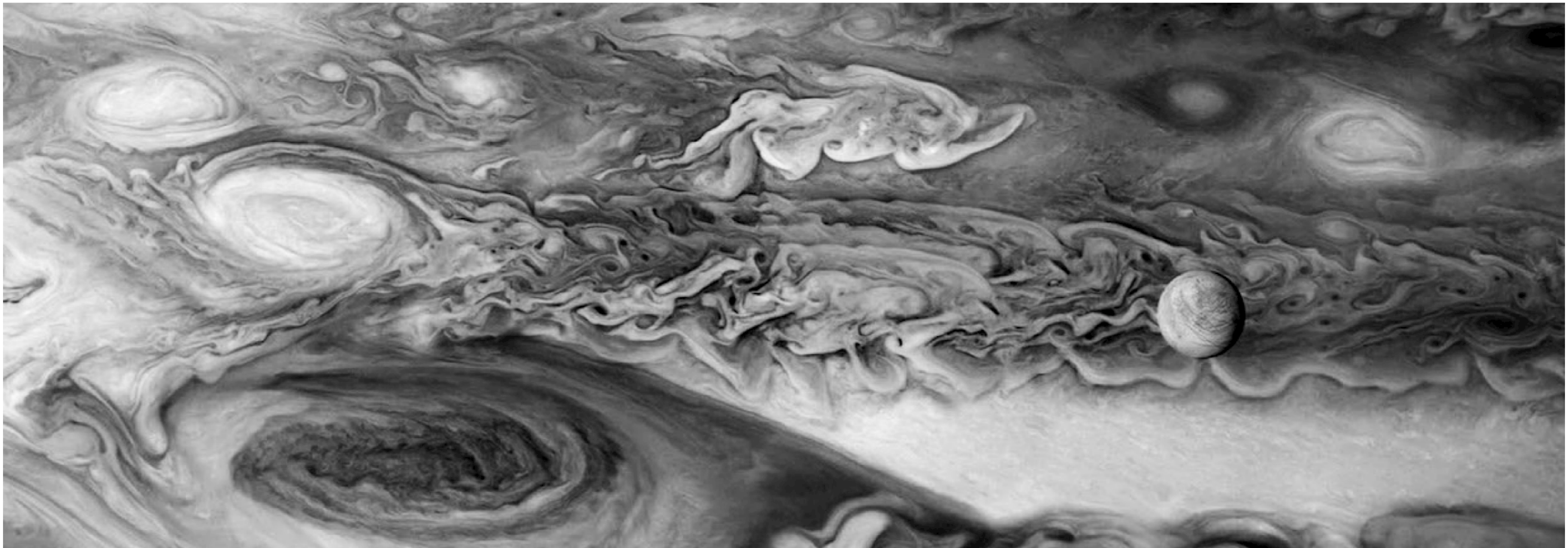


Europa Clipper Update for CAPS

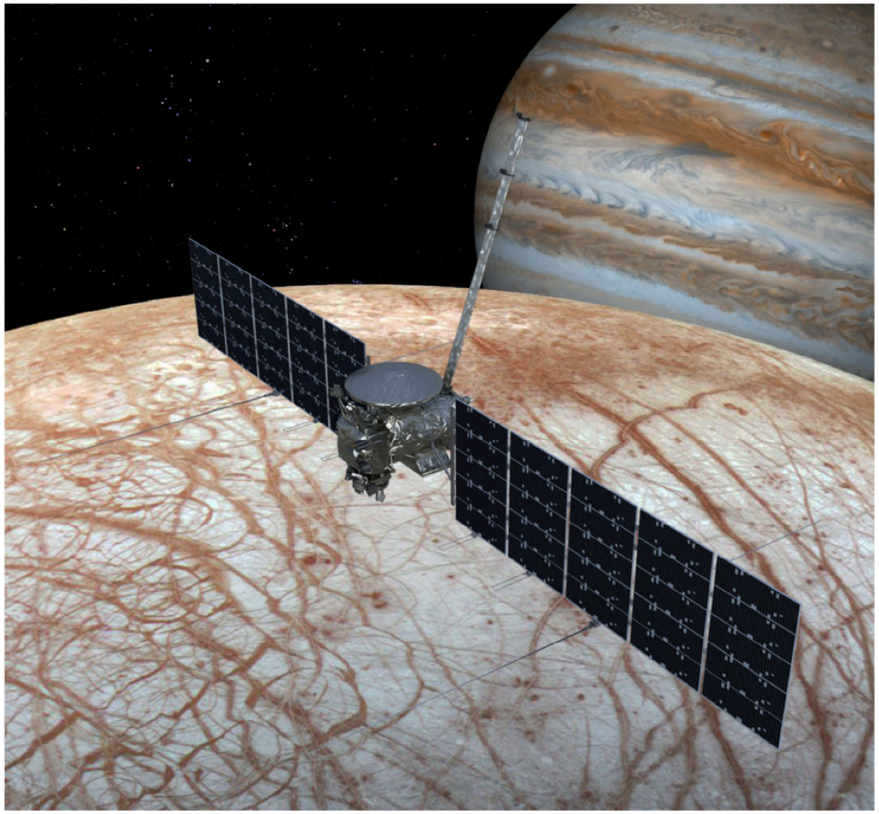
Jan Chodas, Project Manager (Jet Propulsion Laboratory, California Institute of Technology)
Robert Pappalardo, Project Scientist (Jet Propulsion Laboratory, California Institute of Technology)

July 9, 2020

EUROPA CLIPPER

Europa Clipper Update to CAPS: Outline

- Project Overview
- Launch Readiness
- Current Status
- Flight System Progress and Status
- Instrument Progress and Status
- Magnetometer Calibration
- Solar Array and REASON Updates
- EIS-WAC Science Role
- MASPEX Science Role
- Instrument Progress: Hardware
- Continuation Review Science Implications
- Instrument Mapping to Decadal Survey



Project Overview

Salient Features

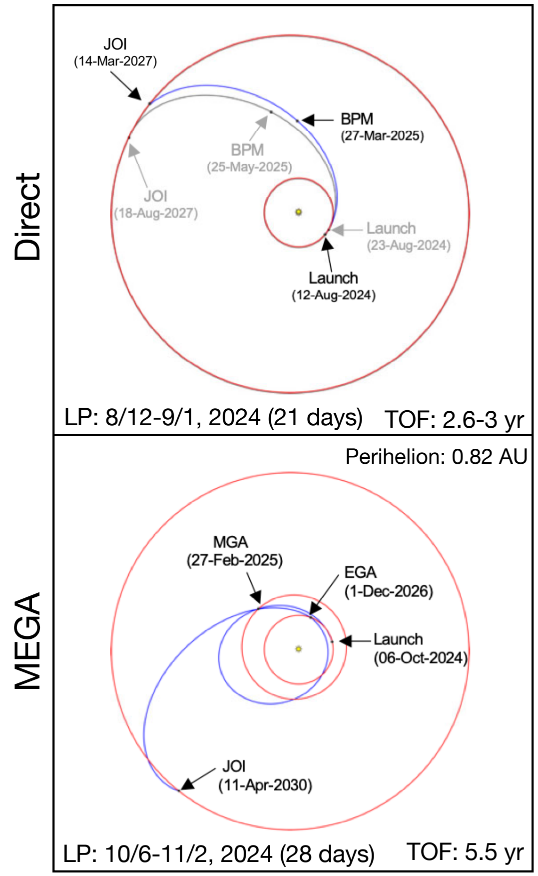
- Mission Directorate: Science Mission Directorate
- Division: Planetary Science Division
- Program: Solar System Exploration Program (MSFC)
- Project Category: Cat-1
- Risk Classification: A (Tailored)

Science

- ~50 Low Altitude Flybys of Europa (25 – 2400 km) over ~3.8 years
- Several opportunistic flybys of Callisto and Ganymede
- 10 Science Investigations
- Investigate The Habitability of Europa
  - Ocean & Ice Shell
  - Composition
  - Geology & Current Activity

Launch Readiness

- Clipper spacecraft will be launch-ready in early 2024 and Clipper is baselining a 2024 Launch Readiness Date (LRD)
- SLS launch opportunities exist in summer and fall 2024 and an ELV launch opportunity exists in fall 2024
  - SLS team is working towards meeting the near-term deliverables required for a 2024 launch
  - NASA's Launch Service Program (LSP) has determined that an Expendable Launch Vehicle commercial option is feasible in 2024
- **Clipper requires a LV decision by end of CY 2020 to continue to mature spacecraft development**
  - Due to launch vehicle uncertainty, Project Critical Design Review (CDR) was delayed until December 2020



Current Status

- Project team is in the midst of re-baselining costs and schedules for the summer 2024 LRD
- COVID-19 impacts to date have been substantial and total extent is still unknown
  - JPL, GSFC and MSFC have been on mandatory telework until recently; on-site tasks are just beginning to ramp up
  - APL is on elective telework and progress has slowed due to utilizing safe-at-work practices
  - On-site work at instrument delivery organizations has been slowed down or stopped
  - Many vendors have slowed down or stopped work
- Re-baselined 2024 schedule will take COVID-19 impacts into account

Flight System Progress

HGA Reflector Completed

Nadir Deck Machining

Upper Propulsion Module

Flight System Status

- System detailed design is in process as the project proceeds to CDR
- Hardware and software designs are maturing; some flight hardware is in fabrication and flight software releases are continuing on schedule
- Technical challenges are in work in some areas
  - Thermal pump used in Heat Rejection System failed multiple times during development; decision was made to revert to Mars heritage pumps, using 2 in series to produce required flow rate
  - Some elements of the hardware do not address internal electrostatic discharge (iESD) mitigations adequately; reviewing all designs to identify shortfalls and add bleed paths and/or filter assemblies if needed
  - Reliability analyses and independent reviews lag hardware builds; prioritizing tasks and adding workforce to catch up

Instrument Critical Design Review (iCDR) Status

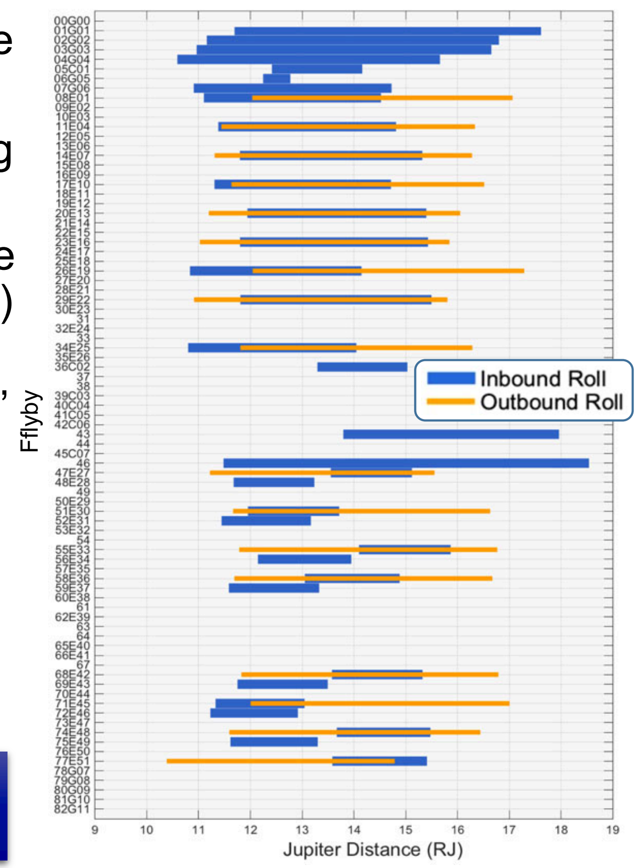
✓ iCDR Completed and Passed

- ✓ **Europa-UVS:** Europa Ultraviolet Spectrograph (Mar. 12-14, 2019, SWRI)
- ✓ **PIMS:** Plasma Instrument for Magnetic Sounding (May 14-16, 2019, APL)
- ✓ **SUDA:** SUrface Dust Analyzer (May 21-23, 2019, Univ. Colorado)
- ✓ **REASON – Electronics:** Radar for Europa Assessment and Sounding: Ocean to Near-surface (July 17-18, 2019, JPL)
- ✓ **E-THEMIS:** Europa Thermal Imaging System (Aug. 7-9, 2019, Arizona State Univ.)
- ✓ **MISE:** Mapping Imaging Spectrometer for Europa (Aug. 26-28, 2019, JPL)
- ✓ **EIS:** Europa Imaging System (Nov. 12-14, 2019, APL)
- ✓ **MASPEX:** MAss Spectrometer for Planetary Exploration (Jan. 14–16, 2010, SWRI)
- **REASON – Antennas:** Radar for Europa Assessment and Sounding: Ocean to Near-surface (Aug. 18-19, 2020, JPL)
- **ECM:** Europa Clipper Magnetometer (Aug. 20-21, 2020, JPL)

Europa Clipper Magnetometer (ECM) Calibration Using Spacecraft Rolls

- Inflight magnetometer calibration is required to achieve Level-1 science of determining ocean salinity and thickness
- Analysis by the ECM Science Team shows that inflight calibration using spacecraft calibration rolls can yield precision better than 1 nT
- Offset drifts <0.5 pT/day have been demonstrated by 24 sensors on the 4 Magnetospheric Multi-Scale (MMS) spacecraft (same UCLA heritage)
- Projected offset drift indicates that inflight calibration on every third Europa encounter should be sufficient, so spacecraft rolls can be "split"
- Challenges: Identify <u>24-h periods</u> in the <u>appropriate magnetospheric location</u> where <u>other science is retained</u> and <u>operational conflicts (notably solar array charging) are minimized</u>
- Magnetometer boom has been changed from 5 m to 8.5 m (coilable) boom, simplifying achievement of magnetic cleanliness requirements, and reducing number of fluxgate sensors needed from 4 to 3

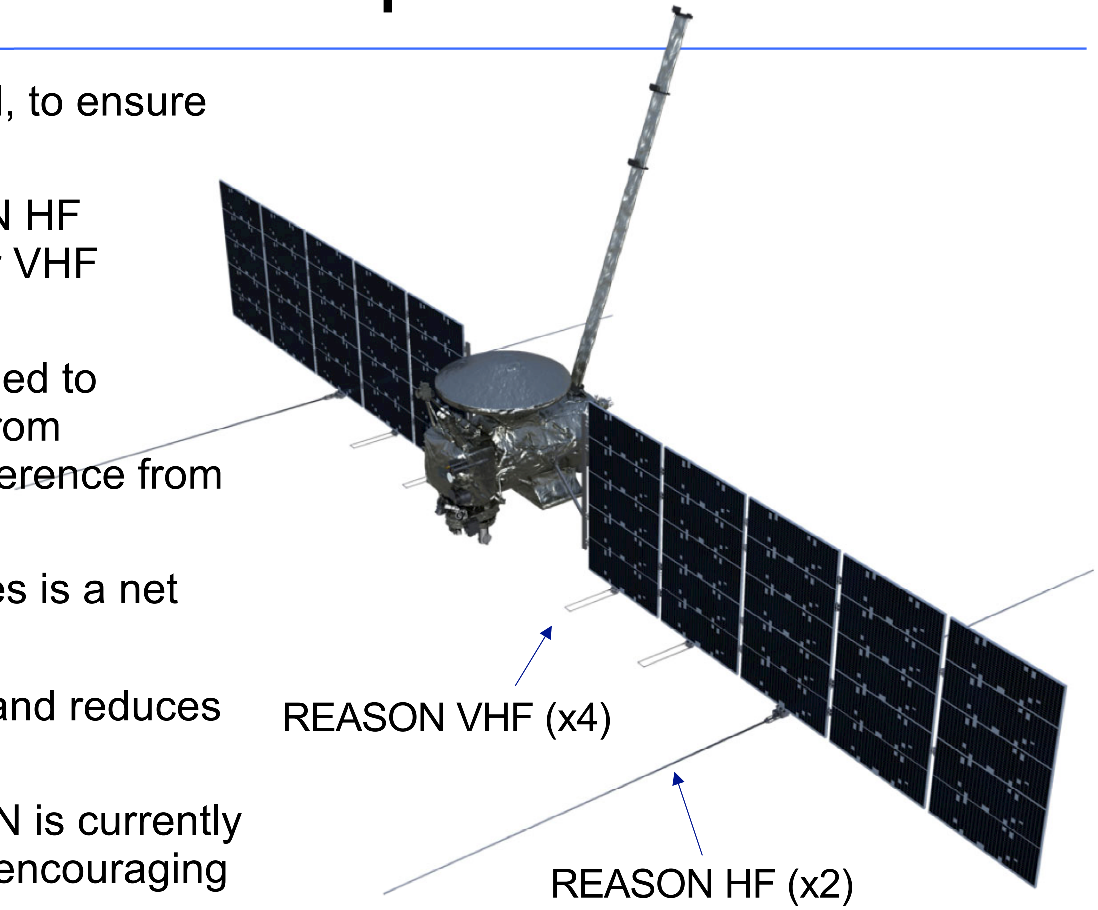
Calibration Roll Opportunities



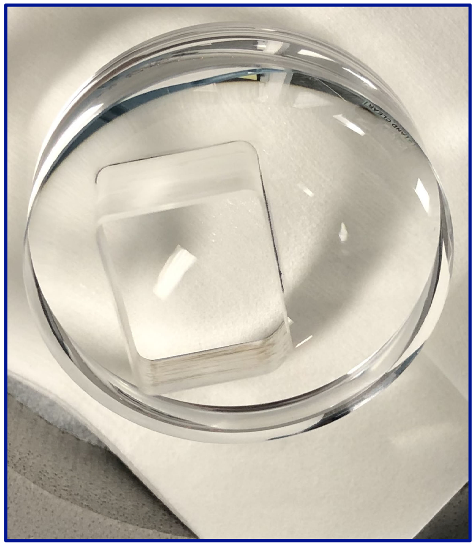
Strong cooperation between the Magnetometer Science and Project teams bodes well for achieving full Level-1 ocean and ice shell science

Solar Array & REASON Updates

- Active side of solar array has been swapped, to ensure sun on arrays when deployed
- To reduce loads on the solar array, REASON HF antennas moved to panel centers, and outer VHF antennas moved inward
- REASON VHF antennas rotated and simplified to deployable dipoles, decoupling solar array from REASON to minimize electromagnetic interference from the solar array
- Detailed analyses of these antennas changes is a net positive for REASON science
- Also assures no EIS field-of-view incursion and reduces contamination to MASPEX
- Effect of lengthened EMC boom on REASON is currently being analyzed, and preliminary results are encouraging

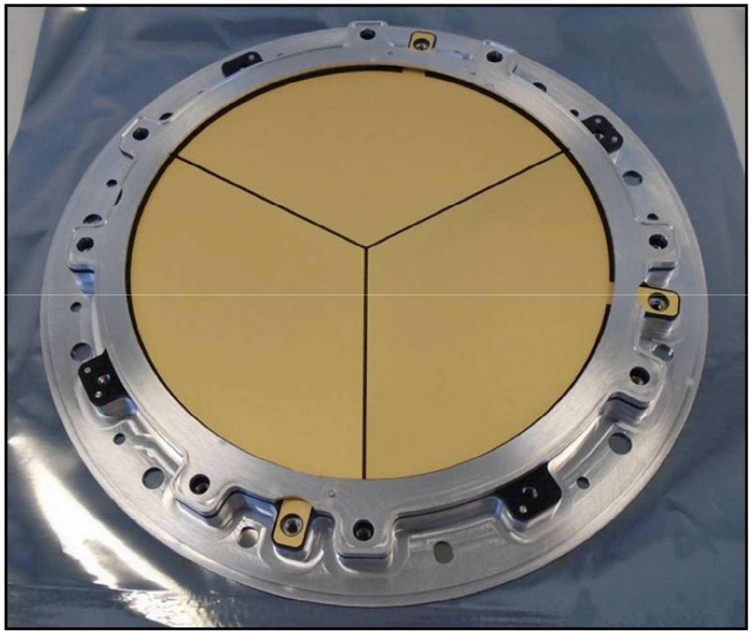


Instrument Progress: Hardware



MISE Flight Dyson CaF_2 Lens

Courtesy D. Blaney, JPL



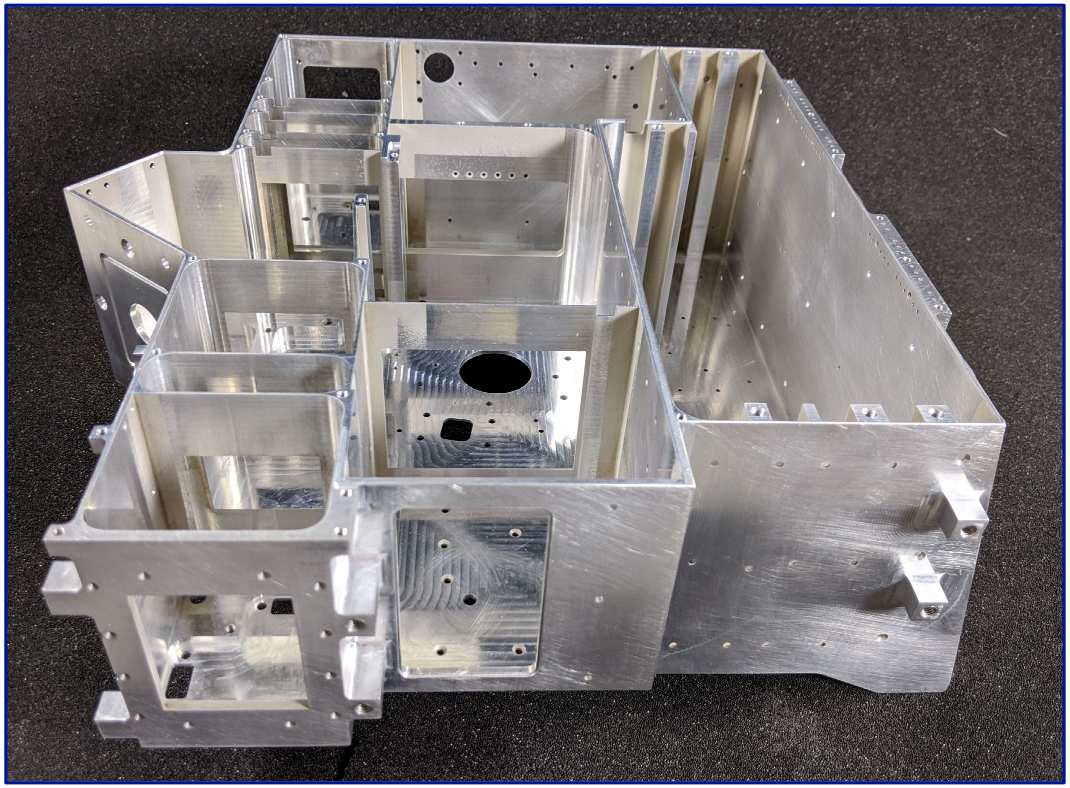
PIMS Flight Collector Assembly

Courtesy J. Westlake, APL

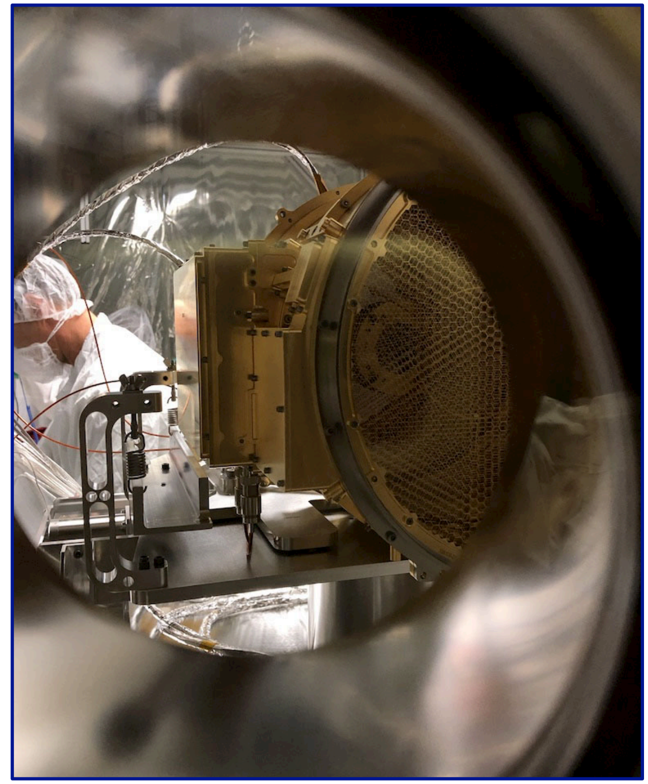
ECM Pathfinder

Courtesy R. Strangeway, UCLA

Instrument Progress: Hardware

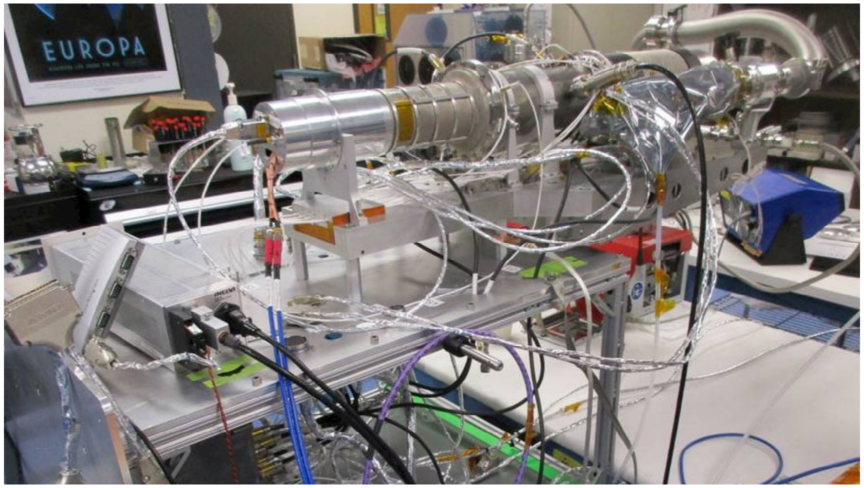


Europa-UVS Flight Model Housing
Courtesy K. Retherford, SWRI

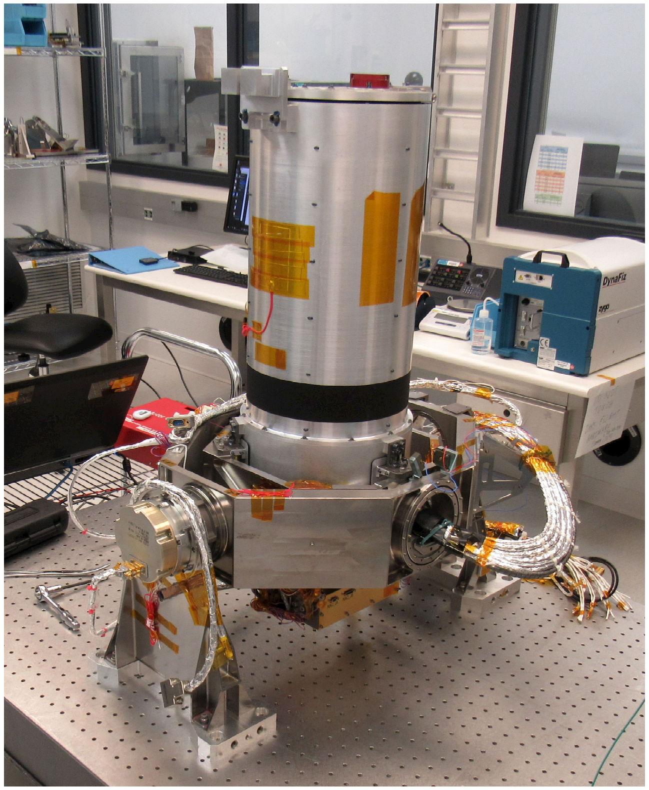


SUDA Engineering Model in Dust Chamber
Courtesy S. Kempf, ASU

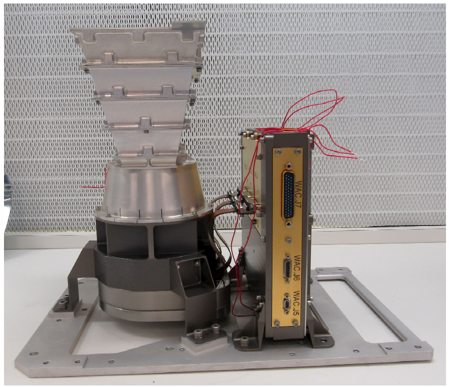
Instrument Progress: Hardware



MASPEX Engineering Model
Courtesy H. Waite, J. Burch, SWRI



EIS-NAC Engineering Model
Courtesy E. Turtle, APL

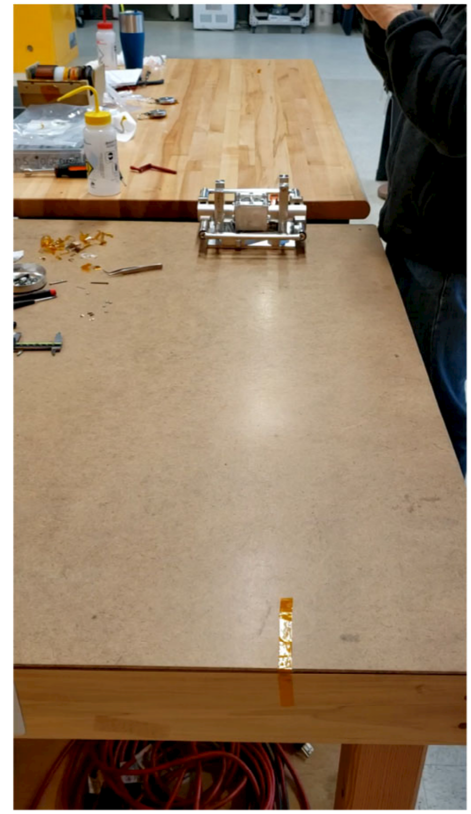


EIS-WAC Prototype
Courtesy E. Turtle, APL

Instrument Progress: Hardware

REASON-HF Prototype Deployment

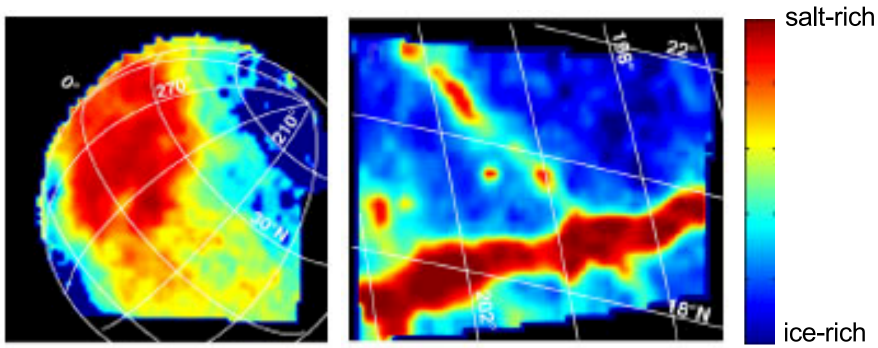
Courtesy A. Moussessian, JPL



REASON-VHF Prototype Deployment

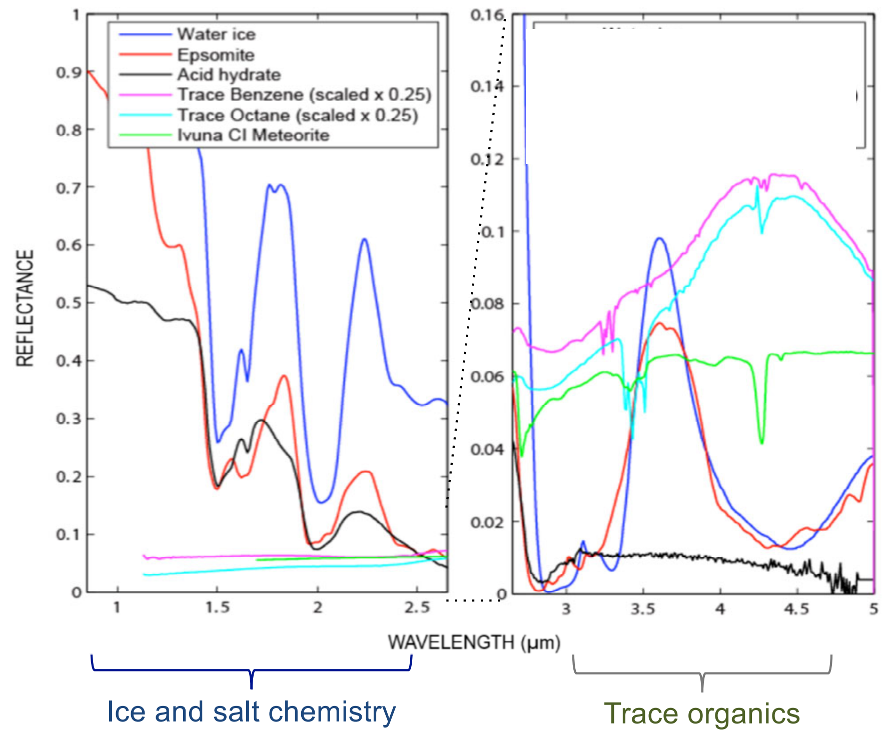
Continuation Review Implications: MISE Science Role

- Mapping Imaging Spectrometer for Europa (MISE) will map IR absorptions at 0.8 – 5 μm, to determine the composition of Europa's surface
- Infrared pushbroom spectrometer with active thermal control
- Scan mirror for image motion compensation and for active scanning



Galileo NIMS: McCord et al., 1998

Key compounds at MISE spectral resolution and sampling:



MISE team, 2015

The role of MISE in the L1 Requirements

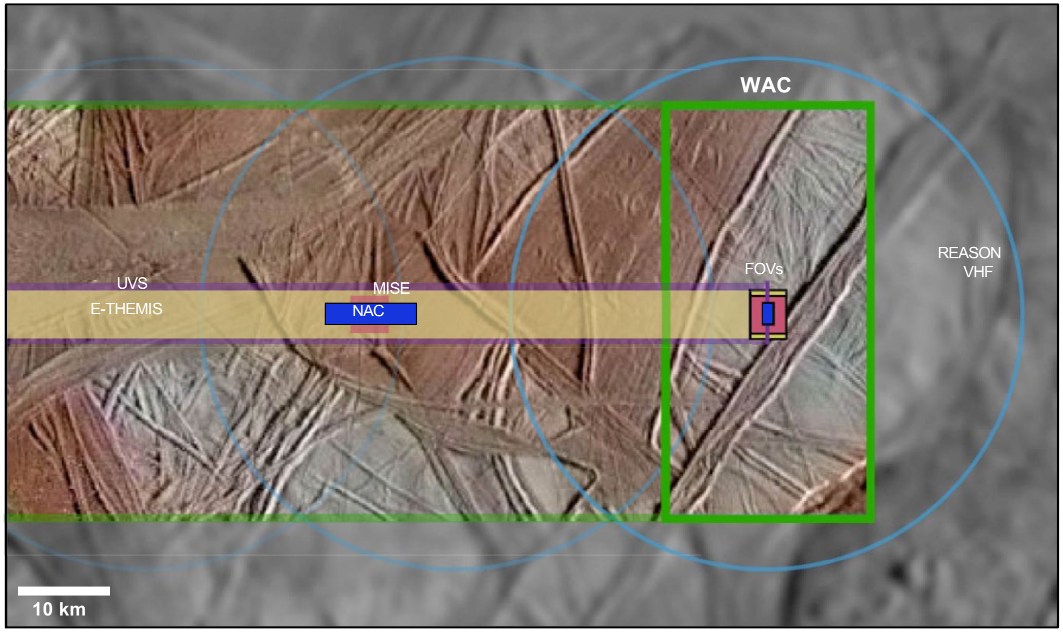
	Potential Edits to Baseline Level-1 Science Requirements	Potential Edits to Threshold Level-1 Science Requirements
Ice & Ocean	**I1:** Map the vertical subsurface structure in regions of potential surface-ice-ocean exchange to >3 km depth along globally distributed ground tracks achieving a total cumulative 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, 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 ≥70% 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, especially organic compounds, 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, especially organic compounds, 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 within at least one third of that surface area.	**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 within at least one third of that surface area.
	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.

MISE Role:
- Primary for L1
- Enhances L1

MISE is critical to the L1s on global composition (C1) and regional composition (C2).
No L1 science impacts resulted from the instrument Cost Control Process.

Continuation Review Implications: EIS-WAC Science Role

- WAC has moderate impact to the Level 1s, but strong links to overall science and instrument synergies
  - Integrates with NAC to provide global imaging coverage and regional-scale topography data
  - Provides coordinated context for remote sensing datasets
  - Aids REASON in identifying false sub-surface radar echoes
  - Provides topographic dataset for Terrain Relative Navigation (TRN) for a potential future lander
  - High public engagement potential (e.g. color flyovers)



WAC images are a base for all close-approach remote sensing datasets

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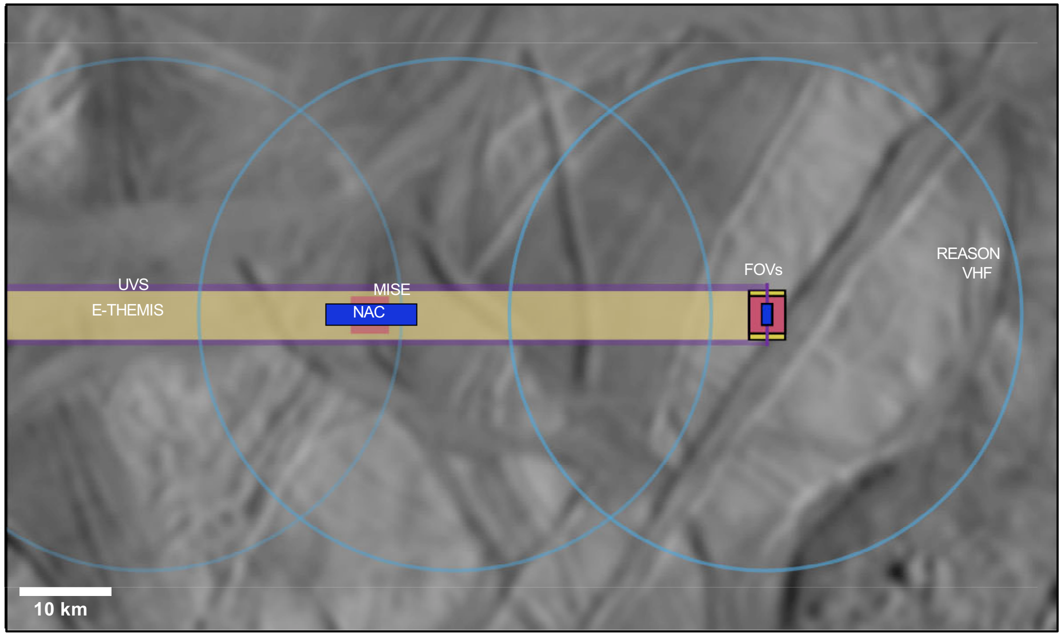

WAC images are a base for all close-approach remote sensing datasets

Removing EIS-WAC from the L1 Requirement Set

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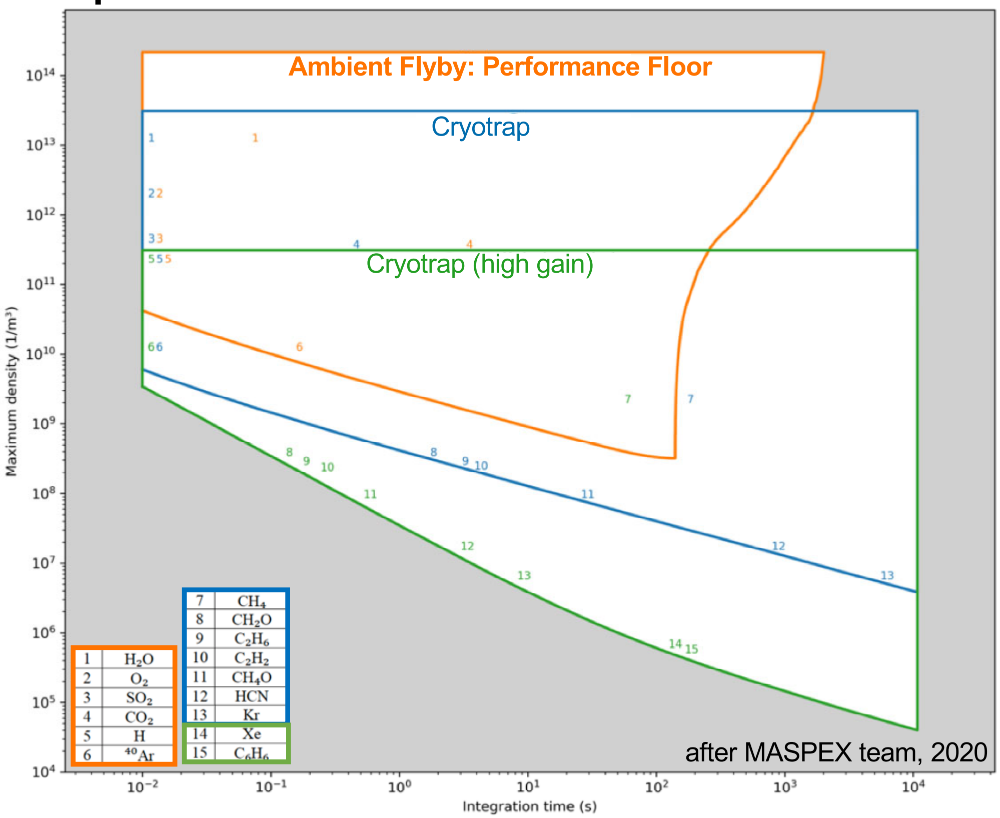
	~~**G3:**~~ Characterize the surface at ~1-m spatial scale to determine surface properties, for ≥18 globally distributed sites.	N/A
Current Activity	**A1:** Search for and characterize any current activity, notably plumes or thermal anomalies, in regions that are globally distributed.	**A1:** Search for current activity, notably plumes or thermal anomalies.

Without EIS-WAC:
- L1 fails
- L1 at risk
- L1 diminished

To remove EIS-WAC from the Level 1s, only the regional topography geology requirement (G2) needs to be reduced to what NAC can achieve. Note that the global geology L1 requirement (G1) can met with NAC only.

Continuation Review Implications: MASPEX Science Role

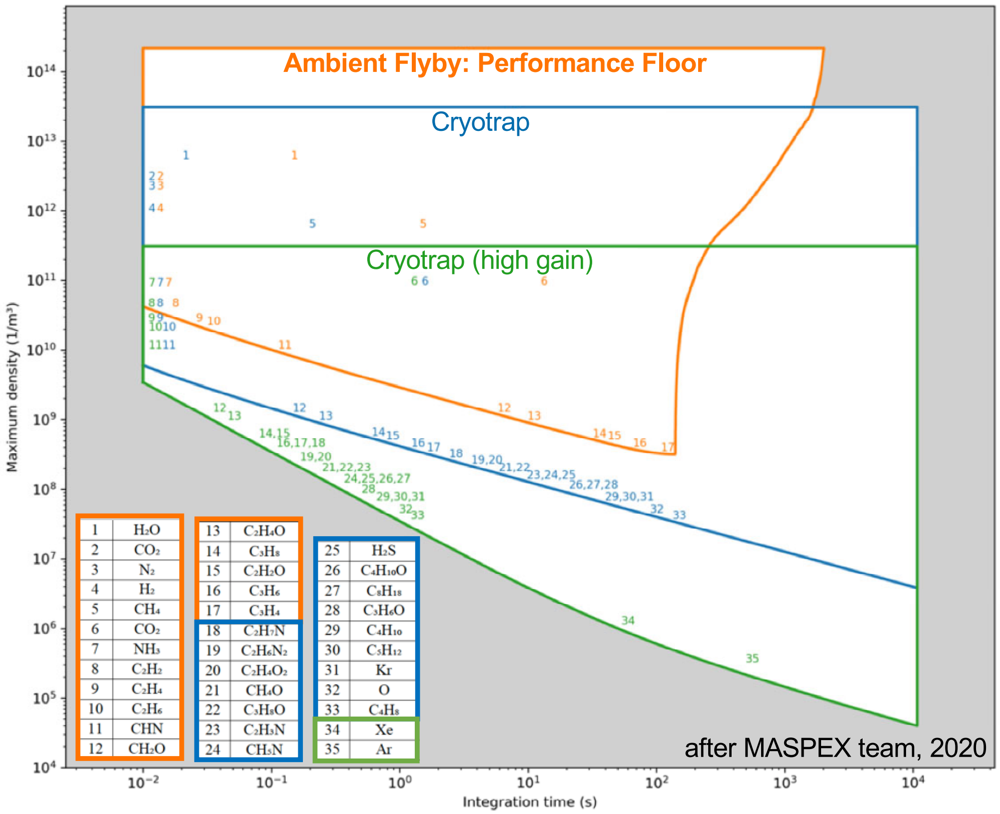
Sputtered Surface Model



- MASPEX offers Europa Clipper's best chance to determine energy for life in Europa's ocean
  - Can measure trace organics in Europa plumes and sputtered atmosphere
  - Organic ratios permit inference of ocean habitability
- However, this habitability measurement is not explicit in the Level 1 requirements
  - "Characterize the composition and sources of volatiles, particulates, and plasma, sufficient to identify the signatures of non-ice materials, especially organic compounds"
  - There is substantial science margin on the relevant L1 to identify organics, especially if plumes exist
- Neutral mass spectrometry of even simple organics/volatiles and their isotopic content would be powerful for characterizing Europa's atmosphere, as per the Europa Science Definition Team recommendation

Continuation Review Implications: MASPEX Science Role

Plume Model



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Ice & Ocean	**I2:** Constrain our knowledge of the average thickness of the ice shell, and the average thickness and salinity of the ocean, 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.
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As an option to remove MASPEX from the Level 1s, the atmospheric composition (C3) requirement could be adjusted to temper the need to address organic compounds for each material state, permitting Europa-UVS to achieve the volatiles requirement. The threshold should be adjusted for parallelism.

Without MASPEX:
- L1 fails
- L1 at risk
- L1 diminished

Mapping of Instruments to Decadal Survey Europa Objectives

✓ = Primary Method – most robust ✓ = Independent Method – not as robust on its own

Decadal Survey Prioritized Objectives	**Europa-UVS** *UV spectrograph*	**EIS-NAC** *Narrow-angle camera*	**EIS-WAC** *Wide-angle camera*	**MISE** *IR spectrometer*	**ETHEMIS** *Thermal imager*	**REASON** *Ice penetrating radar*	**MASPEX** *Gas mass spectrometer*	**SUDA** *Dust mass spectrometer*	**ECM** *Magnetometer*	**PIMS** *Plasma*	**GRAVITY** *Telecom Doppler*
D1: Characterize the extent of the ocean and its relation to the deeper interior.									**✓**	✓	✓
D2: Characterize the ice shell and any sub-surface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.						**✓**					
D3: Determine global surface compositions and chemistry, especially as related to habitability.				**✓**			✓	✓			
D4: Understand the formation of surface features, including sites of recent or current activity, and identify and characterize candidate sites for future *in situ* exploration.	✓	**✓**	✓		✓						
D5: Understand Europa's space environment and interaction with the magnetosphere.									**✓**	✓	

Decadal Survey objectives for Europa remains robustly achieved by the Europa Clipper payload.