

The logo is a triangular shield with a blue border. Inside, a white sailing ship is depicted on a circular path, with a satellite orbiting above it. The text 'EUROPA' is written in large, stylized letters across the bottom. The top of the triangle contains the text 'ASU * UTIS' on the left and 'SWRI * CU-LA' on the right. The bottom of the triangle contains 'JPL * NASA * APL'.

Europa Clipper Update to OPAG

Bob Pappalardo, Europa Clipper Project Scientist
Jet Propulsion Laboratory, California Institute of Technology
and the Europa Clipper Science Team
February 21, 2018



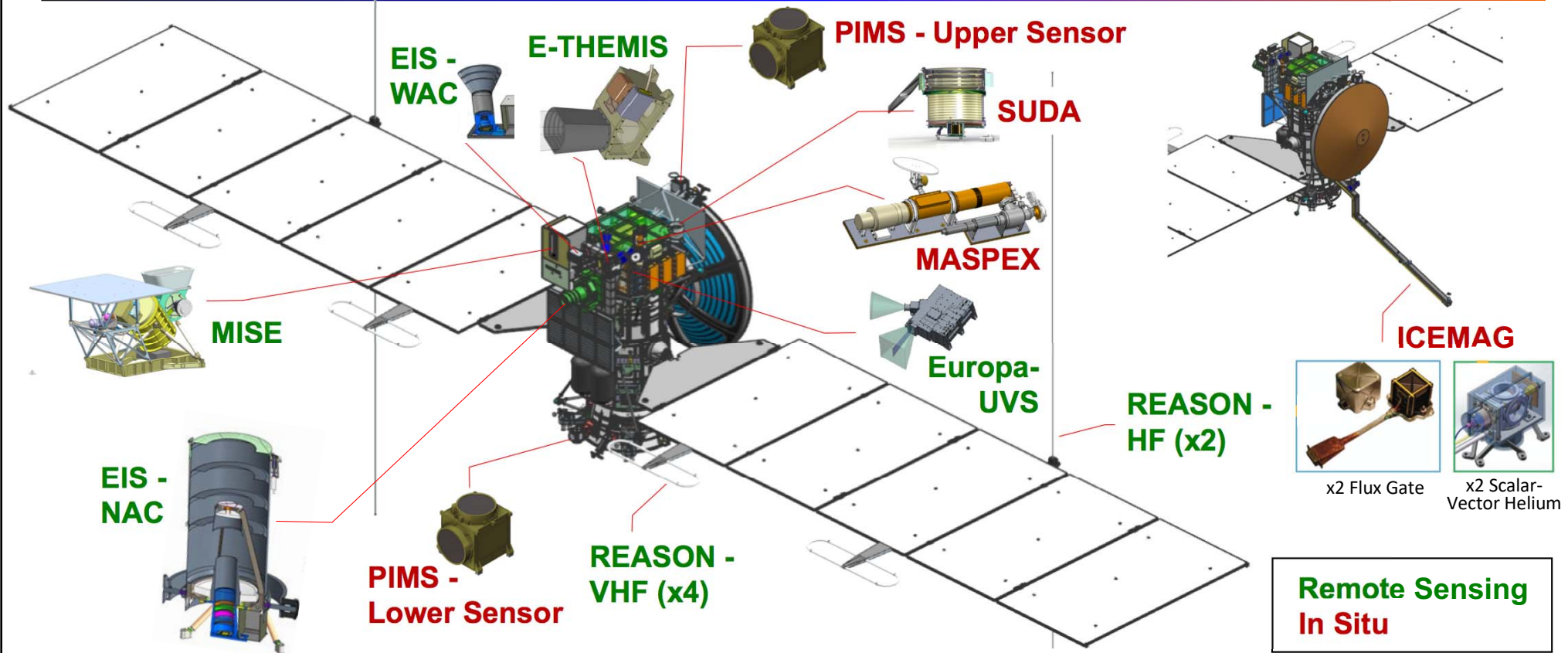
- **Propulsion Subsystem PDR 6/27-29/17 (GSFC)**
- **Propulsion Module PDR 7/24-27/17 (APL)**
- **Flight System PDR 10/17-20/17 (JPL)**
- **Europa-UVS PDR 11/16-17/17 (SWRI)**
- **PIMS PDR 12/6-7/17 (APL)**
- **EIS PDR 1/9-11/18 (APL)**
- **Solar Array Requirements Review 1/22/17 (JPL)**
- **Power PDR 1/23-24/18 (JPL)**
- **SUDA PDR 1/30-31/18 (CU)**
- **Guidance, Navigation & Control PDR 2/7-9/18 (JPL)**
- **Mechanical PDR 2/20-22/18 (JPL)**
- **Thermal PDR 2/27-28/18 (JPL)**
- **Radio Frequency Module / Telecom PDR 3/14-15/18 (APL)**

Spacecraft
Payload
Mission System
Project

- **REASON PDR 3/26-27/18 (JPL)**
- **Magnetometer Boom PDR 4/9-10/18 (JPL)**
- **ICEMAG PDR 4/11-12/18 (JPL)**
- **Radiation Monitor System PDR 4/17/18 (APL)**
- **E-THEMIS PDR 4/19-20/18 (ASU)**
- **MISE PDR 4/24-25/18 (JPL)**
- **Avionics PDR 5/7-10/18 (JPL)**
- **MASPEX PDR 5/15-16/18 (SWRI)**
- **Fault Management PDR 5/21-22/18 (JPL)**
- **Mission System PDR 6/19-21/18 (JPL)**
- **Propulsion Subsystem CDR 6/26-28/18 (GSFC)**
- **Solar Array PDR 7/10-11/18 (Airbus)**
- **Project PDR 8/20-24/18 (JPL)**



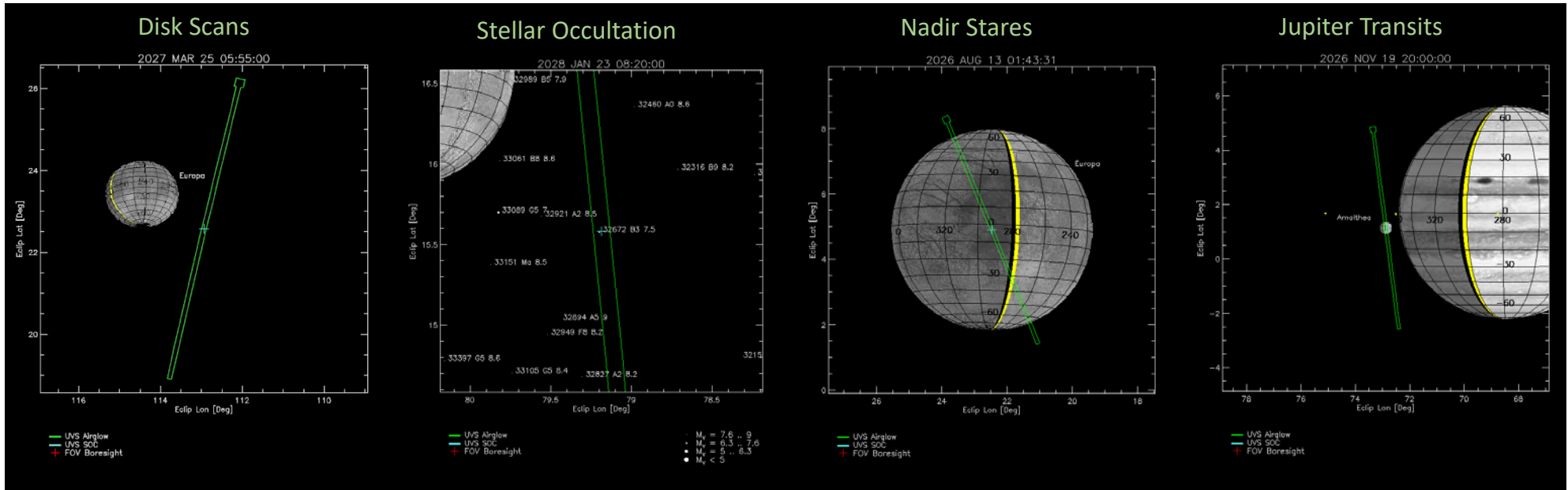
Europa Clipper Science Instruments



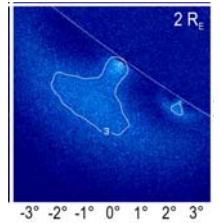


Europa Ultraviolet Spectrograph (Europa-UVS)

PI: Kurt Retherford (SWRI, San Antonio)



- Europa-UVS has identified 464 opportunities for occultation observations of 106 UV-bright stars, with 198 scheduled, in the latest trajectory
- Europa-UVS EM electronics boards have been fabricated and are proceeding through board level testing

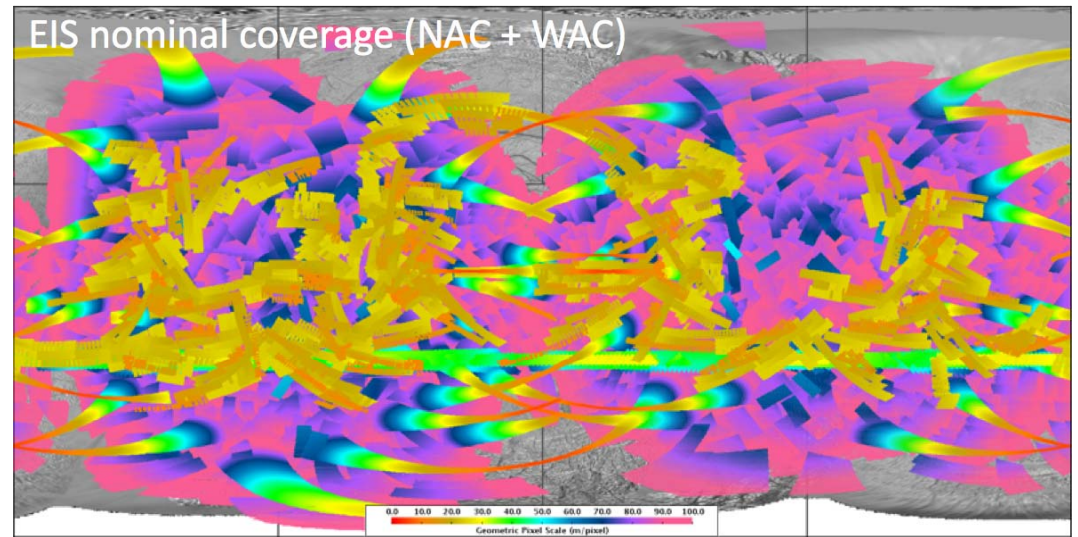
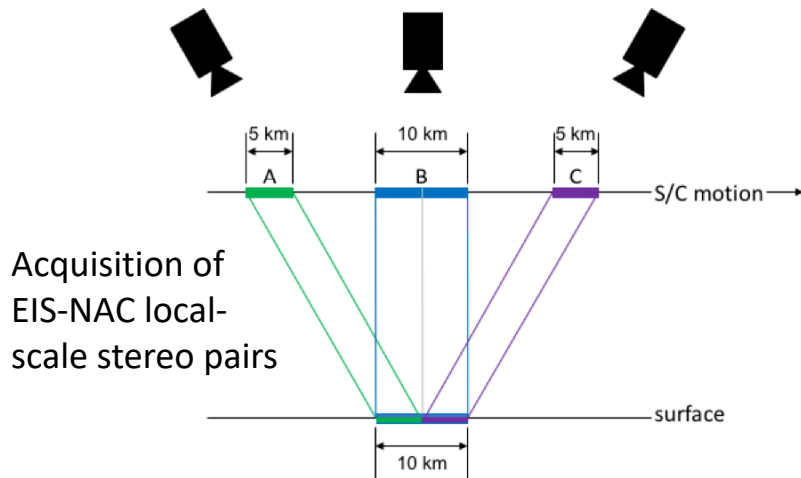




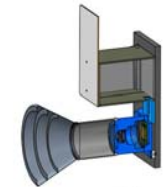
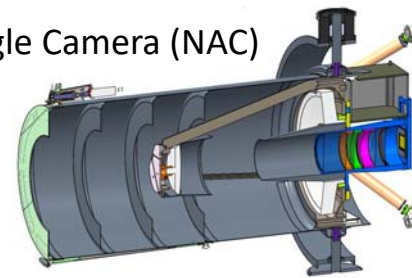
Europa Imaging System (EIS)

PI: Elizabeth Turtle (JHU/APL)

- Demonstrated a preliminary design and operations plan that meets all science requirements
- EIS-NAC gimbal enables near-global coverage (100 m/pixel) and local-scale imaging (1 m/pixel) with stereo topography



Narrow Angle Camera (NAC)

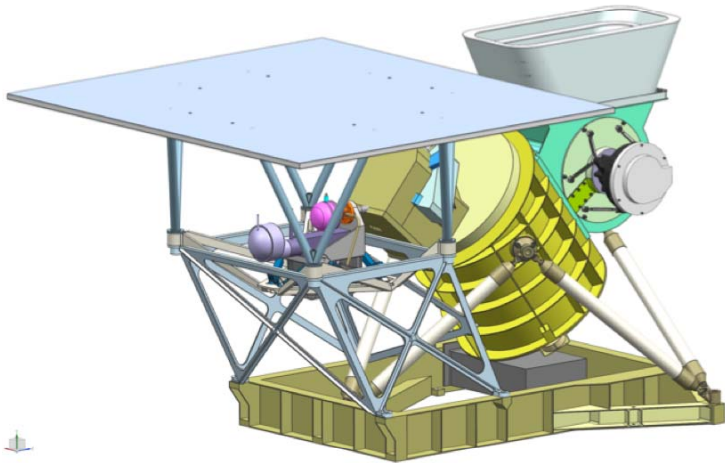


Wide Angle Camera (WAC)



Mapping Imaging Spectrometer for Europa (MISE)

PI: Diana Blaney (JPL/Caltech)



- The instrument changed from an Offner to a Dyson design, improving S/N and reducing energy needs (single cryo-cooler)



Prototype Cooler 1

- MISE cryo-cooler completed radiation testing



Focal Plane Memory Card Prototype

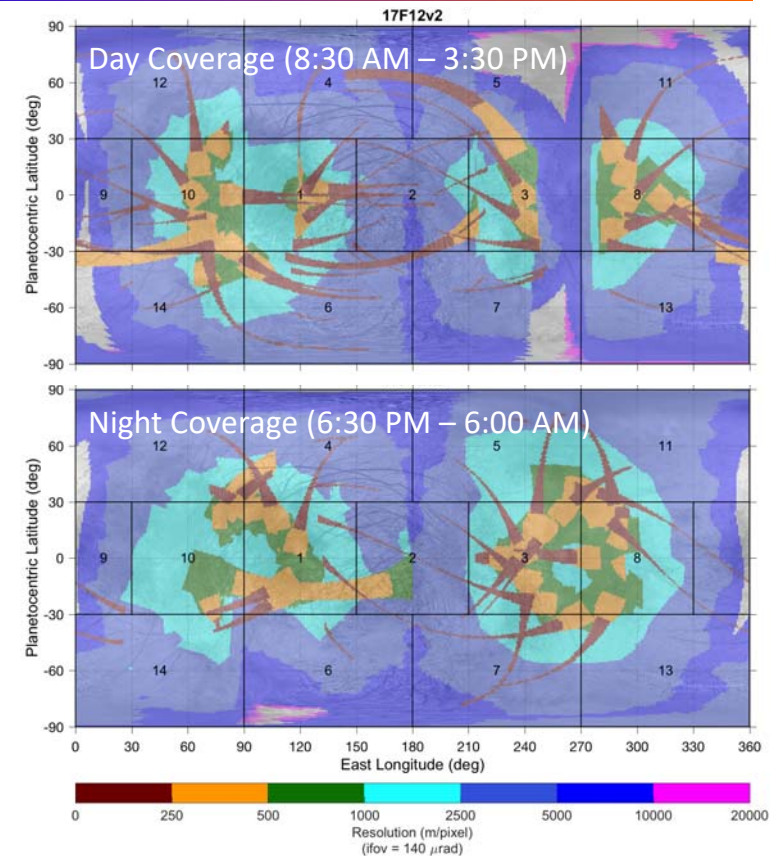
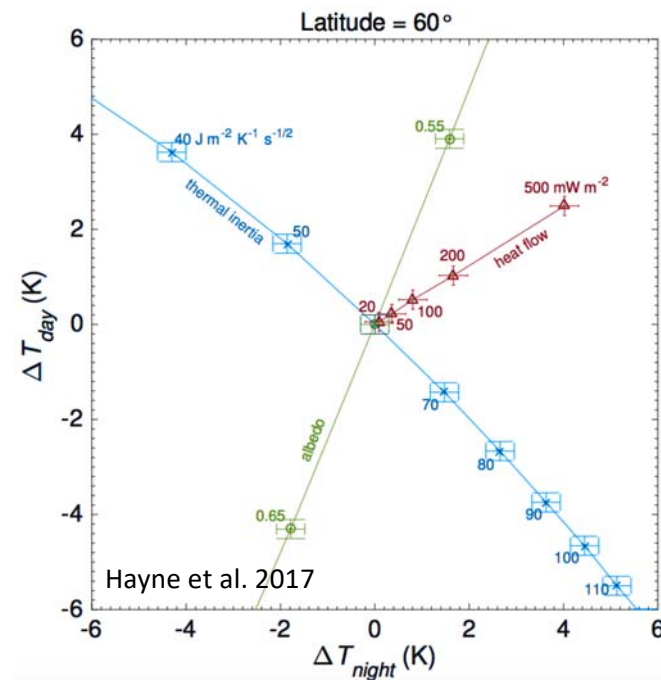
- MISE Data Processing Prototype boards fabricated and are being tested



Europa Thermal Imaging System (E-THEMIS)

PI: Phil Christensen (SESE, Arizona State Univ.)

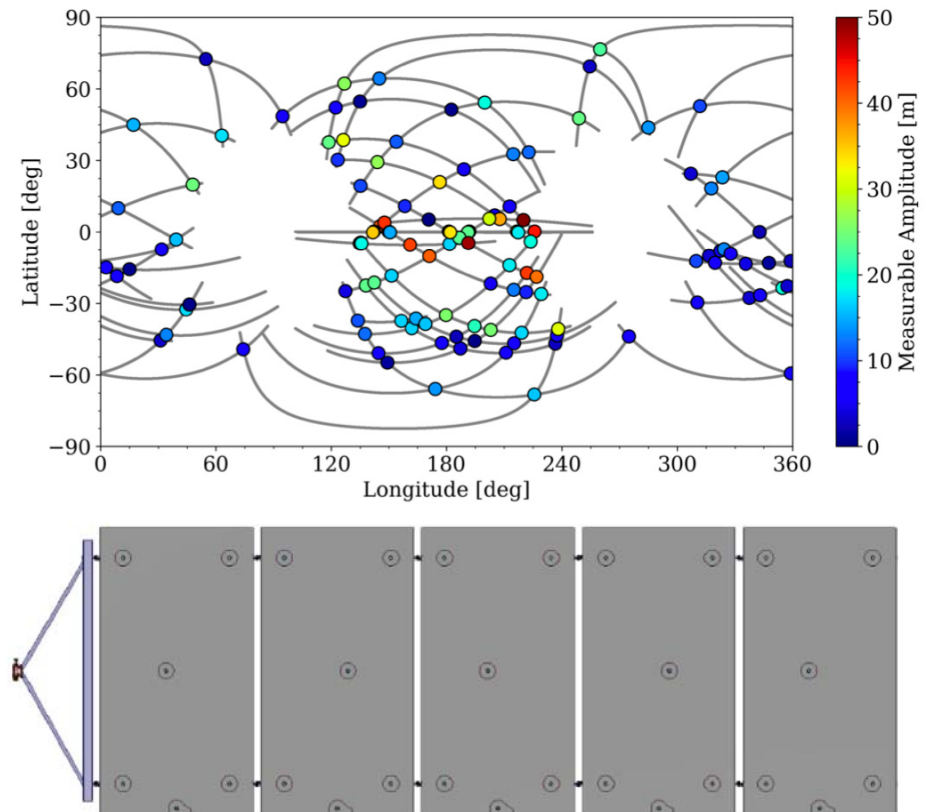
- E-THEMIS microbolometer array successfully passed radiation testing
- Refining methodology using overlapping day-night observations to quickly identify endogenic hot spots with small (0–4 K) deviations from Standard Model prediction, distinguished from thermal inertia or albedo effects





Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) PI: Don Blankenship (Univ. Texas Institute for Geophysics)

- Performed numerical simulations to assess the potential for estimating h_2 using altimetric measurements with a combination of radar altimetry and stereo imaging data (Steinbrügge et al., EPSL, 2018)
 - Love number h_2 accuracy sufficient to unambiguously confirm (or reject) global ocean hypothesis
 - Love number k_2 accuracy sufficient to constrain Europa's ice shell thickness to ± 15 km
- Ensuring appropriate requirements for solar array, given the intimate association of the REASON VHF antennas which are mounted on the array (being built by Airbus)

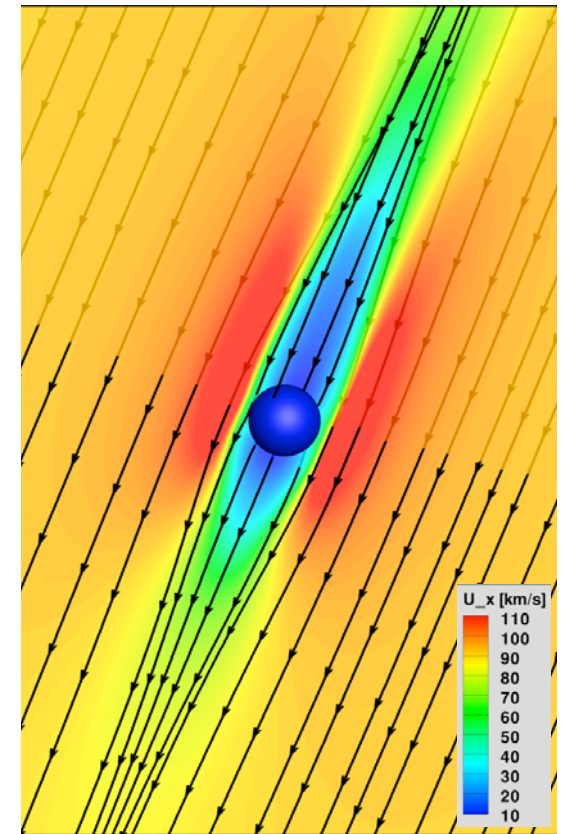
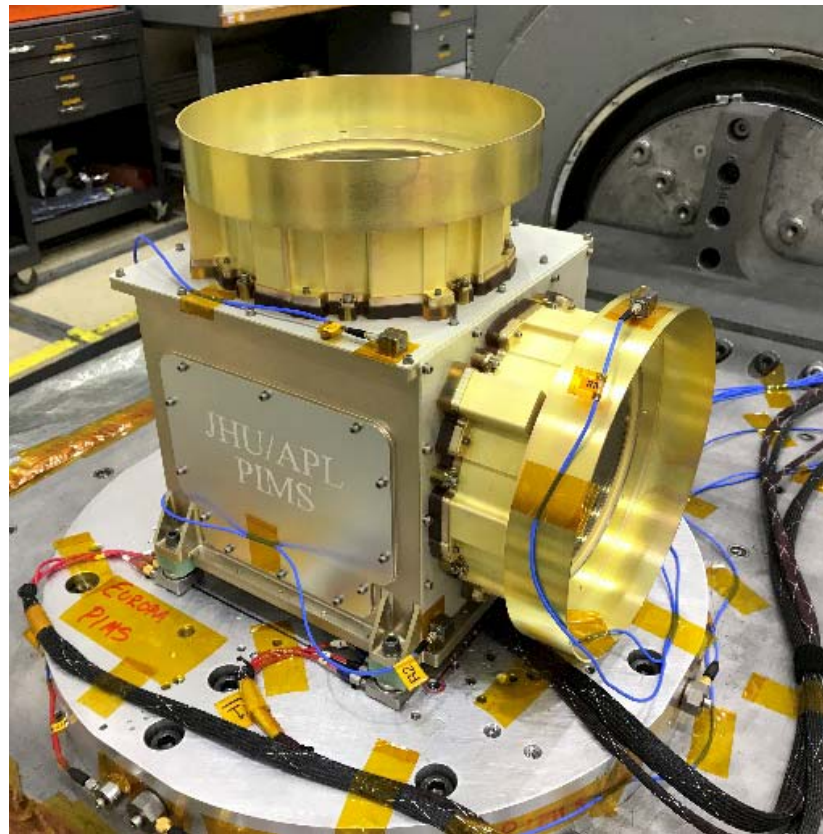




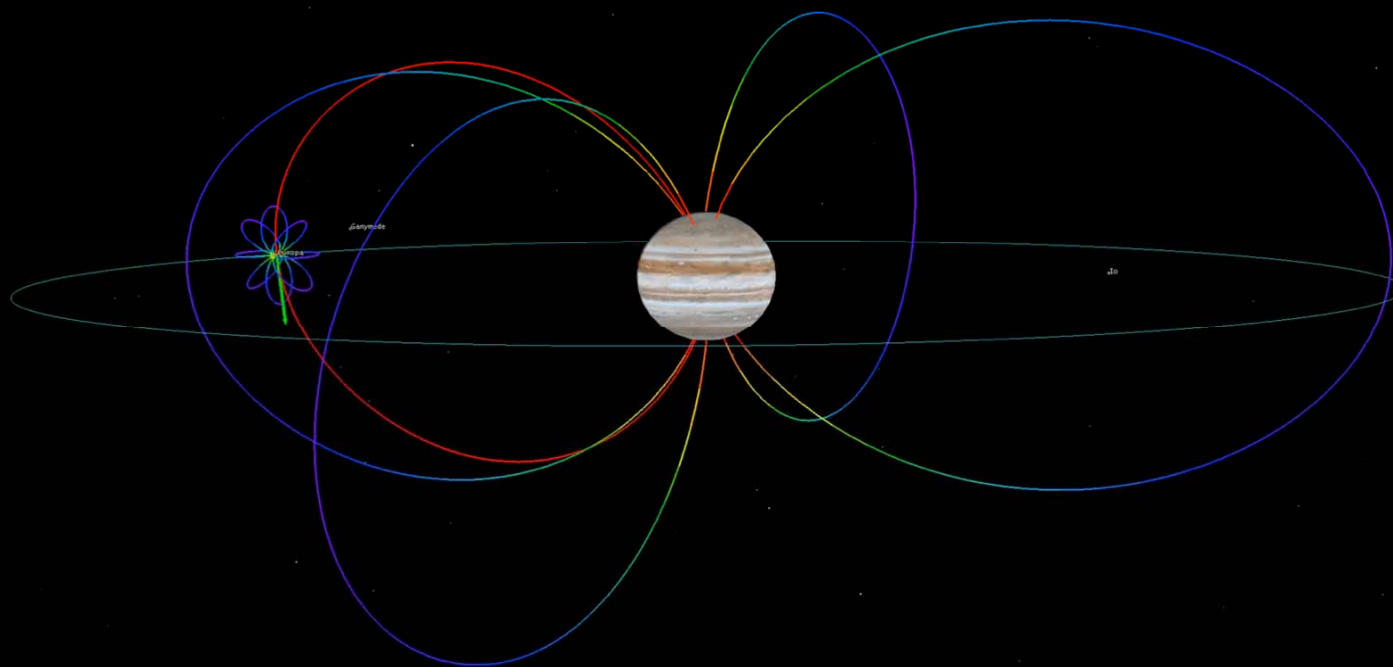
Plasma Instrument for Magnetic Sounding (PIMS)

PI: Joe Westlake (JHU/APL)

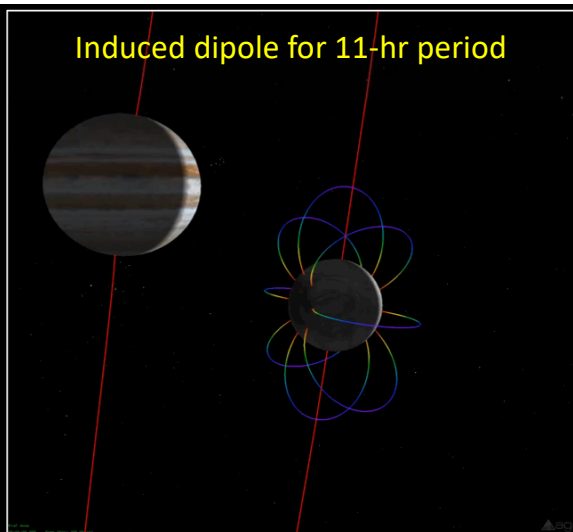
- PIMS prototype instrument has been fabricated, assembled, and successfully completed testing (vibration, ion/electron beam, etc.)
- Progressing to Engineering Model
- Developed a multi-fluid full 3-D magnetohydrodynamic interaction model, to derive moon-plasma interaction magnetic field from simulated Europa Clipper trajectory through the model



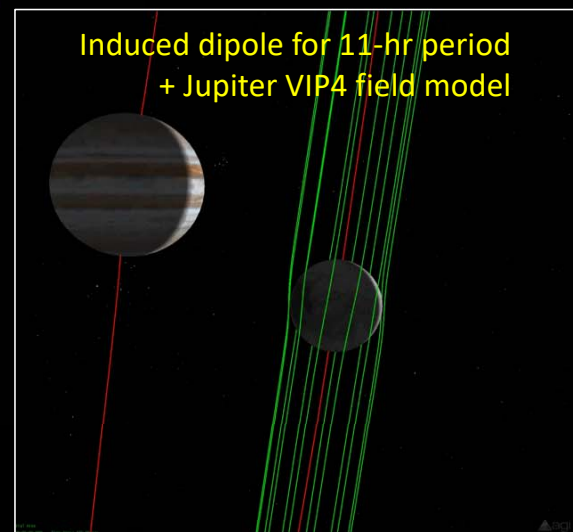
Simulation of Europa's Dipole Field Induced at 11-hr Synodic Period



Induced dipole for 11-hr period



Induced dipole for 11-hr period
+ Jupiter VIP4 field model



June 1– 3, 2017; $\Delta t = 5$ min

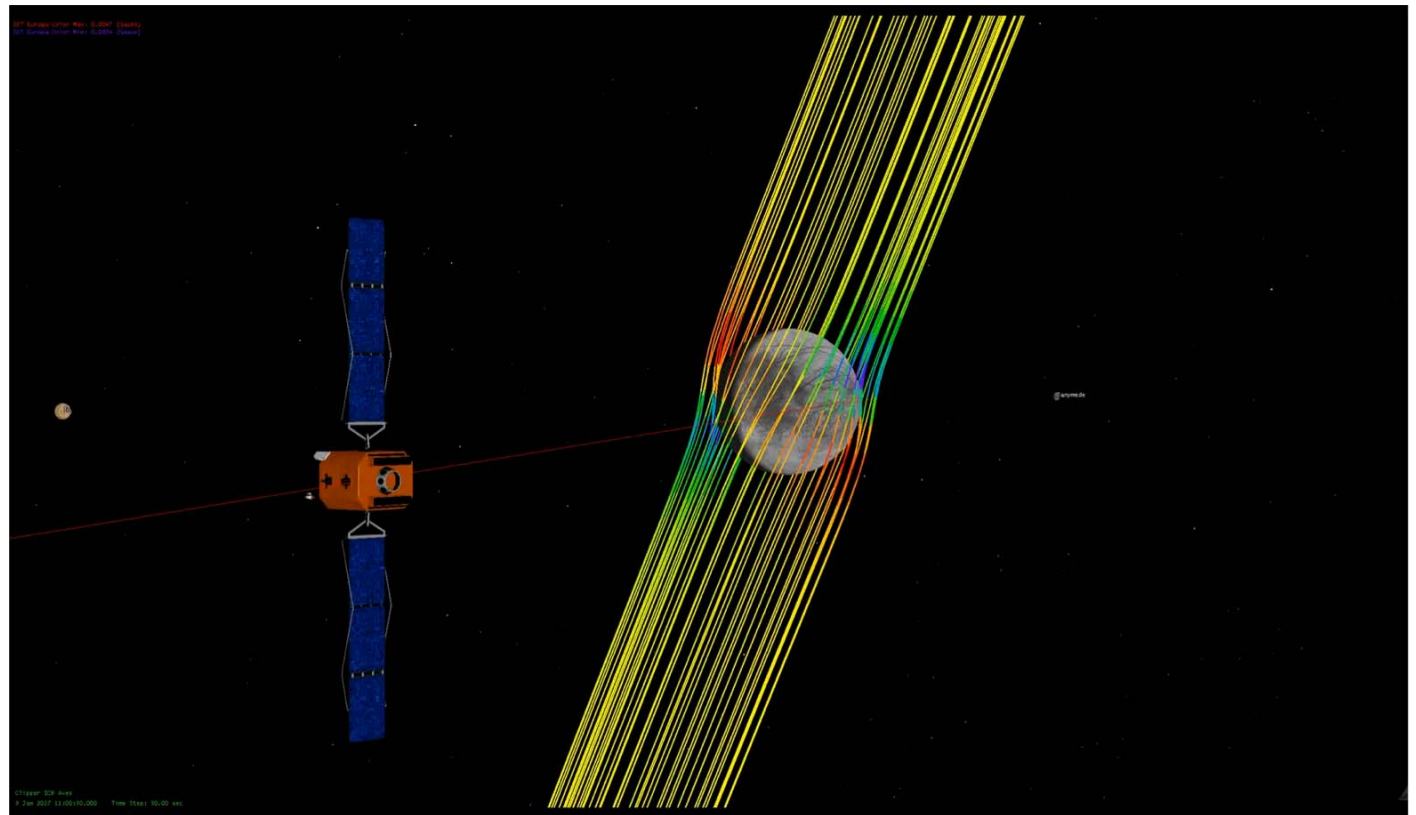
Simulations by Corey Cochrane



Interior Characterization of Europa using Magnetometry (ICEMAG)

PI: Carol Raymond (JPL/Caltech)

- Visualization of a simulation of Europa's induced magnetic field including 11 and 85 hr periods using the VIP4 model of Jupiter's magnetic field, to help in tour evaluation
- Testing low-temperature performance of sensors and optical fiber to minimize thermal energy requirements

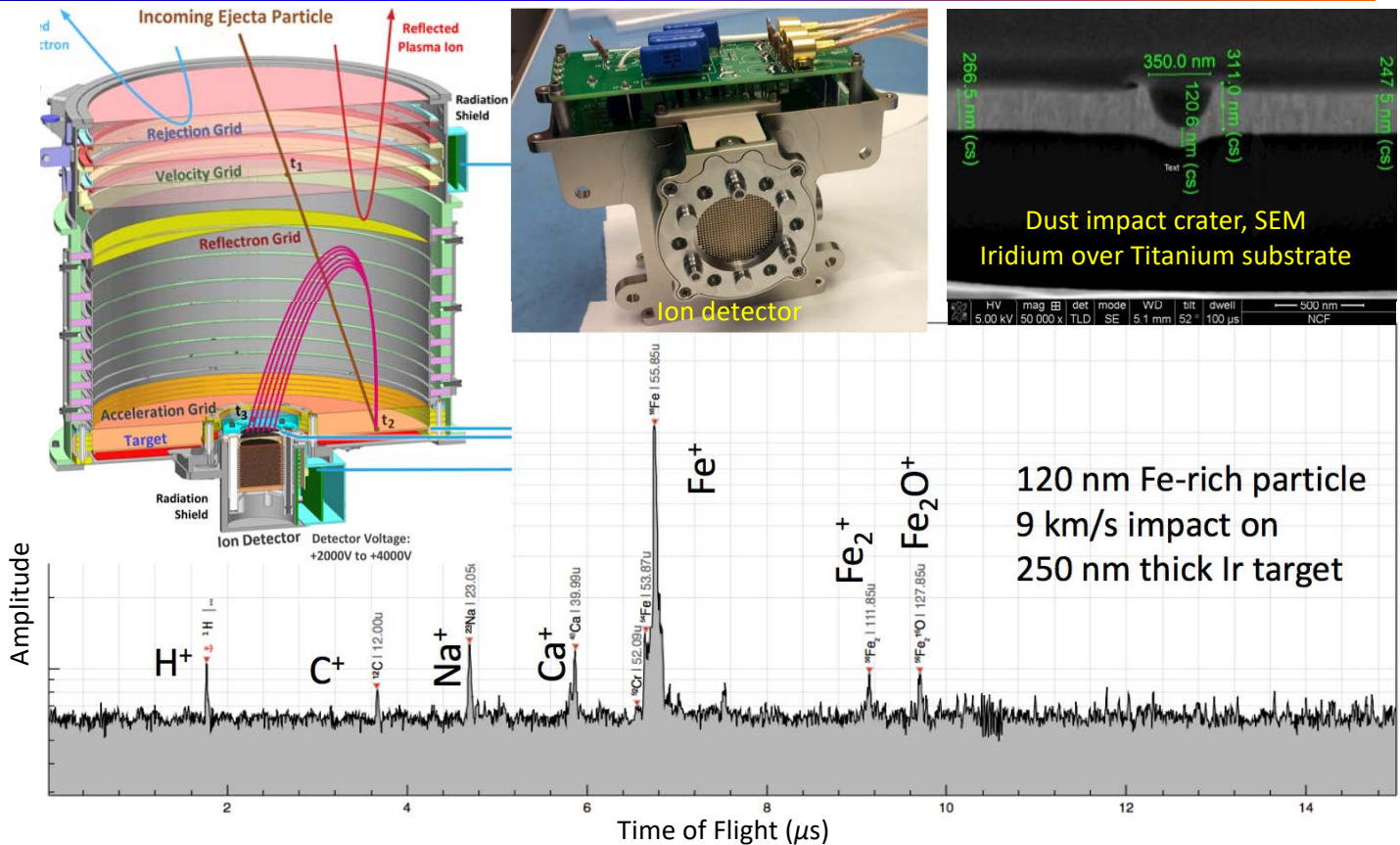




SURFACE DUST ANALYZER (SUDA)

PI: Sascha Kempf (LASP, Univ. Colorado)

- Ion Detector: 2 flight-like prototypes fully developed and successfully tested
 - Reached TRL 6
- Target: 4 flight-like prototypes developed and successfully tested
 - Ir-coated Ti substrate
- Successfully measured mass spectra of dust particles up to 30 km/s

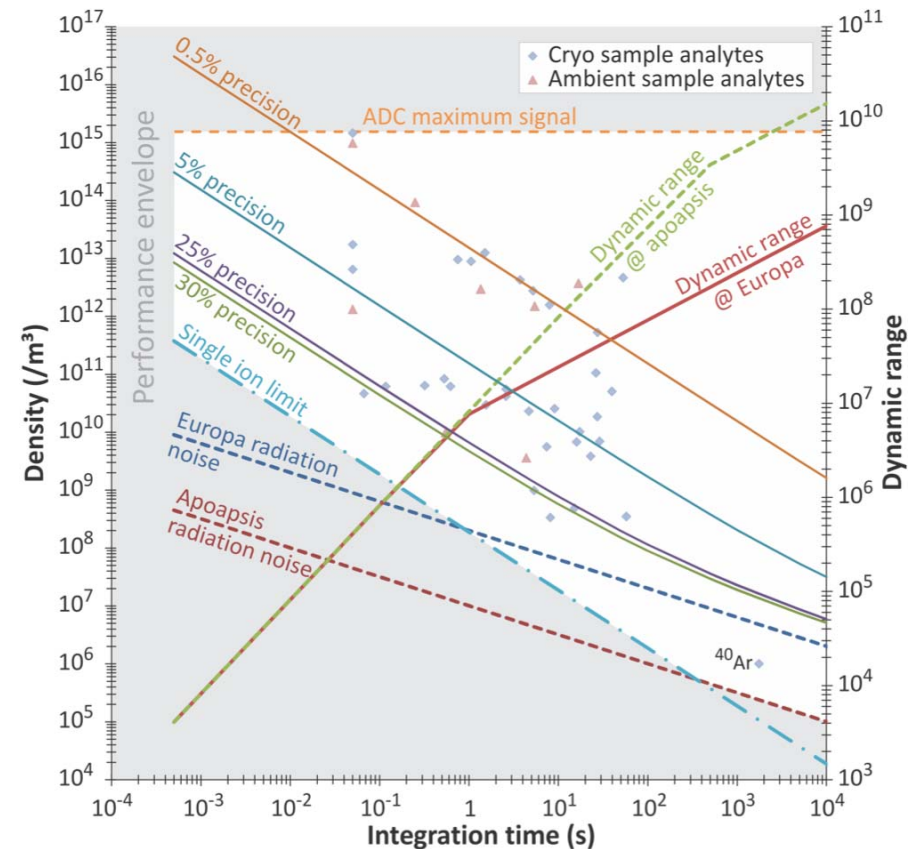
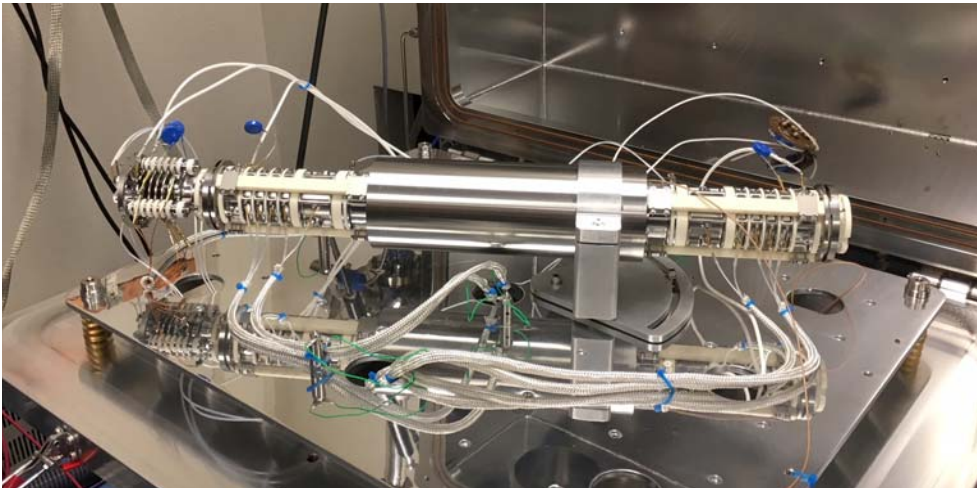




MAss Spectrometer for Planetary Exploration (MASPEX)

PI: Hunter Waite (SWRI, San Antonio)

- MASPEX Engineering Model (EM) has been constructed, and completed vibration testing
- Ambient analytes that fall below the radiation noise line or that require integration in excess of a single flyby can be measured by cryotrapping

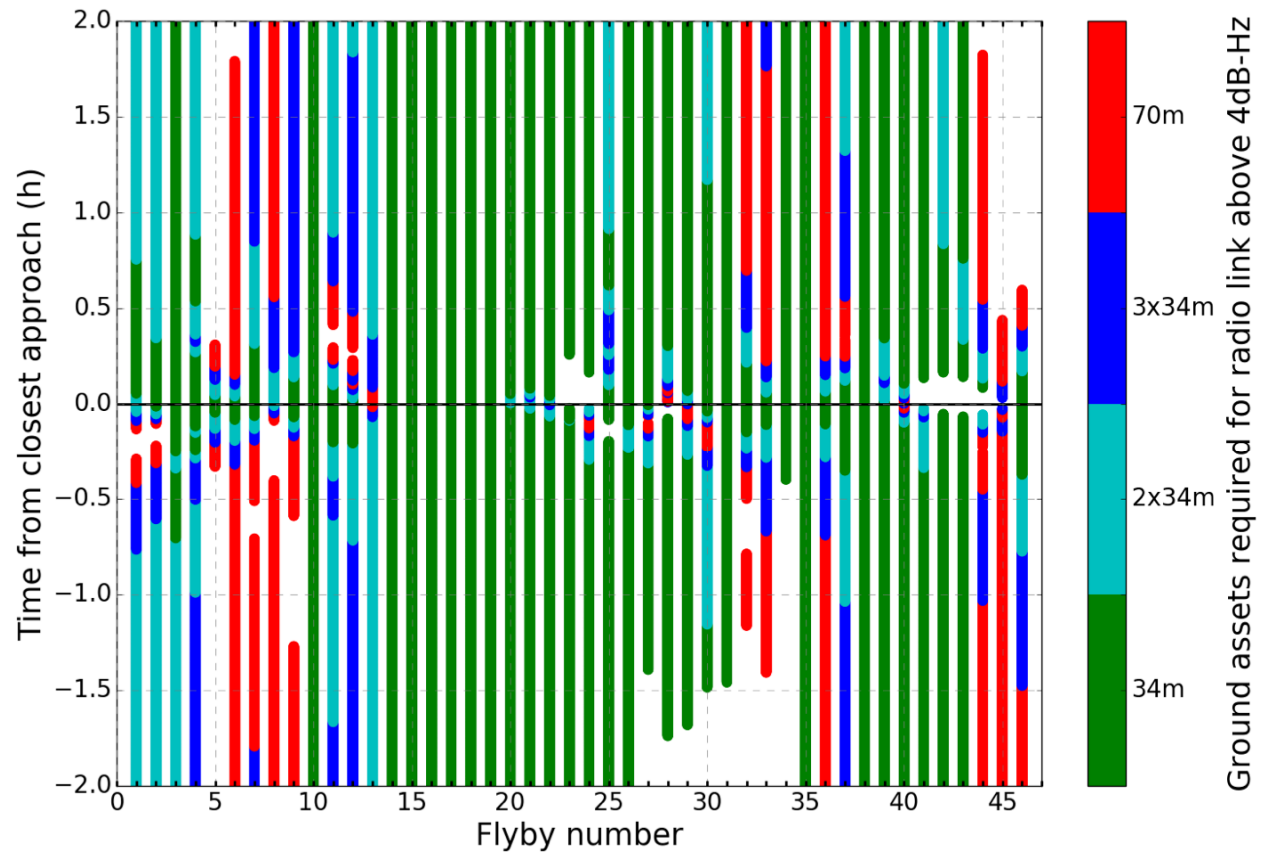
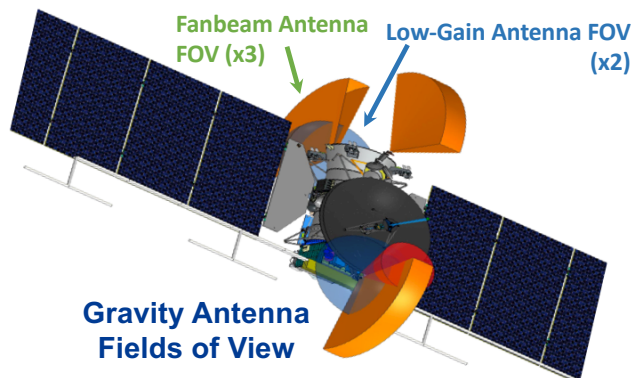




Gravity Science

Subject Matter Expert: Jean-Luc Margot (UCLA)

- Analysis of Gravity Science capabilities (Verma and Margot, 2017)
 - Two-way Doppler data can confirm presence or absence of ocean
 - Determination of hydrostatic equilibrium is possible, pending sufficient crossover range accuracy
 - Arraying DSN stations or use of 70-m antenna can provide additional resilience on tracking requirements





Habitability Working Group

Co-Chairs: Jonathan Lunine (Cornell) & Britney Schmidt (Georgia Tech)

- Identified ways that the Europa Clipper might better constrain habitability of Europa's ocean using data returned from already-planned measurements

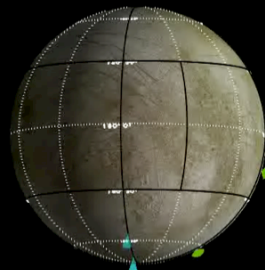
E-THEMIS, ICEMAG, PIMS, MISE	• Temperature	• Concentrations of nutrients	SUDA, MASPEX, MISE
REASON	• Pressure	• Speciation (if amino acid)	MASPEX, SUDA, MISE
SUDA, MASPEX, MISE	• pH	• Ocean vs. rock reservoirs, including salinity	SUDA, MASPEX, MISE
MASPEX, SUDA, MISE	• Oxidation state	• Composition vs. presence of organics	MISE, MASPEX
SUDA, MISE, ICEMAG, PIMS	• Major ions & salinity	• Amount of chemical disequilibrium	MASPEX, SUDA, MISE
E-THEMIS, MISE, MASPEX, SUDA	• Physical and chemical sources of energy	• Energy fluxes	MASPEX, SUDA, E-THEMIS, Europa-UVS
Gravity, MASPEX, SUDA, Europa-UVS, EIS, MISE	• Compositional gradients (surface to ocean), mass transfer		



Plume Focus Group

Co-Chairs: Matt Hedman (Univ. Idaho) & Carly Howett (SWRI, Boulder)

G03: EIS-NAC 2 km/pixel at c/a



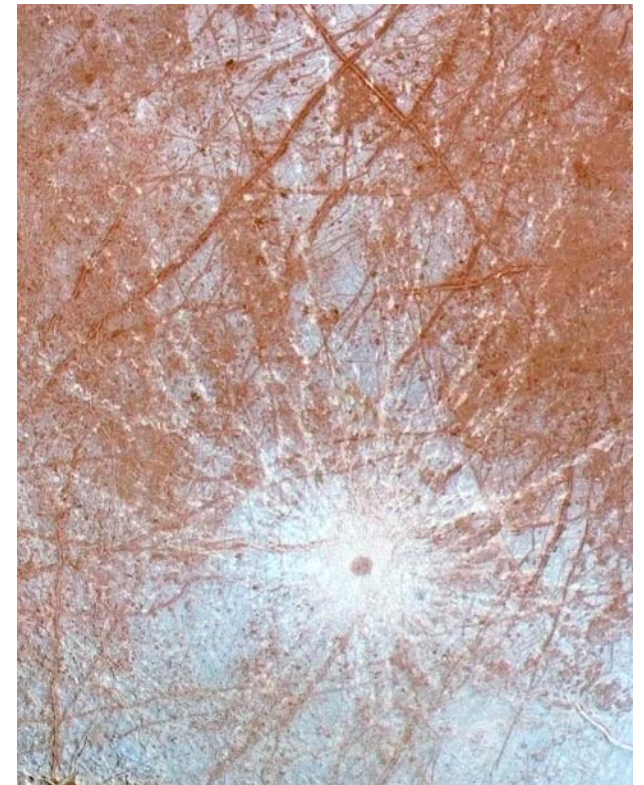
- Identified targets of opportunity to search for current activity *prior to* first Europa flyby:
 - EIS: Plume search
 - Terminator; High phase limb; Europa eclipse
 - Europa-UVS: Plume search & atm. variability
 - Europa scans; Europa transits; Stellar occultations,
 - E-THEMIS: Surface temperatures
 - EIS: Surface color changes
 - MASPEX: Europa torus
 - SUDA: Escaped grains
 - Europa-UVS: Neutral cloud & torus stare



Composition Working Group

Co-Chairs: Murthy Gudipati (JPL/Caltech) & Jason Soderblom (MIT)

- Settled on key priorities in evaluating potential tours, including ensuring acceptable remote sensing and *in situ* observations of:
 - Landform variety
 - “Young” landforms
 - Leading & trailing hemispheres
- Key focuses have been laboratory data and Europa's radiation environment:
 - Plans to hold a community workshop to discuss the current state of laboratories and laboratory data, and what will be needed to best interpret the multi-instrument Europa Clipper data
 - The formation of the Radiation Focus Group (next slide)

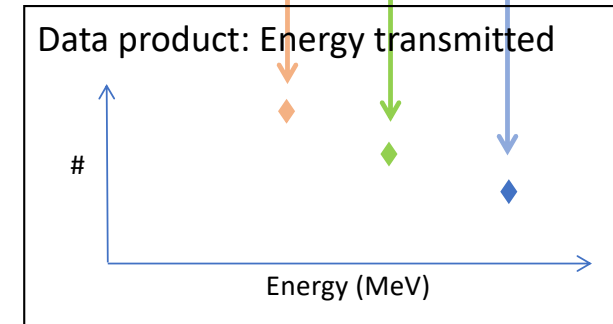
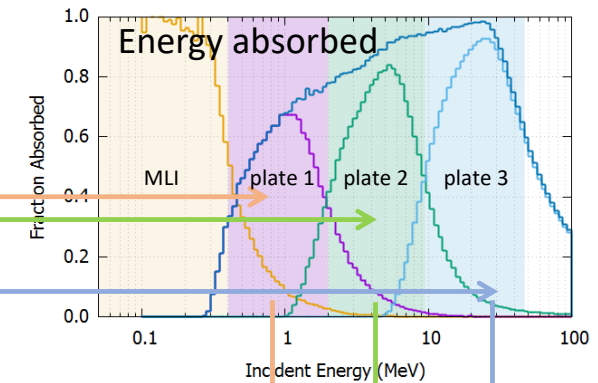
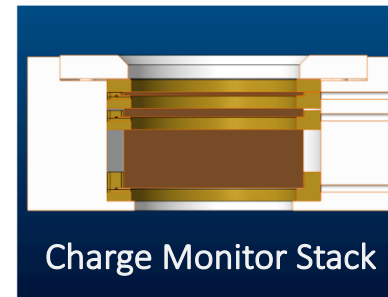




Radiation Focus Group

Co-Chairs: Roger Clark (PSI) & Abi Rymmer (JHU/APL)

- To focus on understanding both the Europa radiation environment and its effects on the surface, and to advise the Project on trades relevant to radiation science
- Briefed on status of the Radiation Monitoring System
 - Charge monitor stack: Three plates of selected thickness provide crude energy spectra
 - Dosimeters: ~8 distributed around the spacecraft, plus hosted in science instruments, each returning integrated radiation flux above an energy determined by local shielding





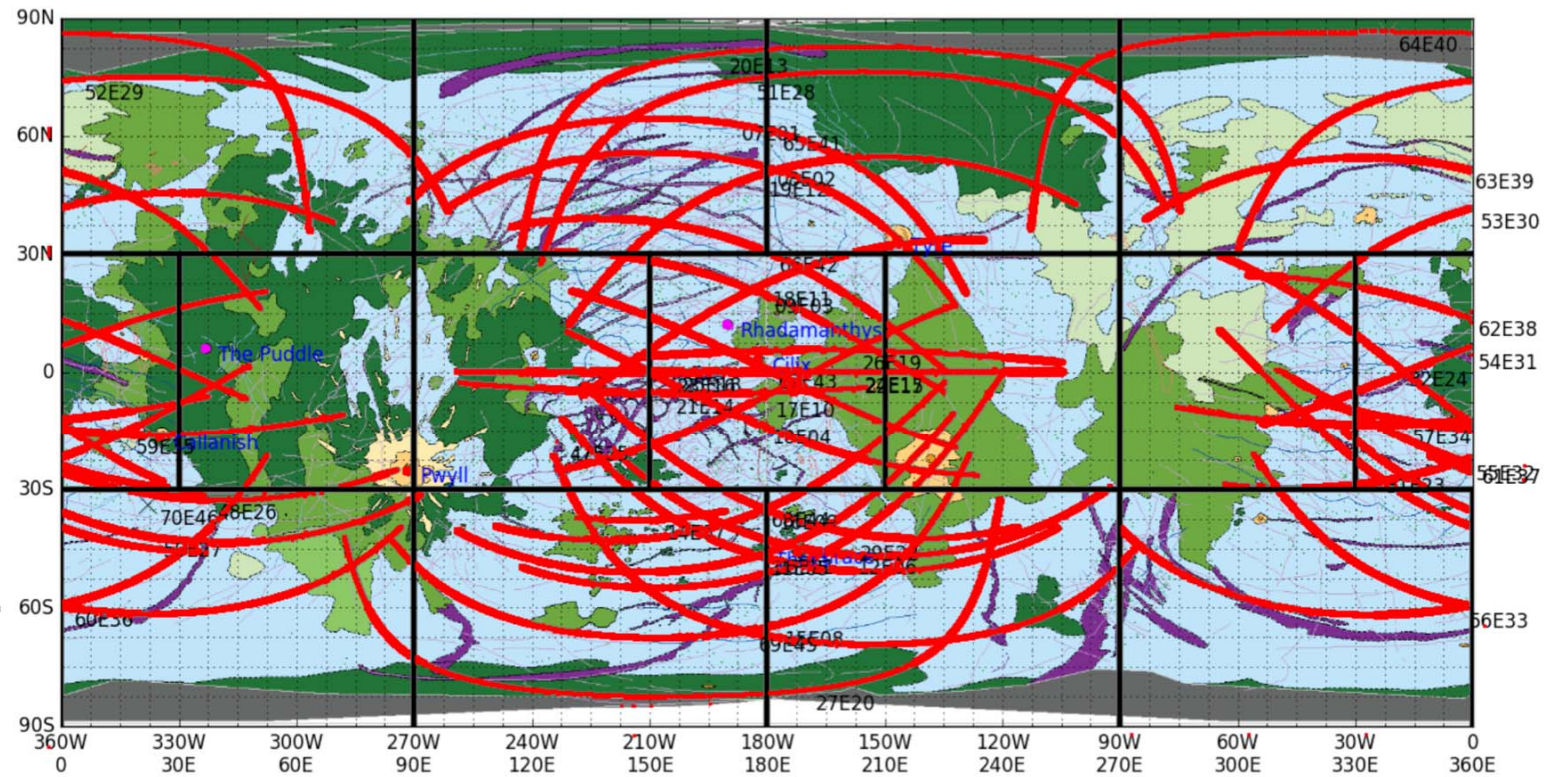
Geology Working Group

Co-Chairs: Geoff Collins (Wheaton Coll.) & Julie Rathbun (PSI)

- Planned nadir ground tracks (red) overfly diverse landforms
- More distant remote sensing can observe other features

Ridged Plains (pr)
 Bands (b)
 High Albedo Bands (bha)
 High Albedo Chaos (chh)
 Mottled Chaos (chm)
 Low Albedo Chaos (chl)
 Knobby Chaos (chk)
 Crater (c)
 Continuous Crater Ejecta (ce)
 Discontinuous Crater Ejecta (cde)

Ridges
 Cycloids
 Bands (<15 km wide)
 Undifferentiated Linea
 Troughs
 Multi-Ring Structures
 Depression Margin
 Microchaos



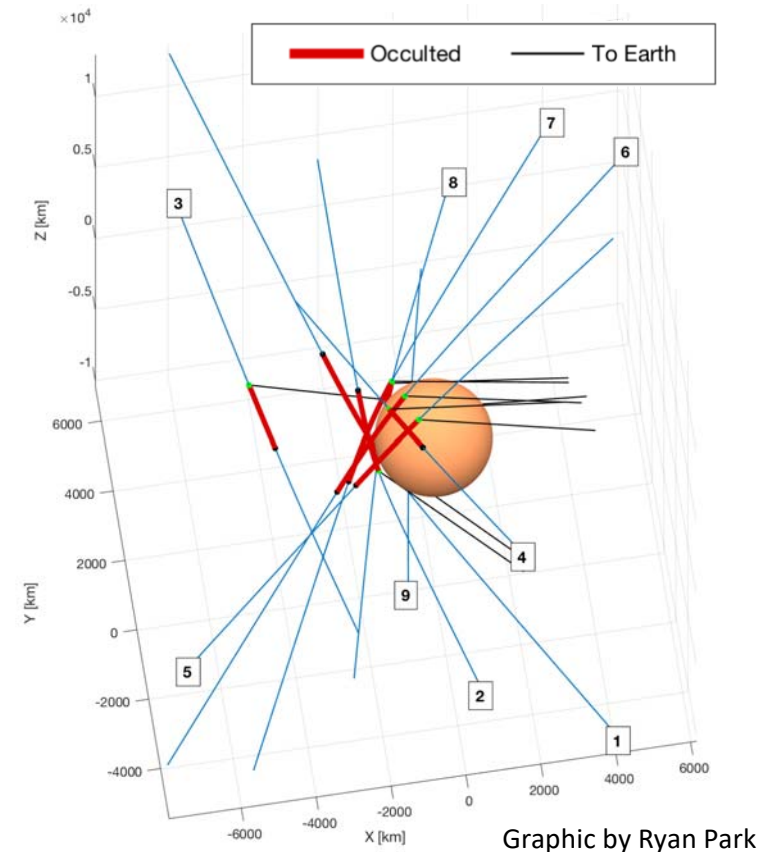
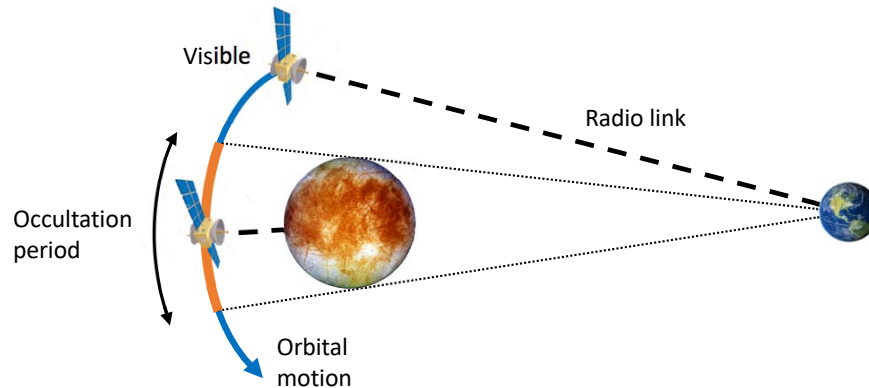
Leonard et al. (2018)



Interior Working Group

Co-Chairs: Carol Paty (Georgia Tech) & James Roberts (JHU/APL)

- Several occultation opportunities exist for the Europa Clipper trajectory, using existing telecom system
 - LGAs & fanbeam antennas (X-band)
 - Two-way: Uplink radio signal from Earth, receive at spacecraft, and retransmit back to Earth
- Would provide vertical profiles of electron density in ionosphere, and useful for Europa position and shape
- Not yet baselined, but seems achievable and valuable



Graphic by Ryan Park



Project Science Team Bystander Intervention Training

- Europa Clipper Project Science team (which includes Investigation Scientists) retreat featured Bystander Intervention Training by Moses Milazzo (USGS)
- “Bystander intervention is an evidence-based framework intended to reduce victims’ burden of protecting themselves from harassment and shift the burden to the community” (Milazzo et al., LPSC, 2018)
- Given extremely positive feedback, the entire Europa Clipper Science Team will be strongly encouraged to participate in future training opportunities, including at Europa PSG meetings.





Upcoming Science Events (Programmatic)

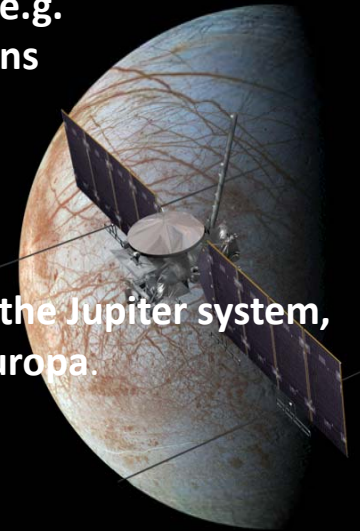
- Mini- Project Science Group Meeting
 - March 23, The Woodlands, Texas
- Project Science Group meeting #6
 - June 11 – 15, JPL
- JUICE – Europa Clipper collaborative science workshop
 - July 22, Caltech



JUICE – Europa Clipper Collaborative Science Discussions

Members of the JUICE and Europa Clipper science teams will discuss potential scientific synergies between the Europa Clipper and JUICE missions

- Investigations if both missions *are* in the Jupiter system at the same time:
 - Multi-point measurements of the characteristics of the Jovian magnetodisc, with each spacecraft providing far-field context for the other
- Investigations if both spacecraft *are not* in the Jupiter system at the same time:
 - Opportunities for observations that are spatially or otherwise complementary, e.g.
 - Complementary coverage in spatial, spectral, energy, and geometric domains
 - Observations providing long temporal baselines, e.g.
 - Time-variability of the Jovian magnetodisc
 - Europa's atmosphere and potential plume activity
- Combined data sets will offer a more complete view of the Europa, Ganymede and the Jupiter system, while enabling in-depth comparative studies of the ocean worlds Ganymede and Europa.





Europa Clipper Science Team

PIs, Co-Is, Project Science (Currently 119 total)

Oleg Abramov
Amy Barr Mlinar
Jordana Blacksberg
Diana Blaney
Don Blankenship
Scott Bolton
Christelle Briois
Tim Brockwell
Shawn Brooks
Lorenzo Bruzzone
Bruce Campbell
Lynn Carter
Tony Case
Phil Christensen
Roger Clark
Corey Cochrane
Geoff Collins
Kate Craft
Brad Dalton
Ingrid Daubar
Ashley Davies
Serina Diniega
Charles Elachi
Carolyn Ernst

Paul Feldman
Leigh Fletcher
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
Howett, Carly
Terry Hurford
Hauke Hussmann
Xianzhe Jia
Steven Joy
Justin Kasper
Sascha Kempf

Krishan Khurana
Randy Kirk
Margaret Kivelson
Rachel Klima
Wlodek Kofman
Haje Korth
William Kurth
Yves Langevin
Jonathan Lunine
Marco Mastrogiuseppe
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
Chris Paranicas

Wes Patterson
Carol Paty
Cynthia Phillips
Sylvain Piqueux
Jeff Plaut
Dirk Plettemeier
Frank Postberg
Louise Prockter
Lynnae Quick
Julie Rathbun
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Carol Raymond
Kurt Retherford
Christina Richey
James Roberts
Lorenz Roth
Chris Russell
Abigail Rymer
Joachim Saur
Juergen Schmidt
Britney Schmidt
Dustin Schroeder
Frank Seelos
Dave Senske

Mark Sephton
Everett Shock
James Slavin
Todd Smith
Jason Soderblom
Krista Soderlund
John Spencer
Ralf Srama
Andrew Steffl
Alan Stern
Michael Stevens
Robert Strangeway
Ben Teolis
Nick Thomas
Gabriel Tobie
Zibi Turtle
Steve Vance
Hunter Waite
Ben Weiss
Joe Westlake
Danielle Wyrick
Duncan Young
Mikhail Zolotov