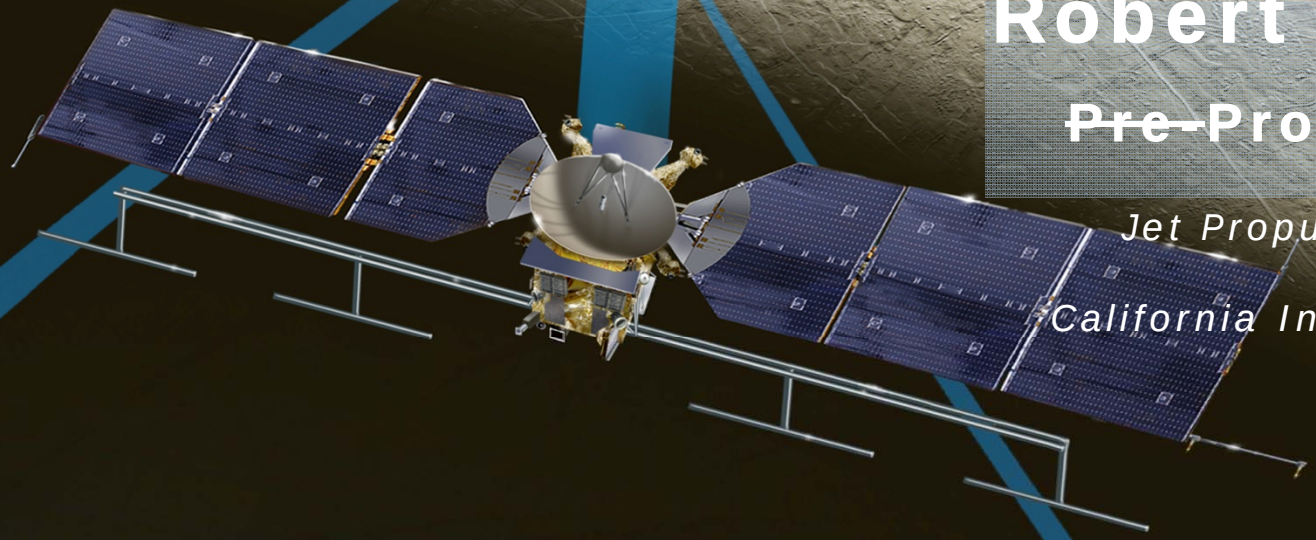
Europa Mission Update

CAPS

September 16, 2015



Barry Goldstein

~~Pre-~~Project Manager

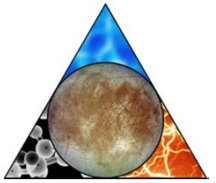
Robert Pappalardo

~~Pre-~~Project Scientist

Jet Propulsion Laboratory,

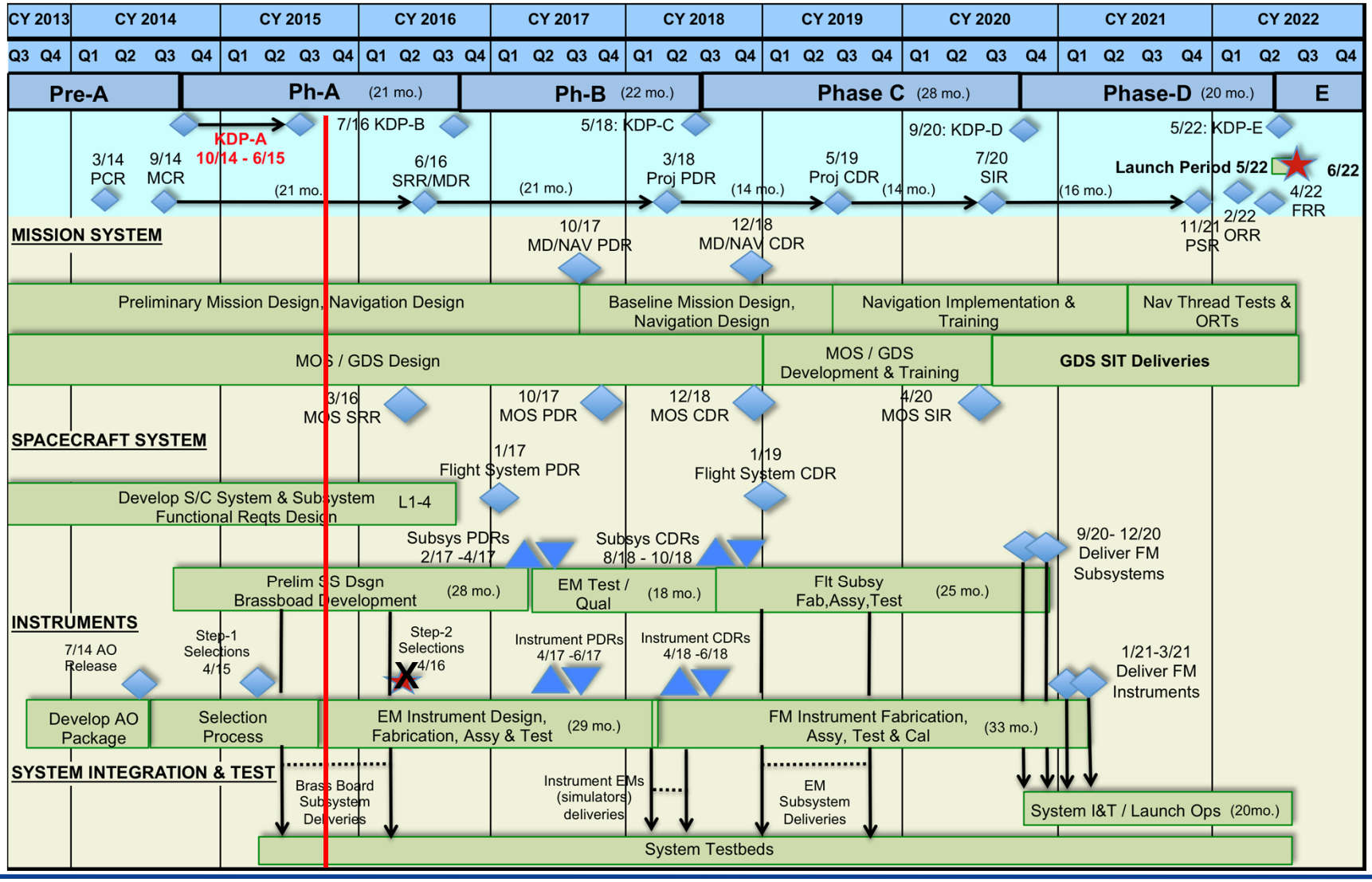
California Institute of Technology

Update Since March ’15



- Instrument Selection (May 2015)
  - Final Selection Made
- Key Decision Point A (June 2015)
  - Official Project Formed
- Major Phase A Activities
  - Instrument Accommodation
  - Rationalization of Mission Requirement Set
    - Moving forward towards next major review, System Requirements Review (SRR) & Mission Definition Review (MDR) June 27, 2016
- Major Phase A Studies/Trades
  - Landed Element?
  - Plume Free Flyer?

Top-Level Development Schedule



Science Investigations of the Europa Mission

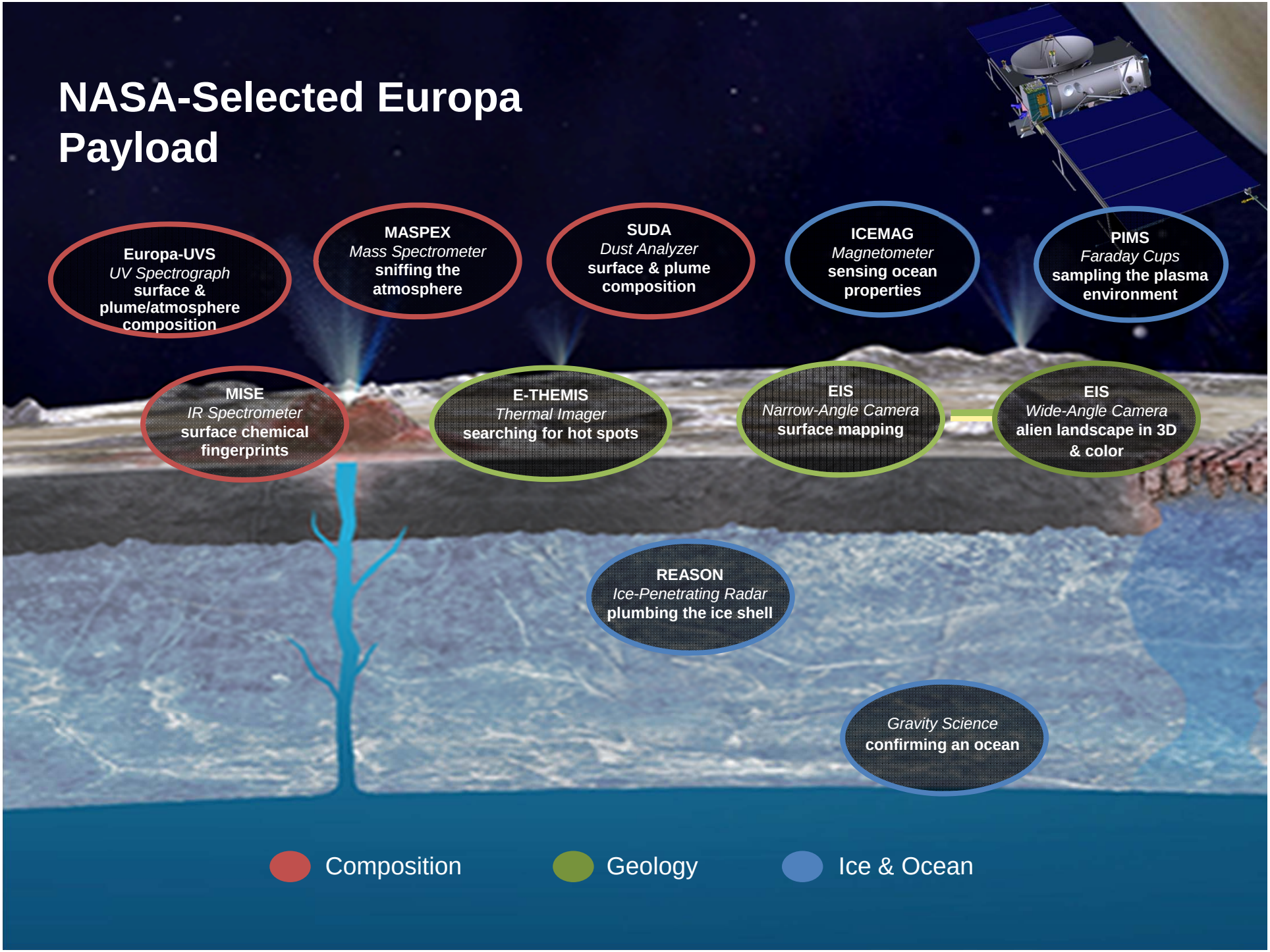
Bob Pappalardo
Europa Mission Project Scientist
Jet Propulsion Laboratory, California Institute of Technology
and the Europa Science Team

CAPS – Sept. 16, 2015

Europa

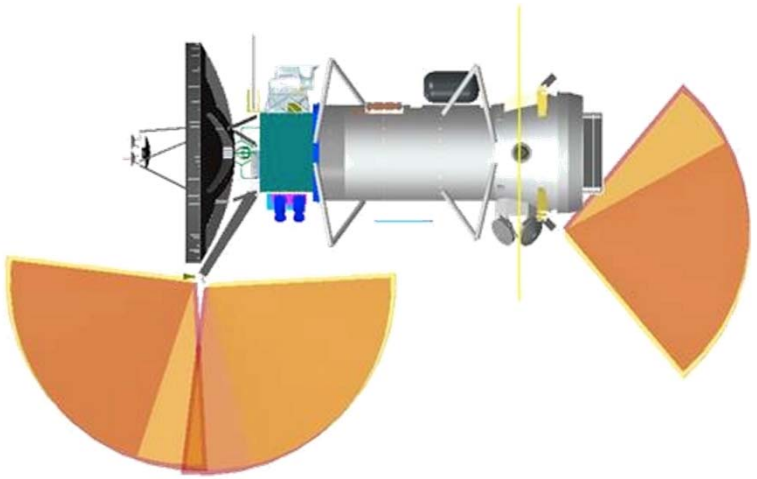
Project Science Group Meeting #1

August 4, 2015

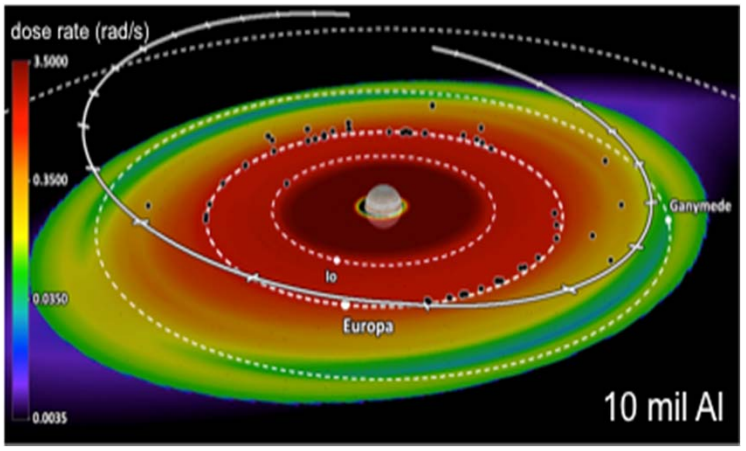

NASA-Selected Europa Payload
Europa-UVS
UV Spectrograph
surface & plume/atmosphere composition
MASPEX
Mass Spectrometer
sniffing the atmosphere
SUDA
Dust Analyzer
surface & plume composition
ICEMAG
Magnetometer
sensing ocean properties
PIMS
Faraday Cups
sampling the plasma environment
MISE
IR Spectrometer
surface chemical fingerprints
E-THEMIS
Thermal Imager
searching for hot spots
EIS
Narrow-Angle Camera
surface mapping
EIS
Wide-Angle Camera
alien landscape in 3D & color
REASON
Ice-Penetrating Radar
plumbing the ice shell
Gravity Science
confirming an ocean
Composition
Geology
Ice & Ocean

NASA-Appointed Working Groups

- Gravity Working Group
  - Focus on whether the existing mission concept and instrument payload can successfully confirm the presence of an ocean, and if not, how that can be corrected

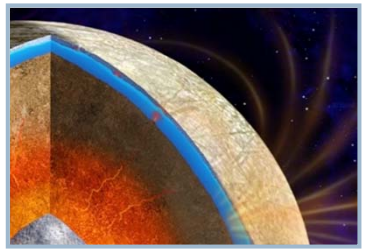


- Radiation Working Group
  - Consider the scientific applications of the data set to be produced by the spacecraft's planned radiation monitoring system

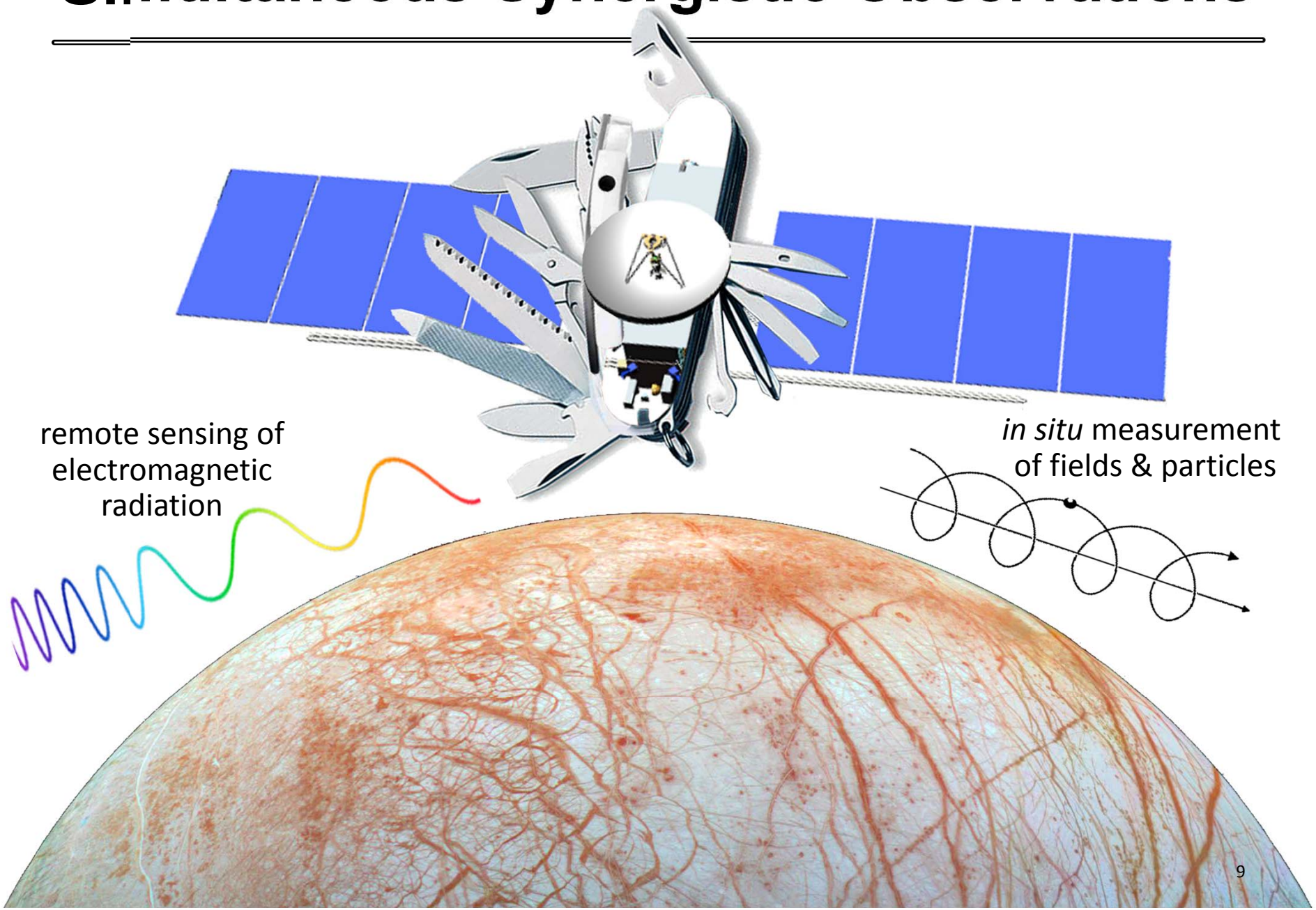


Europa Mission Science Goal & Objectives

- *Goal:* **Explore Europa to investigate its habitability**
- *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



Simultaneous Synergistic Observations

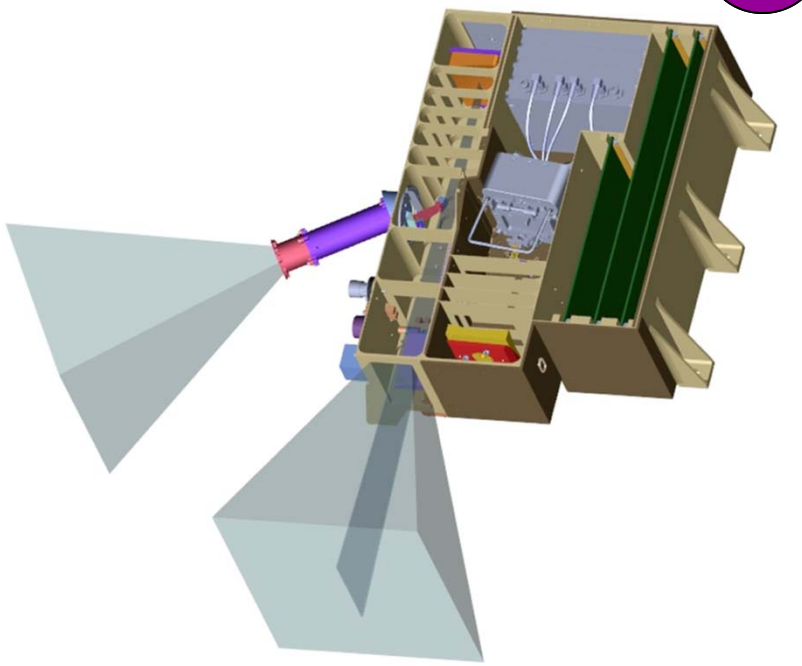


Europa Ultraviolet Spectrograph (Europa-UVS)

UV

Kurt Retherford, SWRI

- **Atmosphere:** Composition & chemistry, source & sinks, structure & variability from equator to pole
- **Plumes:** Distribution, structure, composition, and variability of active plumes
- **Surface:** Explore surface composition & microphysics and relation to endogenic & exogenic processes
- **Plasma Environment:** Investigate energy and mass flow into Europa's atmosphere, neutral cloud & plasma torus



- Spatial and spectral UV imaging
- High spatial resolution mode allows for imaging of detailed surface and plume structures
- Performs solar and stellar occultations to determine composition

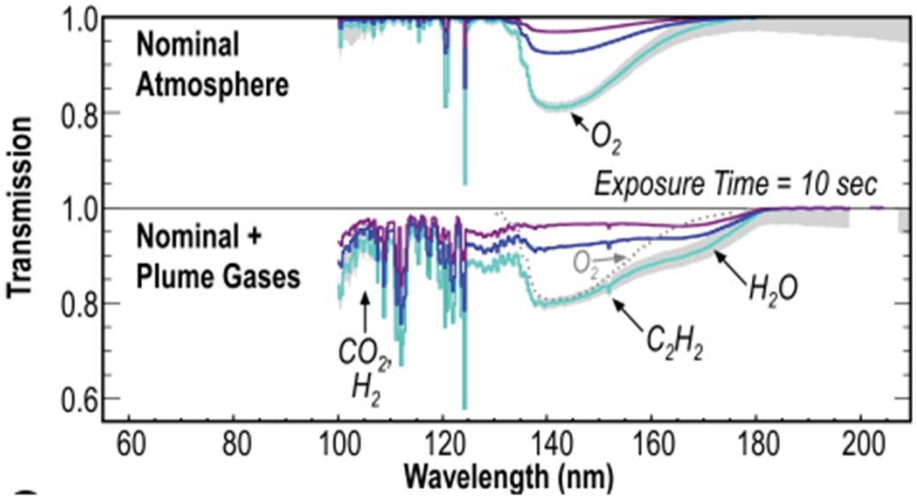
Key instrument Parameters	
Wavelength Range	55 – 210 nm
Spatial Resolution	0.16° (low res); 0.04° (high res) Nyquist sampled
Spectral Resolution	$\lambda/\Delta\lambda$ = 220; <0.6 nm FWHM (point source)
Spectral Cube Size	2048 (spectral) x 512 (spatial)

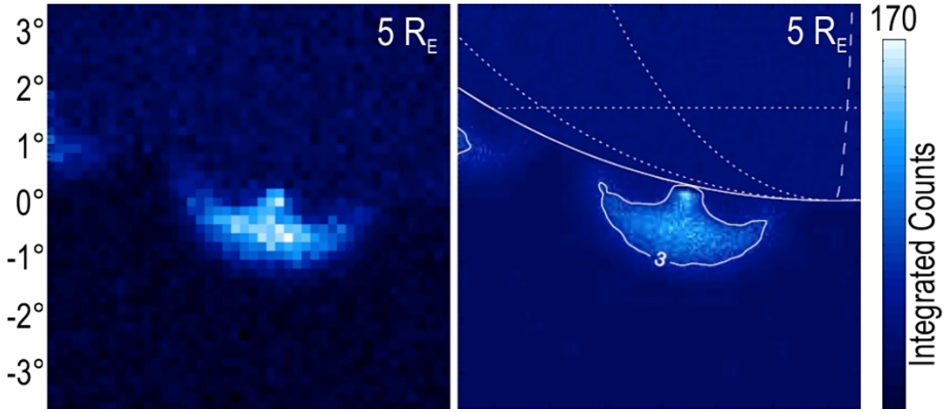
Europa Ultraviolet Spectrograph (Europa-UVS)

UV

Kurt Retherford, SWRI

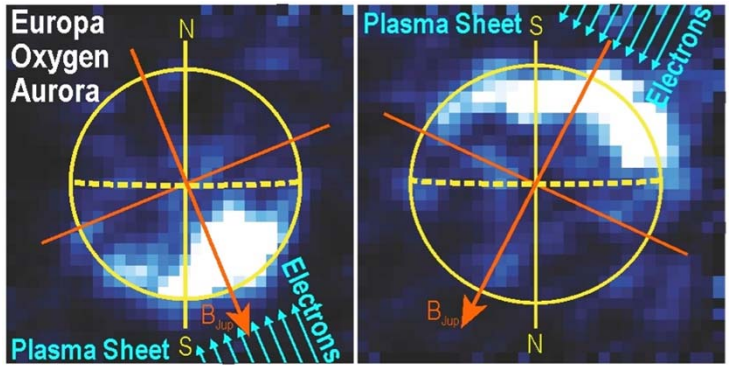
Atmosphere & Plume Composition from UV Spectra

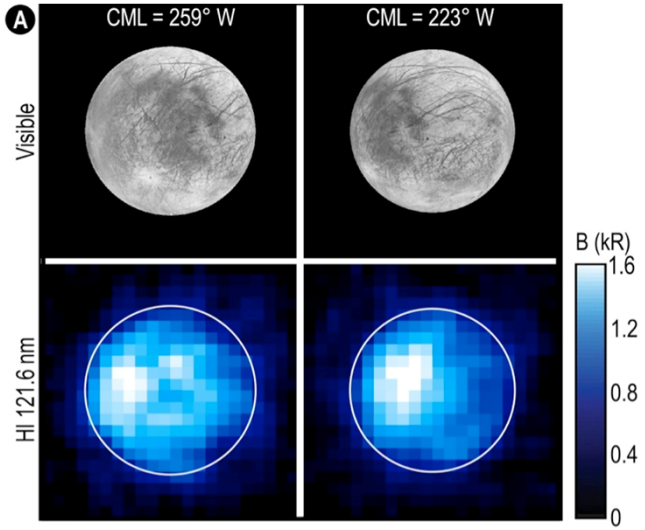




Plume Detection and Density
(low and high resolution modes illustrated)

Plasma Environment from Oxygen Emissions





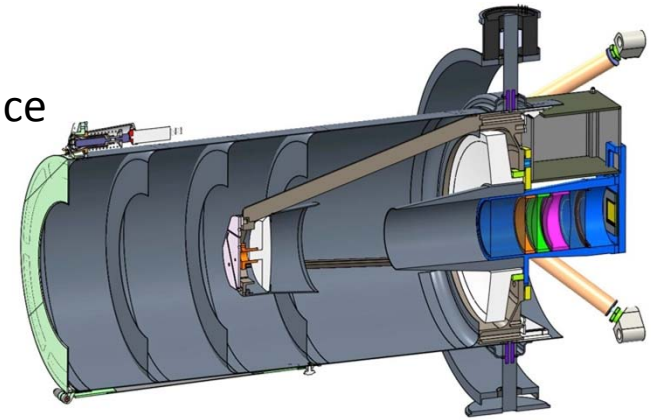
Surface Structure & Composition from
scattering of Ly-α

Europa Imaging System (EIS)

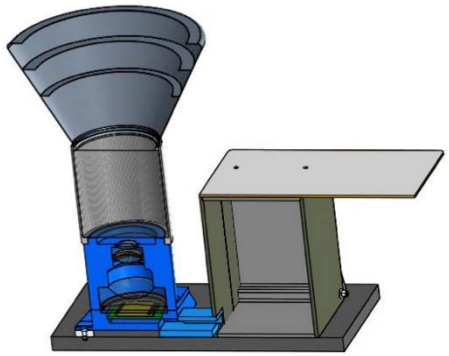
VIS

Zibi Turtle, APL

- Constrain the formation of surface features and the potential for current activity
- Characterize the ice shell
- Characterize small-scale surface processes



Narrow Angle Camera (NAC)



Wide Angle Camera (WAC)

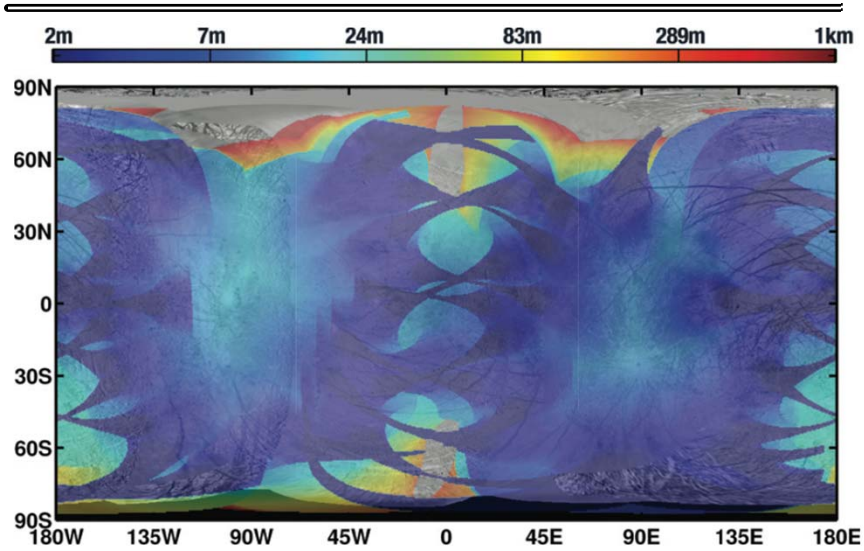
- NAC provides high-resolution, stereo reconnaissance
- NAC gimbal permits independent targeting, enabling near-global mapping, including stereo, and high-phase observations to search for potential plumes
- WAC provides along-track stereo & color context imaging
- WAC supports cross-track clutter characterization for ice-penetrating radar

Key Instrument Parameters		
	NAC	WAC
Detector	4096 × 2048 rad-hard CMOS, framing or pushbroom	
Wavelength Range	Panchromatic	Panchromatic plus 6 filters (350 – 1050 nm)
Instantaneous Field of View	10 µrad (0.5 m/pixel with 2 km swath at 50 km)	218 µrad (11 m/pixel with 45 km swath at 50 km)
Field of View	$2.347^o \times 1.173^o$	$48^o \times 24^o$
TDI	Typically ≤18 lines of digital Time Delay Integration	

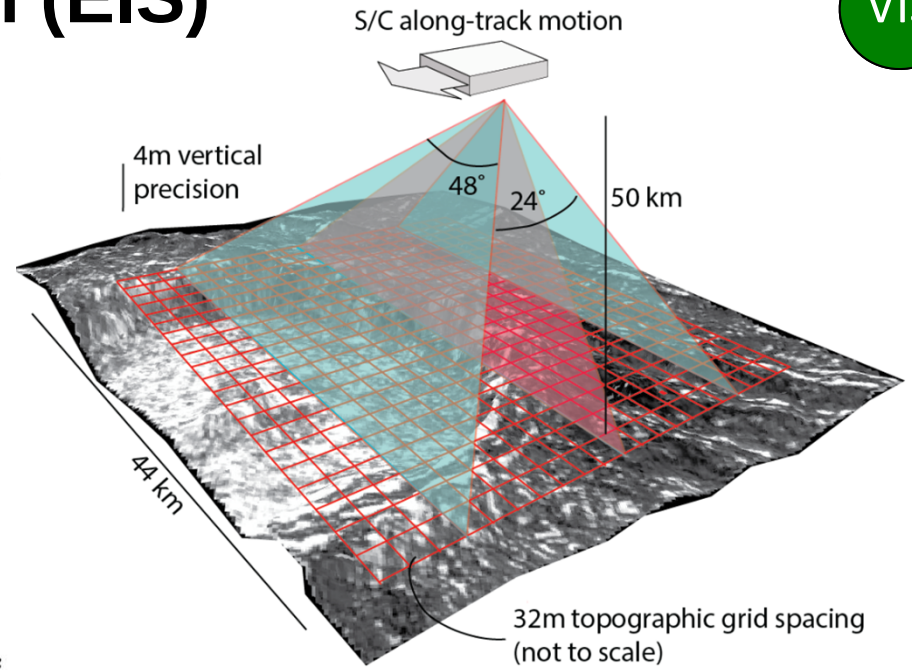
Europa Imaging System (EIS)

VIS

Zibi Turtle, APL



Surface area accessible to NAC; EIS can provide global (>95%) coverage at better than 50 m/pixel using gimbaled NAC



WAC performs 3-line pushbroom stereo imaging, providing topography along ground tracks

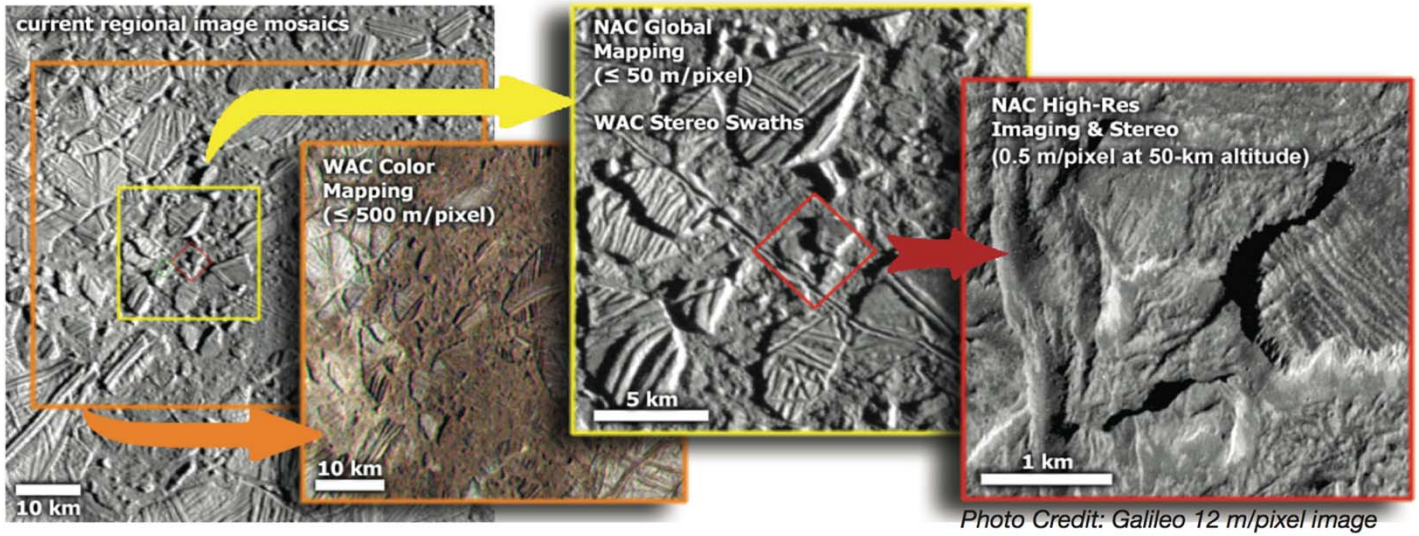


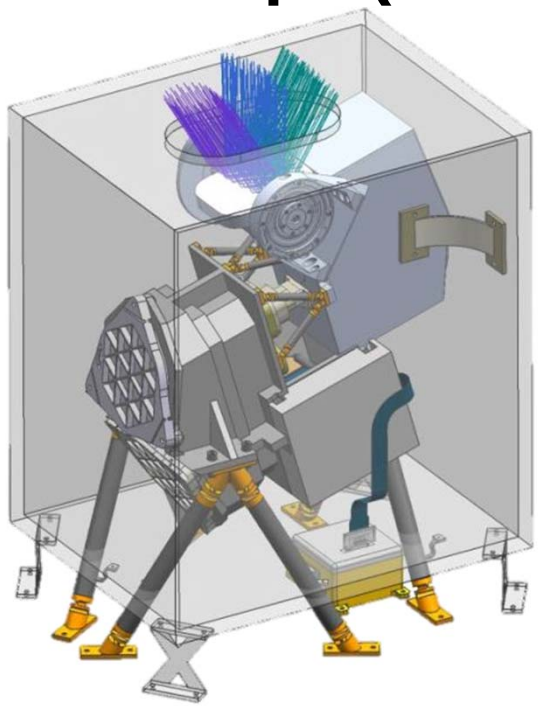
Photo Credit: Galileo 12 m/pixel image

Mapping Imaging Spectrometer for Europa (MISE)

IR

Diana Blaney, JPL

- Assess the habitability of Europa's ocean by understanding the inventory and distribution of surface compounds
- Investigate the geologic history of Europa's surface
- Search for areas that are currently geologically active



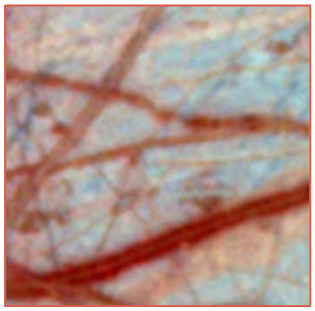
- Imaging spectrometer
- Efficiency tuned grating, and scan mirror
- Spatial sampling at a range of geologic scales

Key instrument Parameters	
Wavelength Range	0.8 to 5.0 µm (800 – 5000 nm)
Spatial Resolution	10km/pixel full-disk images at 40,000 km range 25 m/pixel at 100 km range
Spectral Resolution	10 nm
Spectral Cube Size	300 lines x 80 to 300 samples x 451 spectral channels
Cubes Collected	Up to 8 per flyby
Signal-to-noise Ratio	>100:1 from 0.8–2.6 µm, 10:1 between 2.6 and 3.2 µm, >25 from >3.2 µm

Mapping Imaging Spectrometer for Europa (MISE)

IR

Diana Blaney, JPL

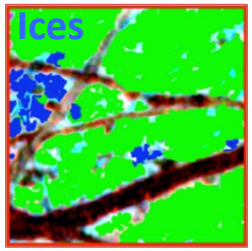


MISE will produce maps of key compounds on Europa's surface and link surface geology and composition.

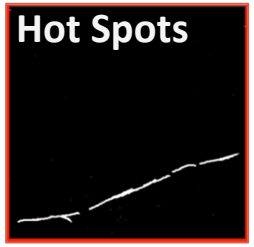
Then use that to …

Determine if Europa's ocean contains organics

Use surface chemistry to consider habitability

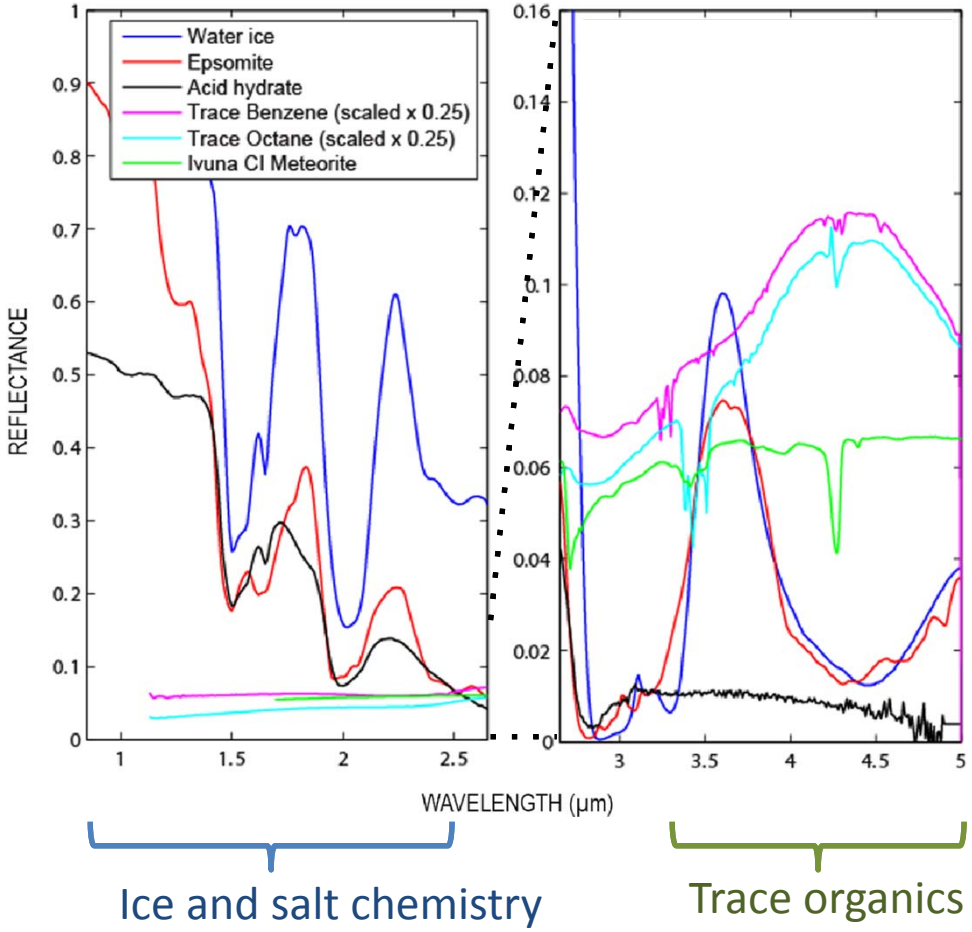


Use differences in ice crystal structure to constrain the age of Europa's surface



Learn if Europa is currently active

Key compounds at MISE spectral resolution and sampling:

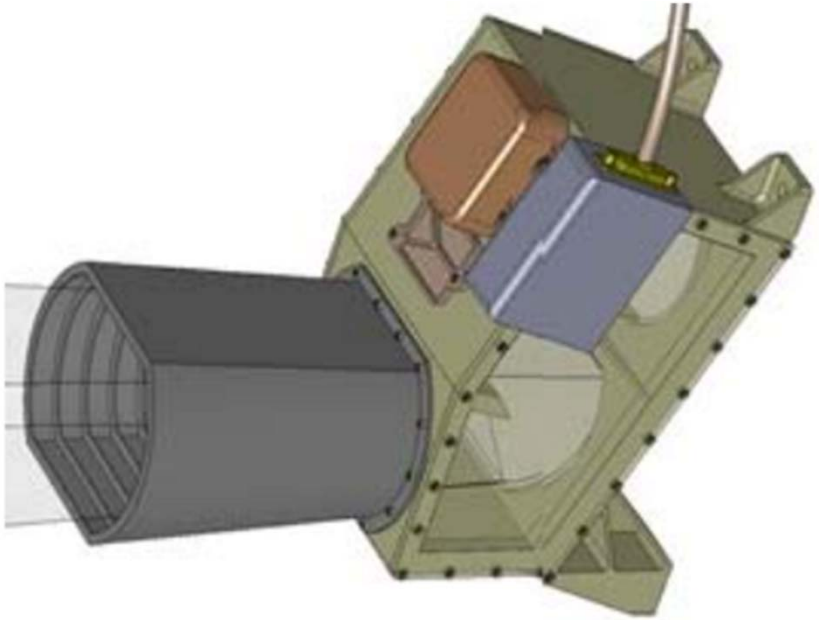


Europa Thermal Imaging System (E-THEMIS)

MIR

Philip Christensen, ASU

- Detect and characterize thermal anomalies that may indicate recent activity
- Identify active plumes
- Determine the regolith particle size, block abundance and subsurface layering for surface process studies



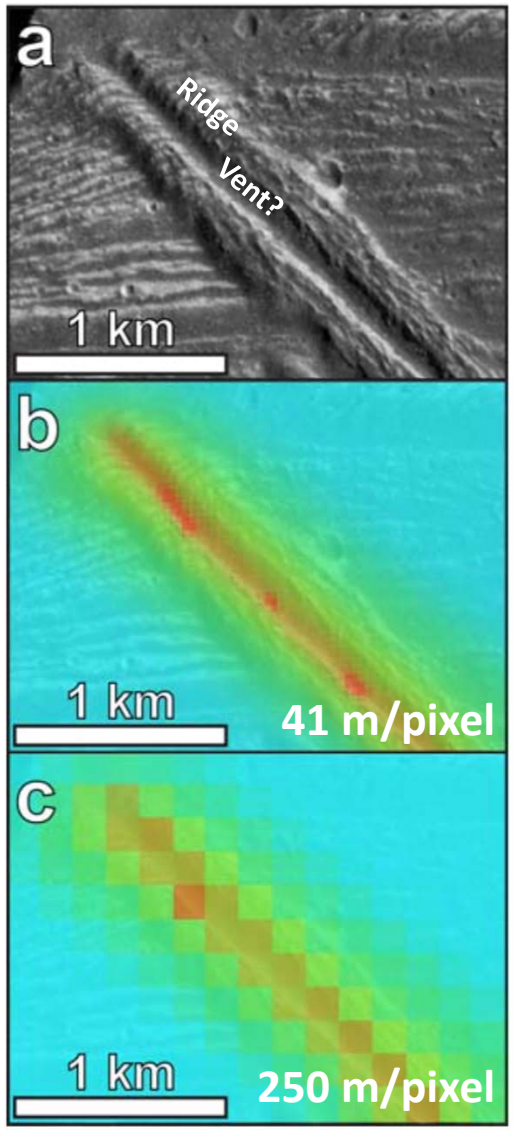
- High-resolution thermal images
- Uncooled microbolometer array with three spectral channels
- Time-delay integration for measuring low temperatures

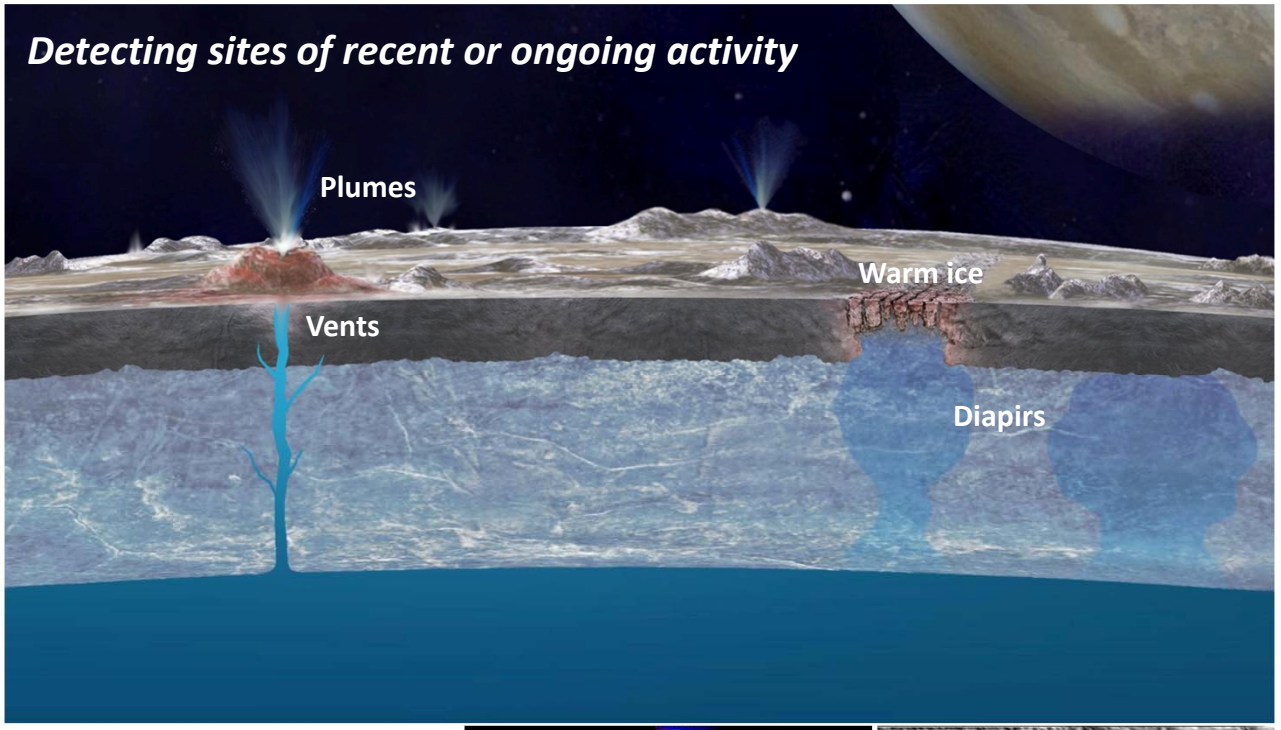
Key instrument Parameters	
Filters	7–14, 14–28, 28–70 µm
Resolution	5 – 35 m at 25 km range
Image width	5.7° cross-track (720 pixels)
Radiometric Precision	0.2 K @ 90 K, 0.1 K @ 130 K, < 0.1 K @ 220 K scene temperature
Radiometric accuracy	1.25%
Time Delay Integration	16 lines

Europa Thermal Imaging System (E-THEMIS)

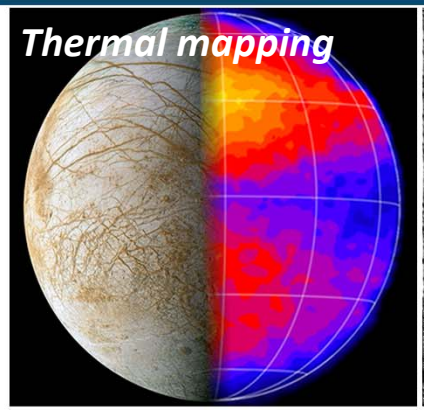
MIR

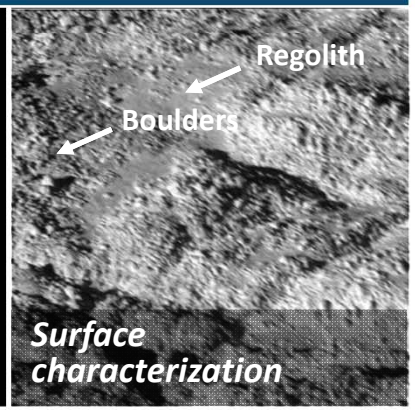
Philip Christensen, Arizona State University





- Ridges on Europa span ~1 km, but active vents may be < 10 m by analogy to Enceladus
- Thermal imaging will pinpoint thermal anomalies



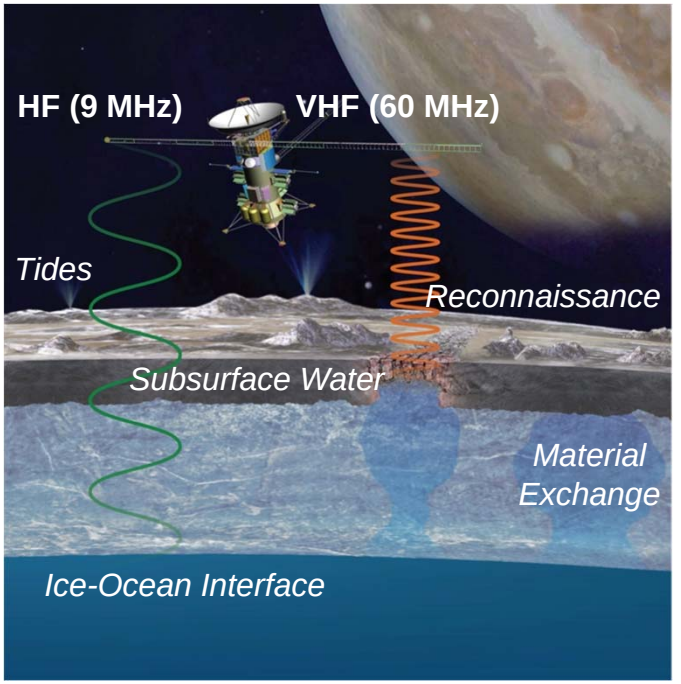


Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)

RADAR

Don Blankenship, University of Texas (Austin)

- Characterize the distribution of any shallow subsurface water
- Search for an ice-ocean interface and characterize the ice shell's global thermophysical structure
- Investigate the processes governing material exchange among the ocean, ice shell, surface, and atmosphere
- Constrain the amplitude and phase of the tides
- Characterize surface properties of scientifically compelling sites



- Simultaneous high resolution, shallow sounding & altimetry along with lower resolution, deep sounding

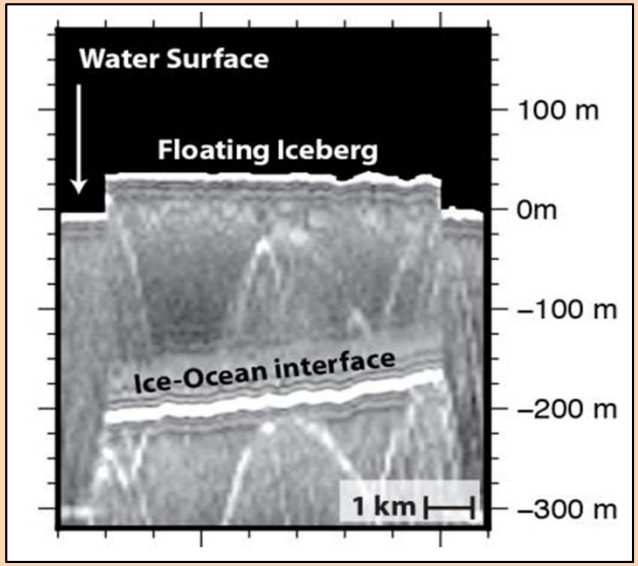
Key instrument Parameters	
Dual Frequencies	60 MHz (λ = 5 m) Very High Frequency (VHF) globally, and 9 MHz (λ = 33.3 m) High Frequency (HF) anti-Jovian
Vertical Resolution	*Shallow sounding*: VHF with <15 m resolution from depths of 300 m to 4.5 km; *Deep sounding*: VHF or HF with <150 m resolution from depths of 1 km to 30km; *Altimetry*: VHF with <15m resolution
Antenna	16m long; ½-wave dipole antennas co-mounted on deployable booms
Radiated Power	10-30 W

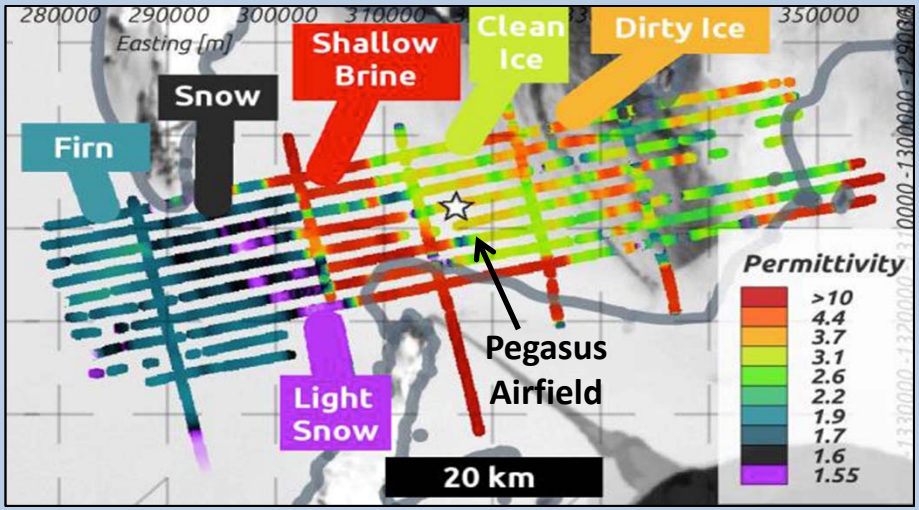
Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)

RADAR

Don Blankenship, University of Texas (Austin)

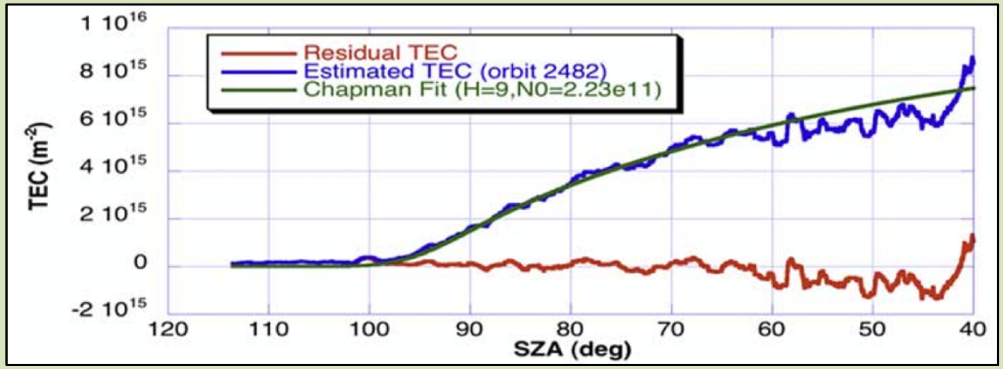
Sounding & Altimetry for subsurface structure and surface elevation. The surface and ice-ocean interface of Iceberg B15, Antarctica, appear as sharp reflectors.





Reflectometry for near-surface roughness, porosity, and composition. Snow, firn, clean ice, dirty ice, and brine are distinguished by permittivity variations over McMurdo Ice Shelf, Antarctica.

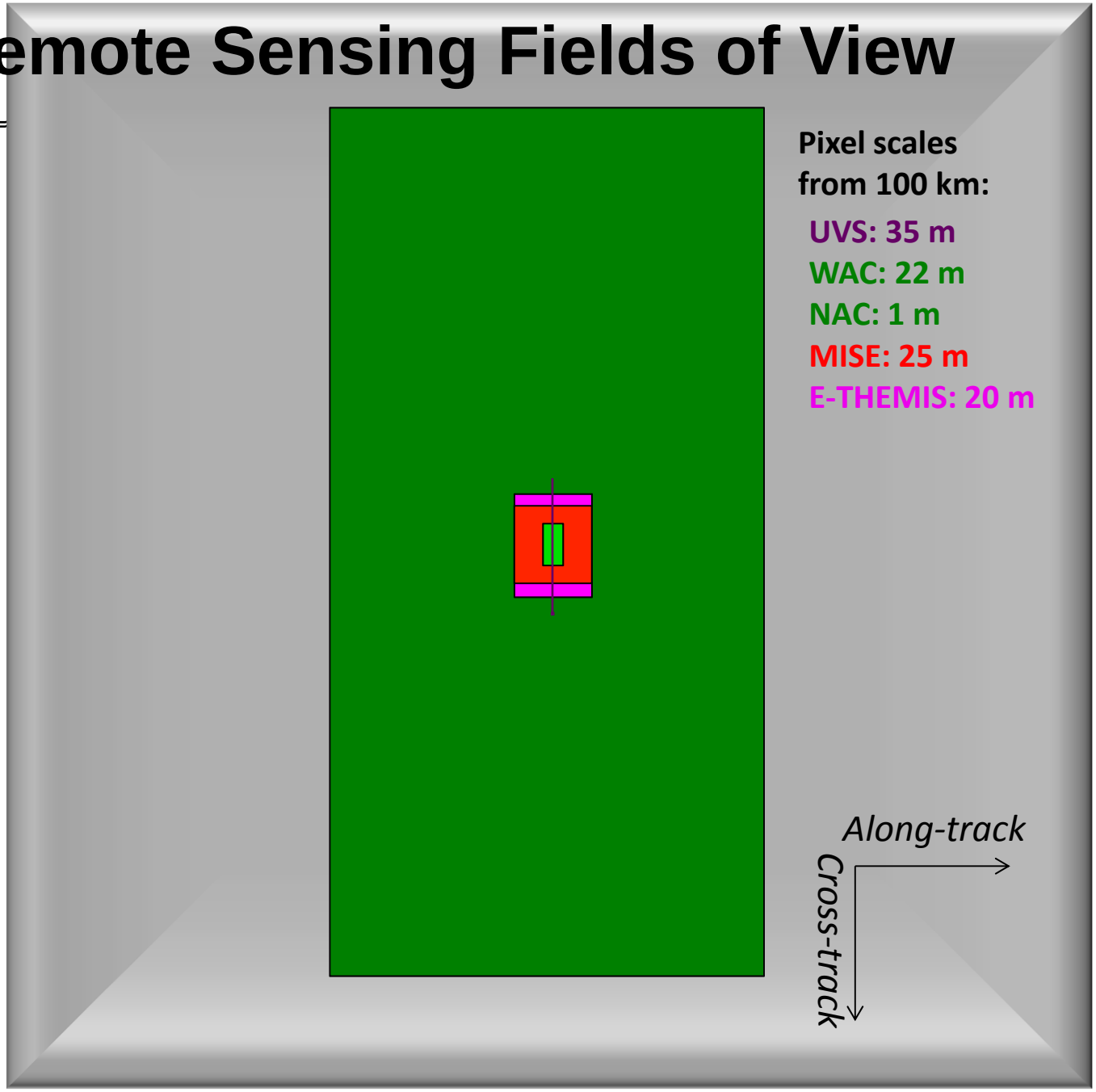
Plasma and Particles to identify active plumes. Total Electron Content (TEC) of Mars' ionosphere derived from MARSIS.



Europa Remote Sensing Fields of View

- **Europa-UVS:**
  7.3° x 0.1°
  + 0.2° x 0.2°
- **EIS WAC:**
  48° x 24°
- **EIS NAC:**
  2.35° x 1.17°
- **MISE:**
  4.3°x 0.86 to 4.3°
- **E-THEMIS:**
  5.7° x 4.3°
- **REASON: 60°**

Note: Pushbroom imaging by EIS, UVS, E-THEMIS, REASON, and (at times) MISE enable arbitrary image lengths along-track (nadir at C/A)

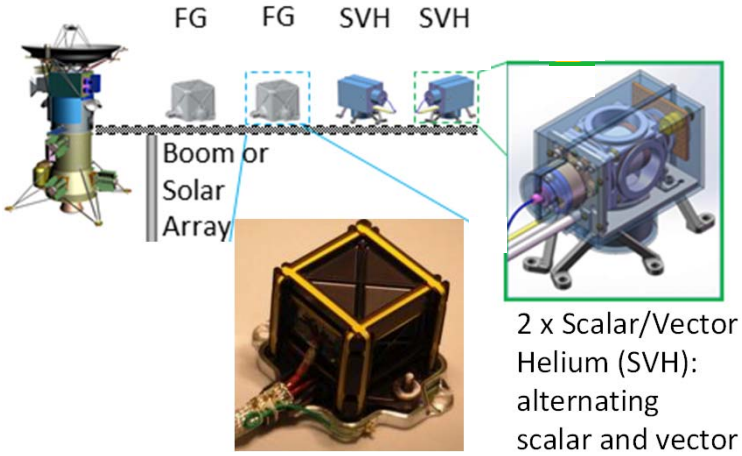


Interior Characterization of Europa using Magnetometry (ICEMAG)

~~Carol Raymond, Jet Propulsion Laboratory~~ (JPL)

- Determine the location, thickness, and salinity of Europa's ocean by magnetic field induction at multiple frequencies
- Identify sources of Europa's atmosphere and atmospheric loss processes by characterizing any active vents, plumes, and ionized plasma trails
- Understand coupling of Europa to Jupiter's ionosphere, and coupling of plumes to flowing plasma

ICEMAG has four magnetometer sensors



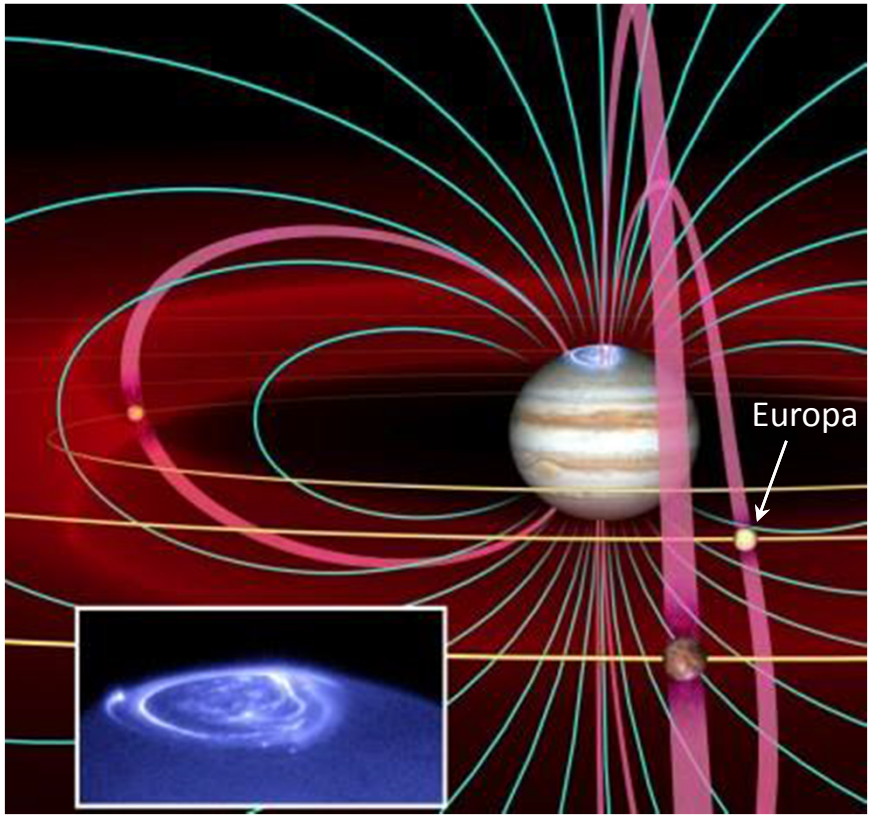
- Combines flux gate magnetometers & self-calibrating helium magnetometers
- Performs dynamical removal of the fluctuating spacecraft field, relaxing magnetic cleanliness requirement
- No need for special spacecraft maneuvers for calibration

Key instrument Parameters	
Vector magnetic field accuracy	< 0.8 nT
Range	± 1500 nT
Precision	0.01 nT
Baseline stability	< 0.1 nT over > 3 yr
Spacecraft magnetic field knowledge	< 0.5 nT
Sampling rate	16 samples / sec

Interior Characterization of Europa using Magnetometry (ICEMAG)

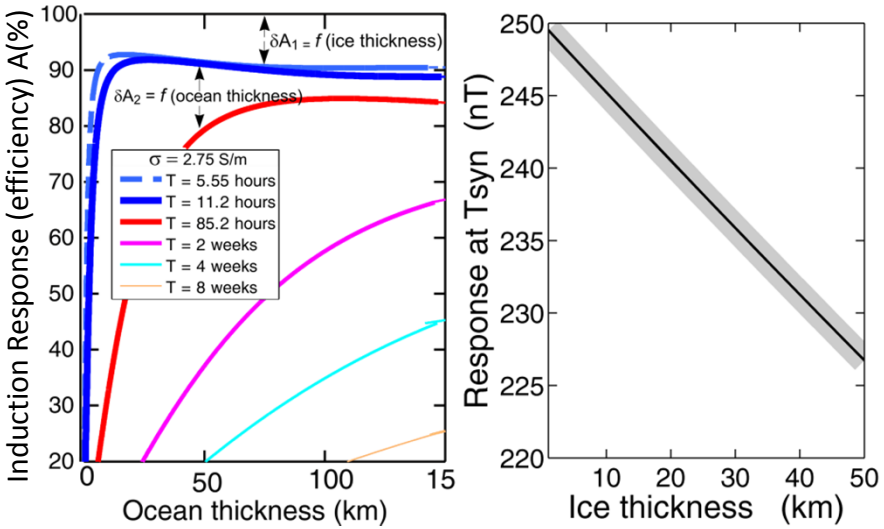
~~Carol Raymond, Jet Propulsion Laboratory~~ (JPL)

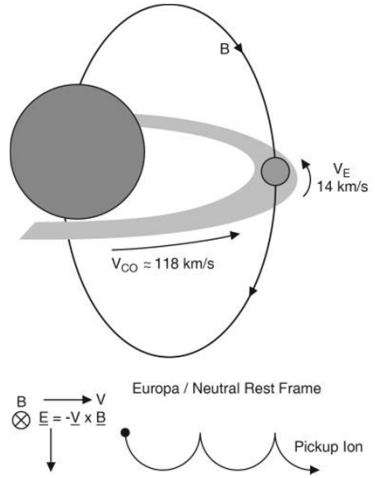
ICEMAG will characterize the complex magnetic environment at Europa



Jupiter's magnetospheric field lines (blue);
Io torus (red);
magnetic flux tubes of Io, Europa, Ganymede (pink)
with their auroral footprints (inset)

Ocean parameters can be retrieved from induction response of Europa at multiple frequencies





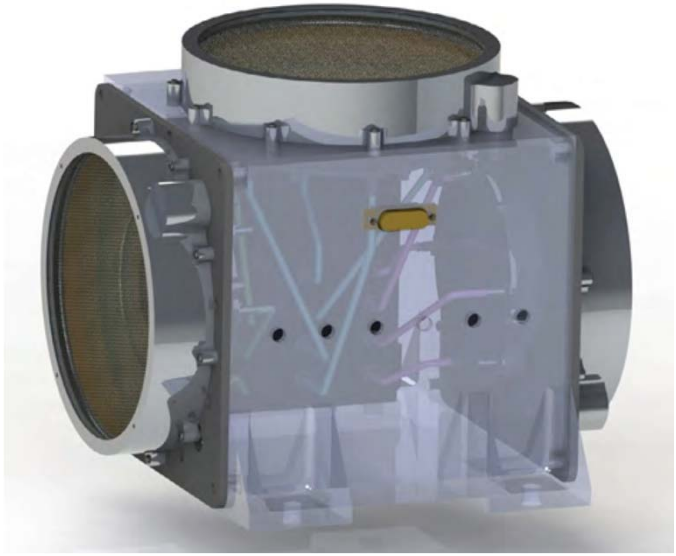
Europa's atmosphere is ionized by Jupiter's plasma torus (gray ring), creating ion cyclotron waves, measured by ICEMAG to reveal atmosphere loss and composition

Plasma Instrument for Magnetic Sounding (PIMS)

Joseph Westlake, JHU/APL

PIMS measures the plasma around Europa to:

- Determine Europa's magnetic induction response, corrected for plasma contributions, to estimate ocean salinity and thickness
- Understand mechanisms of weathering and releasing material from Europa's surface into the atmosphere
- Understand how Europa influences its local space environment and Jupiter's magnetosphere

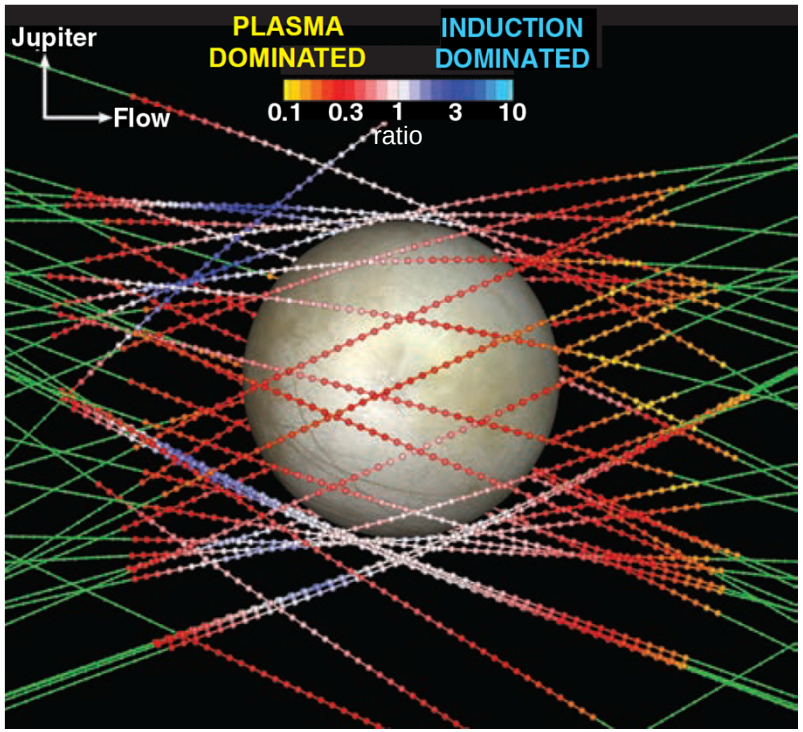


- 3 Faraday Cup plasma sensors with 90° fields of view
- Instruments measure:
  - ion density, temperature, & velocity;
  - electron density & temperature
- Sensors are immune to degradation and background noise from penetrating radiation

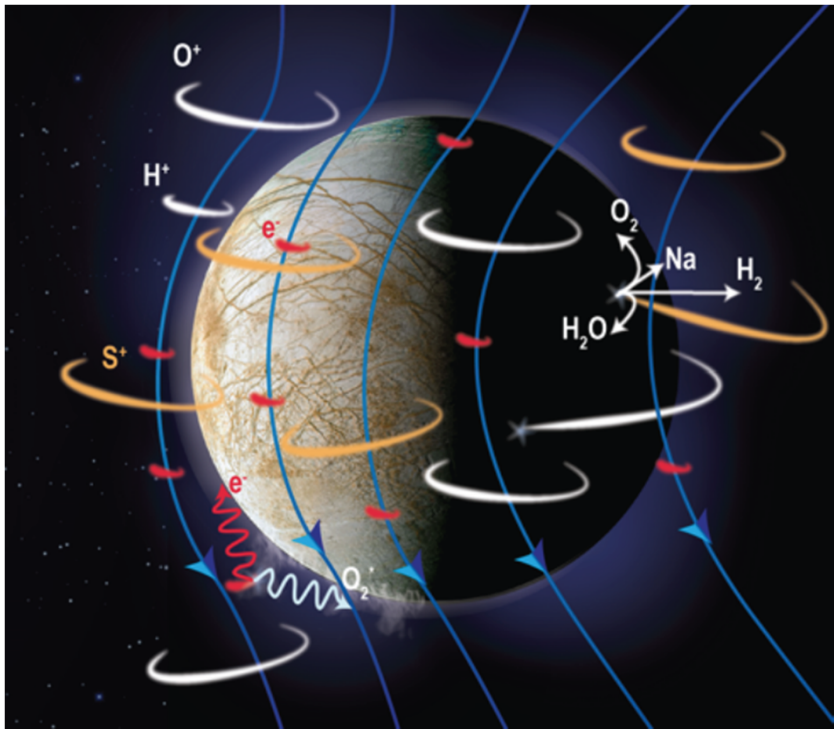
Key instrument Parameters	
Ion Energy Range	0.1 – 50 eV, 0.02 – 7 keV
Electron Energy range	0.1 – 50 eV, 0.01 – 2 keV
Energy Resolution	<15%
Sensitivity	0.5 – 10^5 pA/cm^2
Time Resolution	1 – 4 s

Plasma Instrument for Magnetic Sounding (PIMS)

Joseph Westlake, JHU/APL



Plasma near Europa has a strong contribution to the observed magnetic field (plotted) and masks the induction response from the subsurface ocean.



Charged particles from Jupiter's magnetosphere produce Europa's sputtered atmosphere and weathering of the surface ices

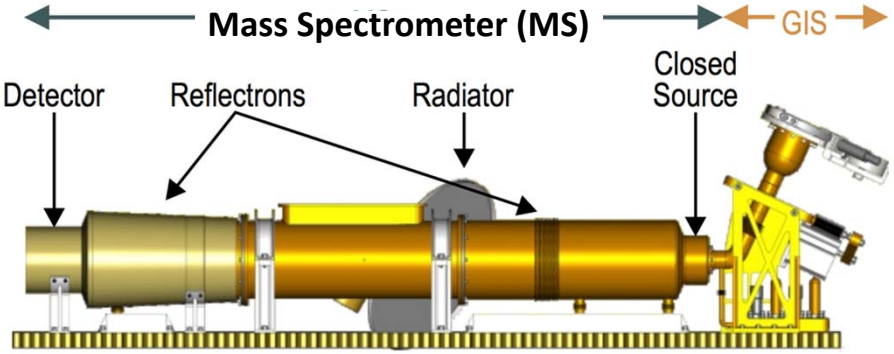
MAss Spectrometer for Planetary EXploration (MASPEX)

Jack "Hunter" Waite, Southwest Research Institute (SwRI) San Antonio

- Determine the distribution of major volatiles and key organic compounds in Europa's exosphere/plumes and their association with geological features

  (H_2O, H_2 , CH_4, C_2H_4, C_2H_6, HCN, $H_2O/^{40}Ar$)

- Determine the relative abundances of key compounds to constrain the (chemical gradients across Europa's ocean, isotopic ratios of H_2O products, hydrocarbons C1-C8 in plume materials)

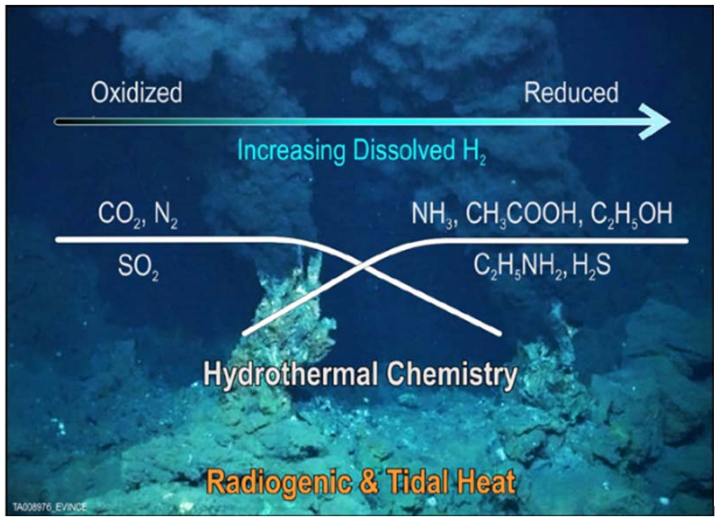


- Multi-bounce time-of-flight mass spectrometer
- Region-of-Interest scanning for high resolution over a broad mass range
- Cryotrap allows storage for high-resolution analysis at apoapse (esp. for ^{40}Ar)

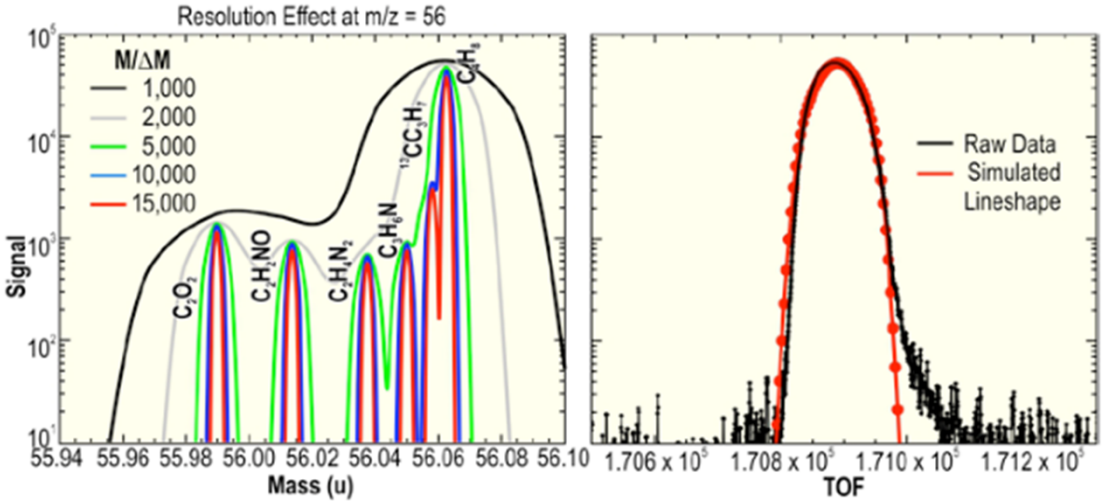
Key instrument Parameters Capability (Driving Requirements)	
Mass Range	2 – 1000 u
Mass Resolution	m/∆m up to 24,500
Dynamic range	10^{10}
Min. Density	$5x10^5/m^3$

MAss Spectrometer for Planetary EXploration (MASPEX)

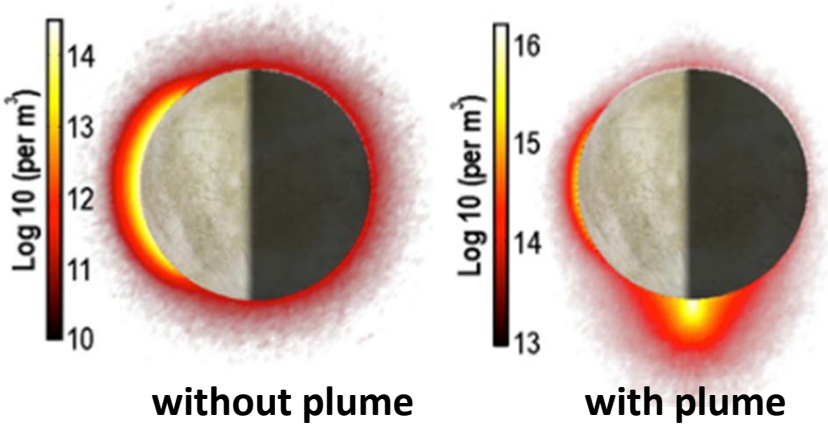
Jack "Hunter" Waite, Southwest Research Institute (SwRI) San Antonio



Ocean composition, indicators of chemical disequilibrium, & biological drives toward equilibrium



High mass resolution to distinguish among organics, permitting isotopic analysis

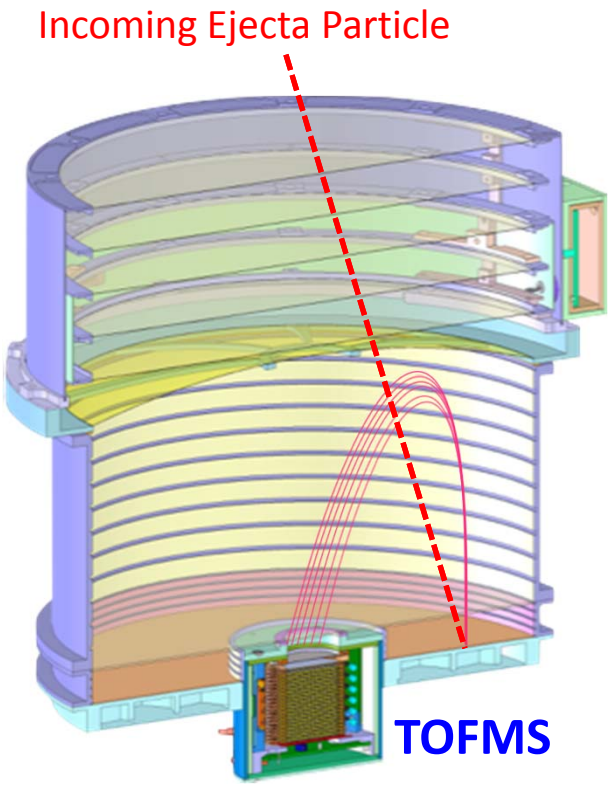


Global-regional coverage enables atmospheric search for plume signatures

SUrface Dust Analyzer (SUDA)

Sascha Kempf, LASP, CU Boulder

- Map the surface composition of Europa
- Characterize the alteration of Europa's surface via exogenous dust
- Determine the composition of the particulate matter in active plumes

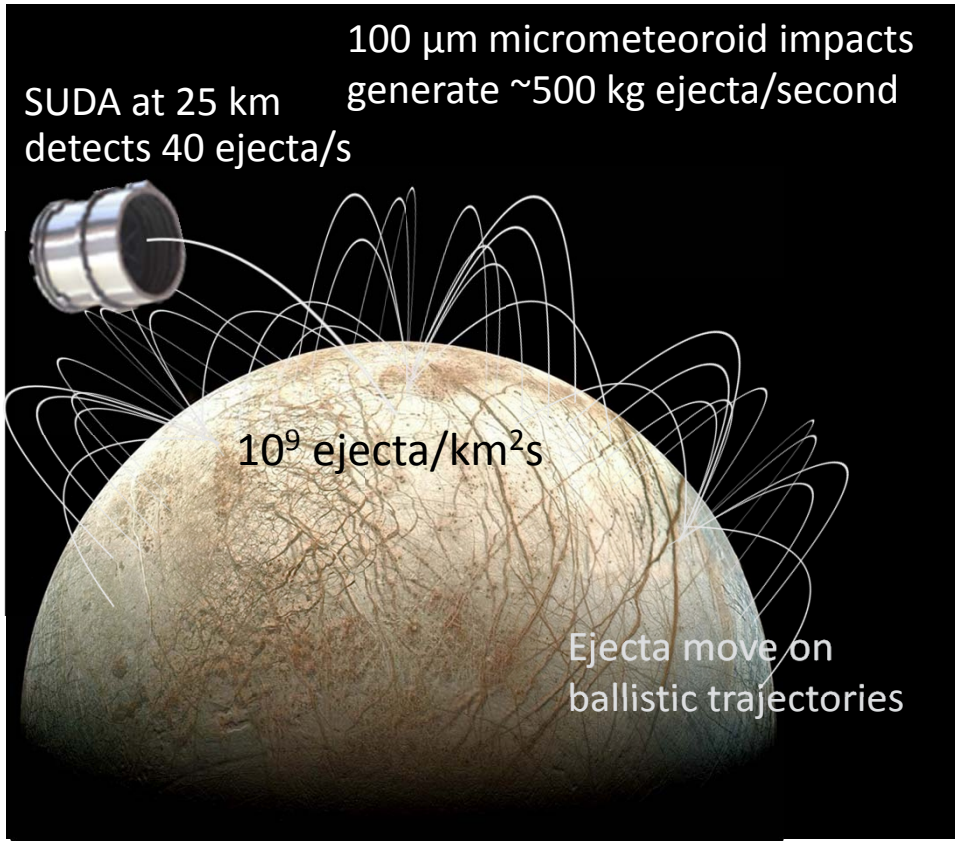


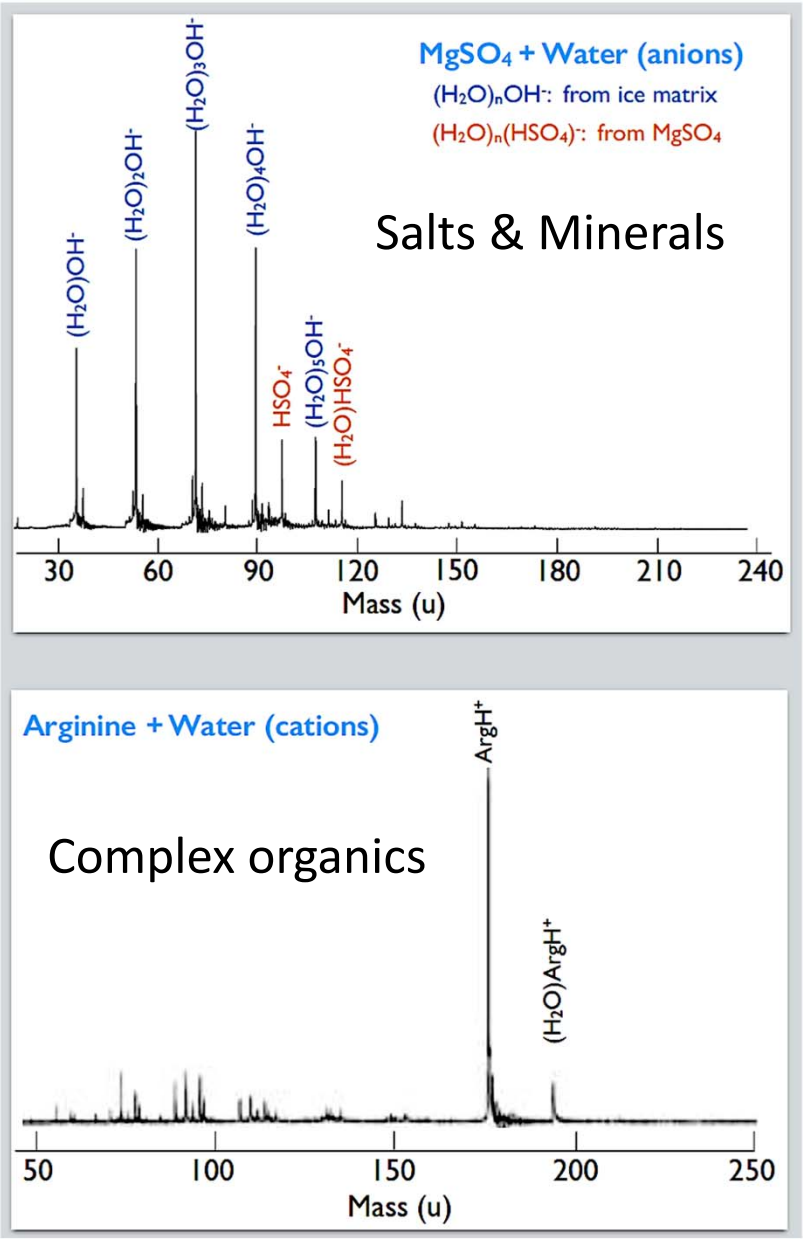
- Time-of-flight mass spectrometer (TOFMS)
- Ejecta composition can be correlated with geologic features
- Trace amounts of complex organics can be detected in ice grains (better than 0.1 ppm)

Key instrument Parameters	
Mass Resolution	m/Δm ≥ 200 for m ≤ 150 u
Dust Grain Properties	Impact Speed Range: 0.5 – 10 km/s (Δ ≤ 1%) Charge Sensitivity ≥ 0.15 fC (Δ≤ 10%) Grain Size Range: 0.2 – 10 μm (Δ ≤ 25%)
Surface Resolution	Better than spacecraft altitude
Detection Limits	40 ejecta per second

SUrface Dust Analyzer (SUDA)

Sascha Kempf, LASP, CU Boulder

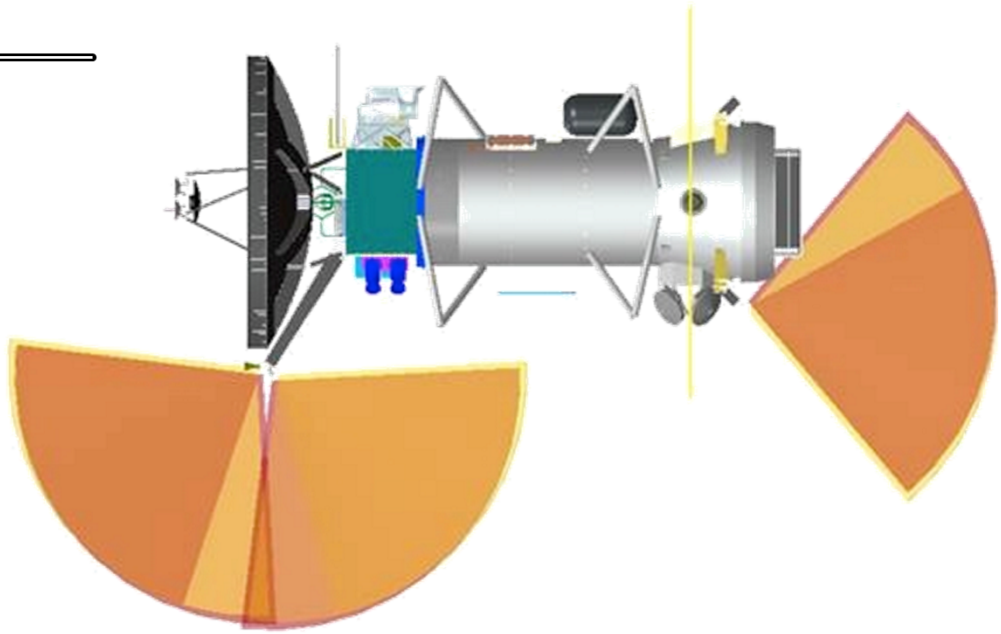




Gravity Science Investigation

Working Group for Phase A

- Characterize Europa's time-varying gravitational tides
- Confirm the existence of Europa's subsurface ocean

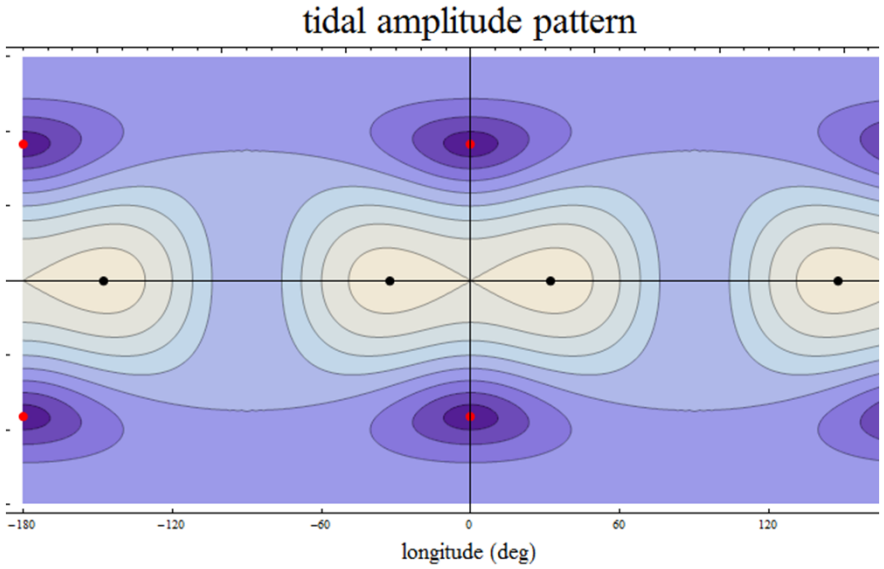


- Three Fixed Fanbeam antennas
- X-band up/down
- Radio Science Receivers used at DSN
- Opportunities for augmenting the DSN with ESA antennas
- Opportunity to augment the telecom system with a Deep Space Atomic Clock (DSAC)
- Non-intrusive with nadir flyby

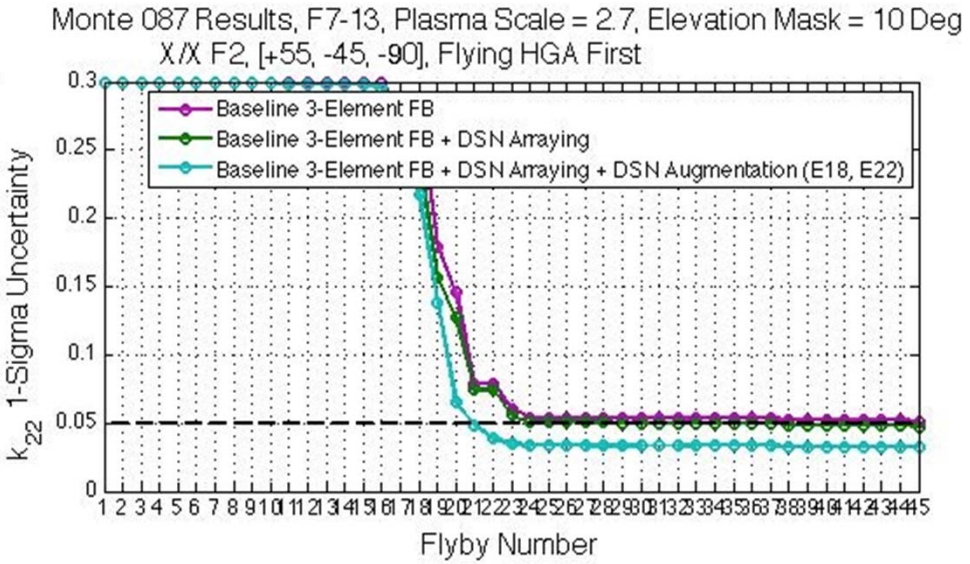
Key instrument Parameters	
Gain	9.5 dB min @D/L
Field of View	±15˚ by ±50˚
Resolution	0.07 mm s^{-1} (60 s integration time)

Gravity Science Investigation

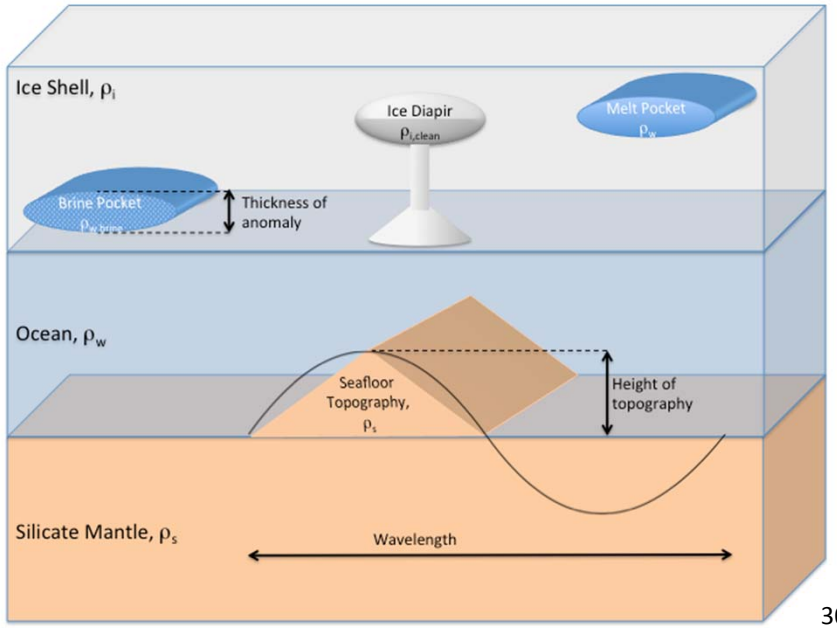
Working Group for Phase A



Characterize Amplitude and Phase of tides



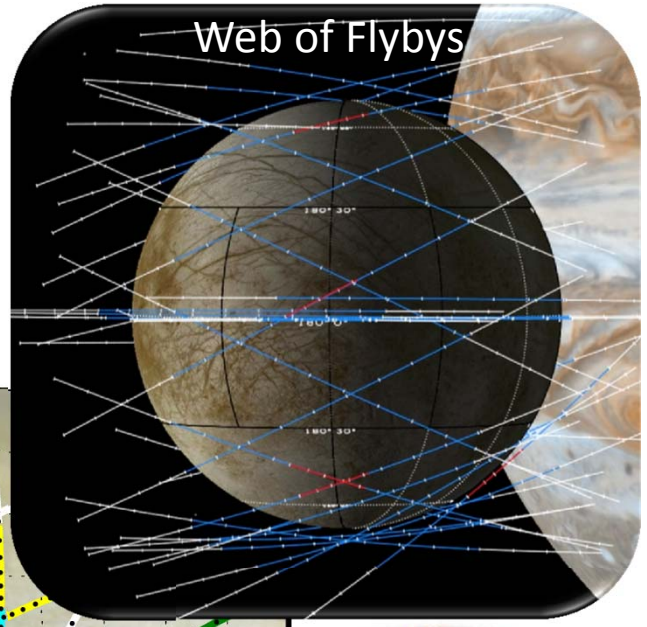
Determine Love number k_2 to <0.05

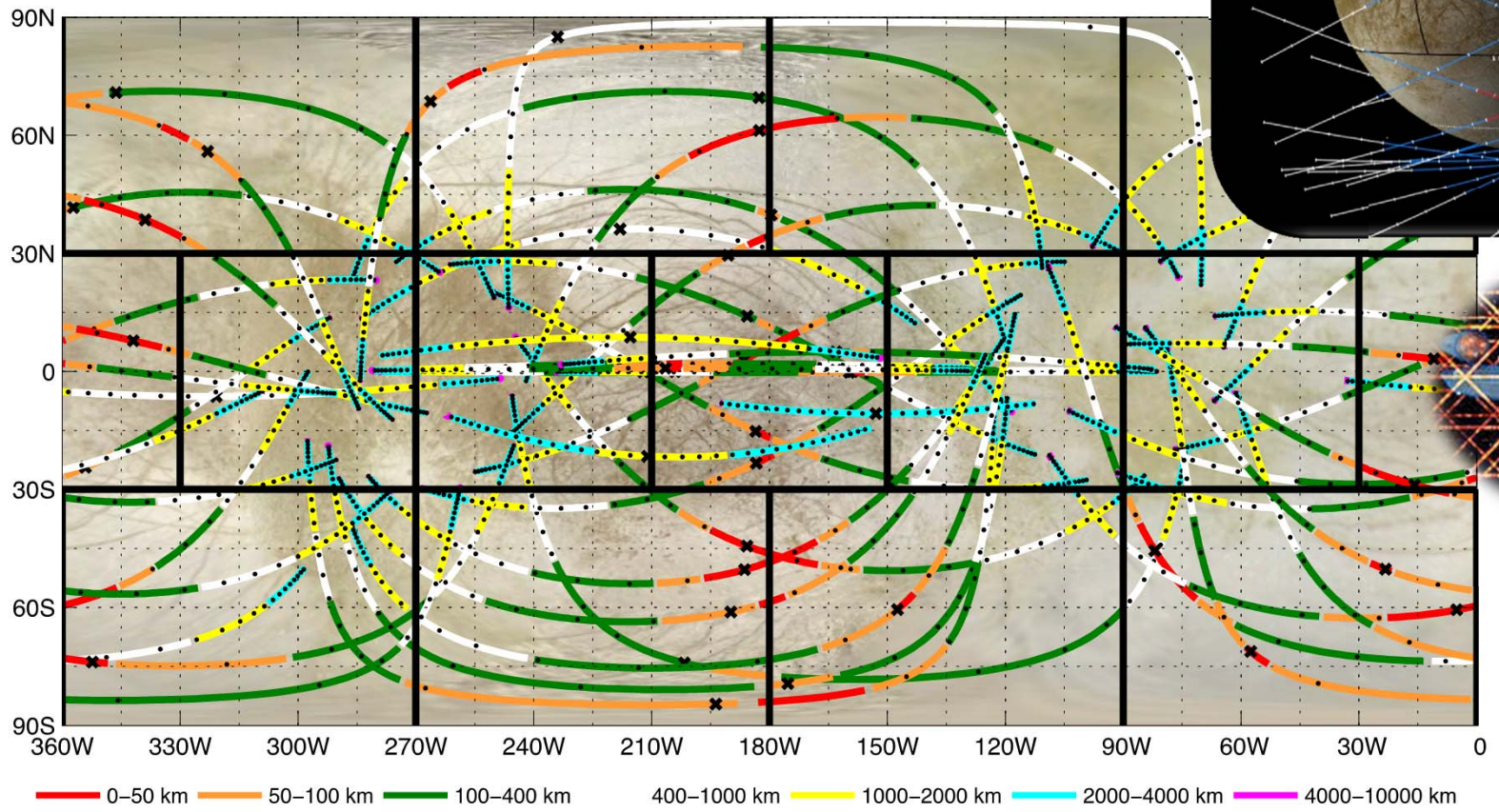


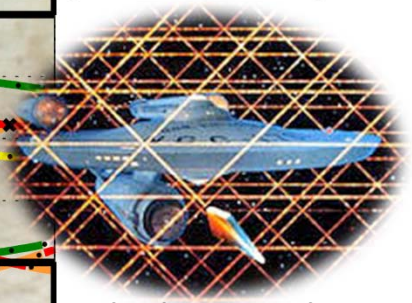
Opportunity to identify density anomalies on seafloor and within ice shell

“Global-Regional” Surface Coverage

- Utilize multiple satellite gravity assists to enable “global-regional” coverage of Europa while in orbit around Jupiter
- Current mission design consists of 45 low-altitude flybys of Europa from Jupiter orbit over 3.5 yr







Tholian Web

Europa: The Adventure Begins!