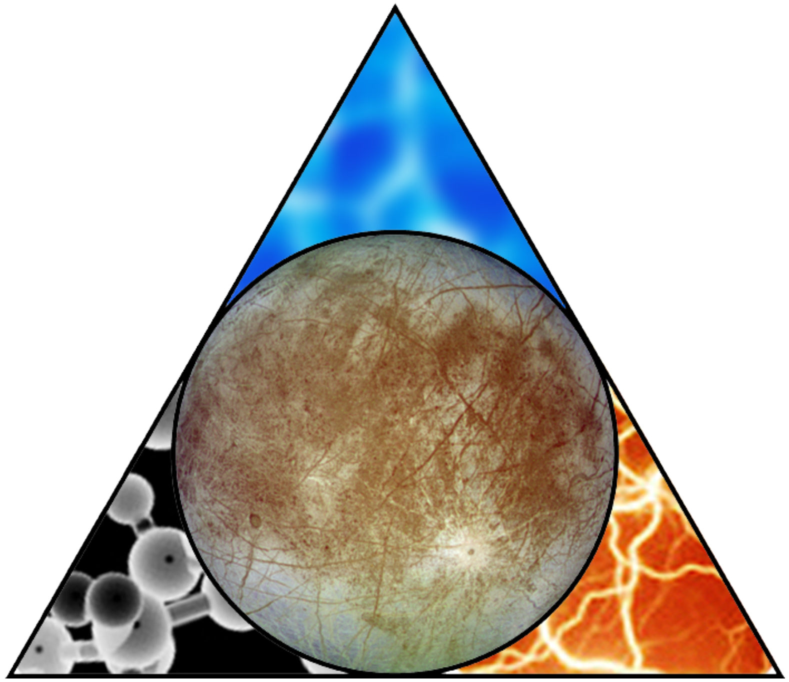
Europa Study Update

OPAG meeting, Pasadena, CA
10/19/2011



Science

Bob Pappalardo

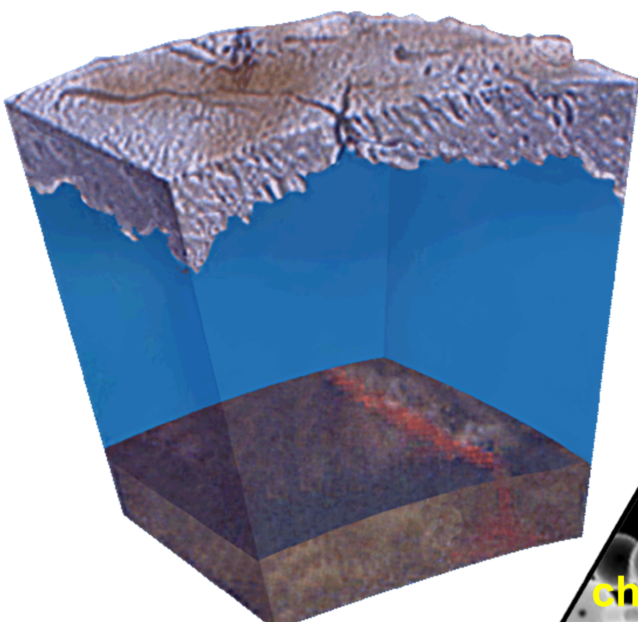
Europa Study Scientist and SDT Chair

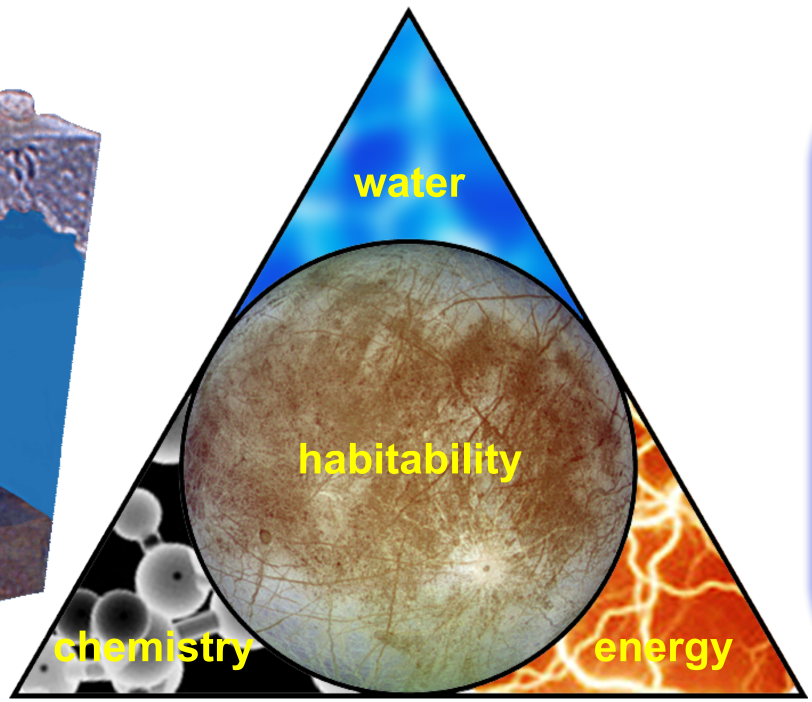
OPAG meeting, Pasadena, CA

10/19/2011

Ingredients for Life

- Three "ingredients" necessary for life:
  - *Water:* Solvent to facilitate chemical reactions
  - *Chemistry:* Constituents to build organic molecules
  - *Energy:* Disequilibrium to drive metabolism



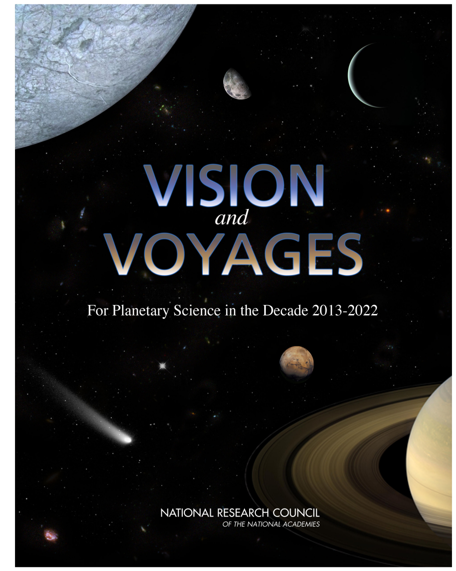


"Because of this ocean's potential suitability for life, Europa is one of the most important targets in all of planetary science."

–NRC Planetary Decadal Survey 2011

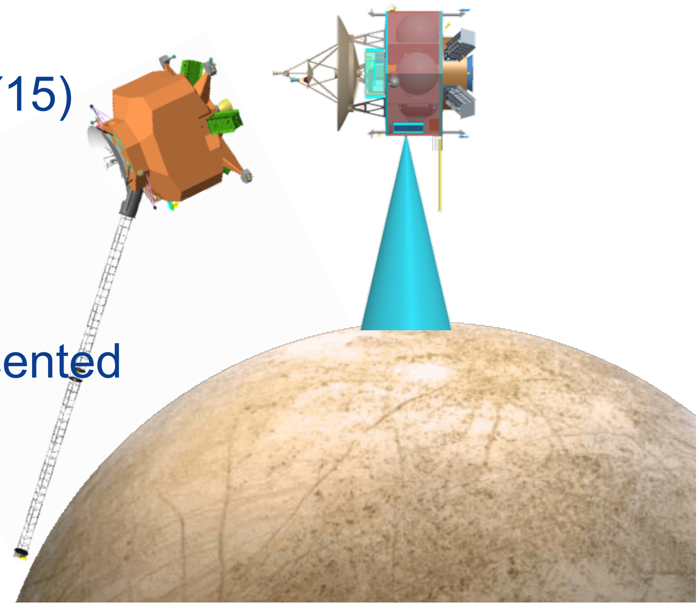
Decadal Survey Recommendations

- "[B]oth **JEO and the Mars Sample Return campaign** (beginning with MAX-C) **were found to have exceptional science merit**."
- JEO is "**second highest priority Flagship** mission" relative to MAX-C, based on "**pragmatic reasons** associated with the required spending profiles."
- JEO's "cost as currently designed is so high that **both a decrease in mission scope** and an **increase in NASA's planetary budget** are necessary to make it affordable."
- "**Possible pathways to lower cost** include use of a **larger launch vehicle that would reduce cost risk** by shortening and simplifying the mission design, and a **significant reduction in the science payload**. Other possible descopes were listed in section 4.1.5 of the 2008 JEO mission study final report."
- For plutonium savings, **switch from MMRTG to ASRGs**
- MAX-C was chosen over JEO foremost "**to maintain programmatic balance by assuring that no one mission takes up too large a fraction of the planetary budget at any given time**."



Europa SDT Summary

- To achieve the highest priority JEO Europa science objectives, invoke a two-element approach
  - Orbiter element to perform geophysical measurements ("Ocean" science) which can only be achieved from Europa orbit
  - Multiple-flyby element to perform remote measurements ("Chemistry" and "Energy" science) which can be achieved from Jupiter orbit
- Each achieves key science objectives, and each has very high science value of its own
  - Neither science nor element cost (~$1.5B FY15) is a clear discriminator between elements
- The complementary elements would fly separately, and staggered in time
  - Anticipate the second element would be presented to the next Decadal Survey for consideration
- A landed element is now being studied by the Europa SDT at NASA's request



Europa Science Definition Team

2011-2012

Fran Bagenal	Univ. Colorado	Plasma
Amy Barr	SwRI	Geophysics
Bruce Bills	JPL	Geophysics
Diana Blaney	JPL	Composition
Don Blankenship	Univ. Texas	Ice shell
Will Brinckerhoff*	GSFC	Astrobiology
Jack Connerney	GSFC	Magnetometry
Kevin Hand*	JPL	Astrobiology
Tori Hoehler*	Ames	Astrobiology
Bill Kurth	Univ. Iowa	Plasma
Melissa McGrath	MSFC	Atmosphere
Mike Mellon*	Univ. Colorado	Ice Physics
Jeff Moore	Ames	Geology
Bob Pappalardo	JPL	Chair / Study Scientist
Louise Prockter	APL	Deputy / Geology
Dave Senske	JPL	Deputy / Geology
Everett Shock*	ASU	Geochemistry
David Smith	MIT	Geophysics

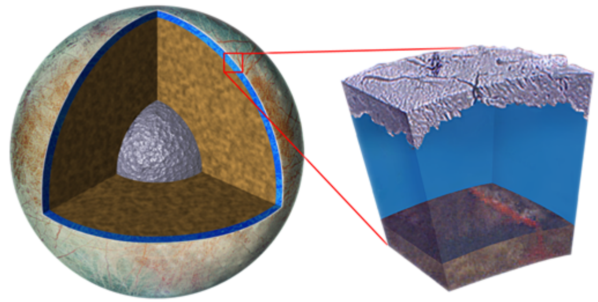
*Recent SDT augmentations

Europa SDT Meetings

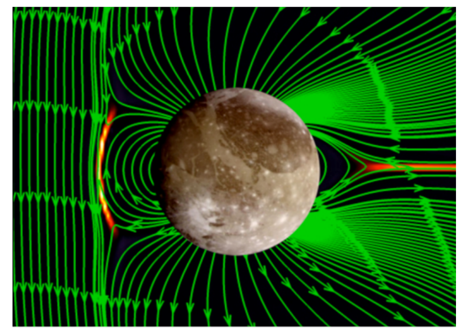
- May 2–3, 2011, JPL
  - Considered Europa objectives and mission design trades, and converged on two-element mission concept
- June 23–24, 2011, JPL
  - Provided feedback on initial orbiter and flyby mission designs, and iterated on model payload and mission requirements
- Aug. 22–23, 2011, JPL
  - Finalized science traceability, model payloads, and mission requirements
- Oct. 17–18, 2011, JPL
  - Developed initial objectives and investigations for a landed element
- *Upcoming:* Nov. 29–30, 2011, Boulder, Colo.
  - Will develop lander element model payload and associated mission requirements

Reduced from EJSM-JEO to a Europa-Only Focus

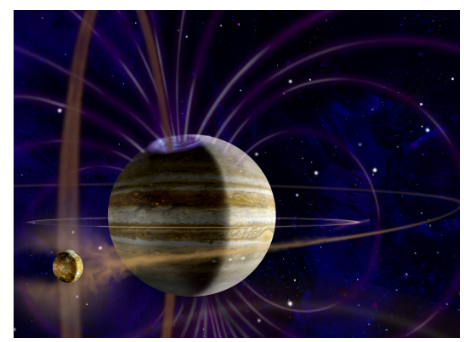
1. Europa:
   Explore Europa to investigate its habitability



2. Ganymede:
   Characterize Ganymede as a planetary object including its potential habitability



3. Jupiter System:
   Explore the Jupiter system as an archetype for gas giants

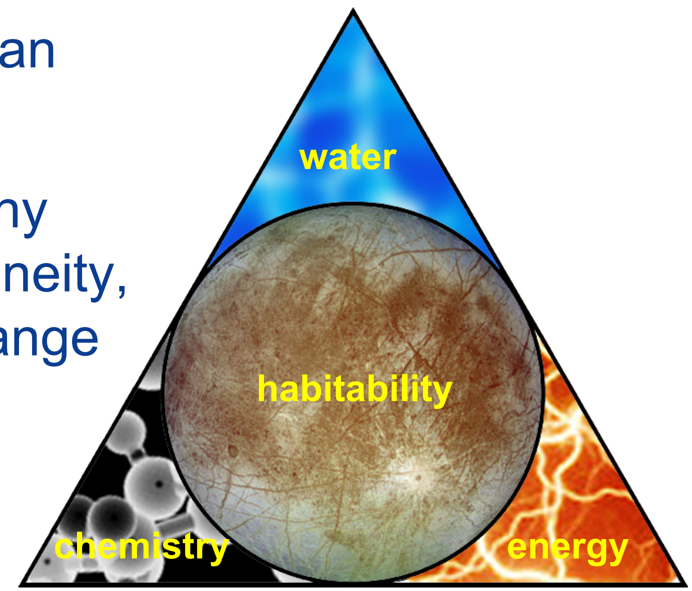


Science Goal, Objectives, and Themes

Modified and Simplified from JEO

- *Goal:* Explore Europa to investigate its habitability
- *Objectives:*
  - *Ocean:* Characterize the extent of the ocean and its relation to the deeper interior
  - *Ice Shell:* Characterize the ice shell and any subsurface water, including their heterogeneity, 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

Themes:



Science as a Driver of Mission Architecture

Science traceability leads to a two element mission concept:

***Orbiter Element:* Geophysical measurements that can be achieved only from orbit**

- Science focused primarily to address "Ocean" objective:
  - Gravity field
  - Tidal amplitude
  - Induction signatures
  - Plasma correction
  - Stratigraphic mapping

***Flyby Element:* Remote measurements that can be accomplished via multiple flybys**

- Science focused primarily to address "Chemistry" and "Energy" themes:
  - Subsurface dielectric horizons
  - Surface constituents
  - Atmospheric constituents
  - Targeted landforms

- Each element achieves key Europa science objectives
- The elements are complementary, and each has very high science value of its own

Two-Element Approach

Objective	Europa Science	Orbiter	Multiple Flyby
Ocean	Gravity field	✓	
	Tidal amplitude	✓	
	Induction signatures	✓	
	Plasma correction	✓	
Ice Shell	Subsurface dielectric horizons		✓
Composition	Surface constituents		✓
	Atm. constituents		✓
Geology	Stratigraphic mapping	✓	
	Targeted landforms		✓

Orbiter Element Traceability

Ocean Emphasis

Goal	Objective		Investigation		Model Instruments	Theme		
						W	C	E
Explore Europa to investigate its habitability	Ocean	Characterize the extent of the ocean and its relation to the deeper interior.	O.1	Determine the amplitude and phase of gravitational tides.	Radio subsystem, Laser altimeter	✓		
			O.2	Determine Europa's magnetic induction response.	Magnetometer, Langmuir probe	✓		
			O.3	Determine the amplitude and phase of topographic tides.	Laser altimeter, Radio subsystem	✓		
			O.4	Determine Europa's rotation state.	Laser altimeter, Mapping camera	✓		
			O.5	Investigate the deeper interior.	Radio subsystem, Laser altimeter, Magnetometer, Langmuir probe	✓		✓
	Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.	G.1	Determine the distribution, formation, and three-dimensional characteristics of magmatic, tectonic, and impact landforms.	Mapping camera, Laser altimeter	✓		✓

Themes: W= Water, C = Chemistry, E = Energy

Flyby Element Traceability

Chemistry & Energy Emphasis

Goal	Objective		Investigation		Model Instr.	Theme W	Theme C	Theme E
Explore Europa to investigate its habitability	Ice Shell	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.	I.1	Characterize the distribution of any shallow sub-surface water and the structure of the icy shell.	Radar sounder, Topo. Imager	✓		✓
			I.2	Search for an ice-ocean interface.	Radar sounder, Topo. Imager	✓		✓
			I.3	Correlate surface features and subsurface structure to investigate processes governing material exchange among the surface, ice shell, and ocean.	Radar sounder, IR spectrometer, Topo. imager	✓	✓	✓
			I.4	Characterize regional and global heat flow variations.	Radar sounder	✓		✓
	Composition	Understand the habitability of Europa's ocean through composition and chemistry.	C.1	Characterize the composition and chemistry of the Europa ocean as expressed on the surface and in the atmosphere.	IR spectrometer, INMS	✓	✓	
			C.2	Determine the role of Jupiter's radiation environment in processing materials on Europa.	IR spectrometer, INMS		✓	✓
			C.3	Characterize the chemical and compositional pathway's in Europa's ocean.	IR spectrometer, INMS	✓	✓	
	Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.	G.2	Determine sites of most recent geological activity, and characterize high science interest localities.	Topo. Imager	✓		✓

Themes: W= Water, C = Chemistry, E = Energy

Pre-Decisional — For Planning and Discussion Purposes Only

Traceability Matrix Example

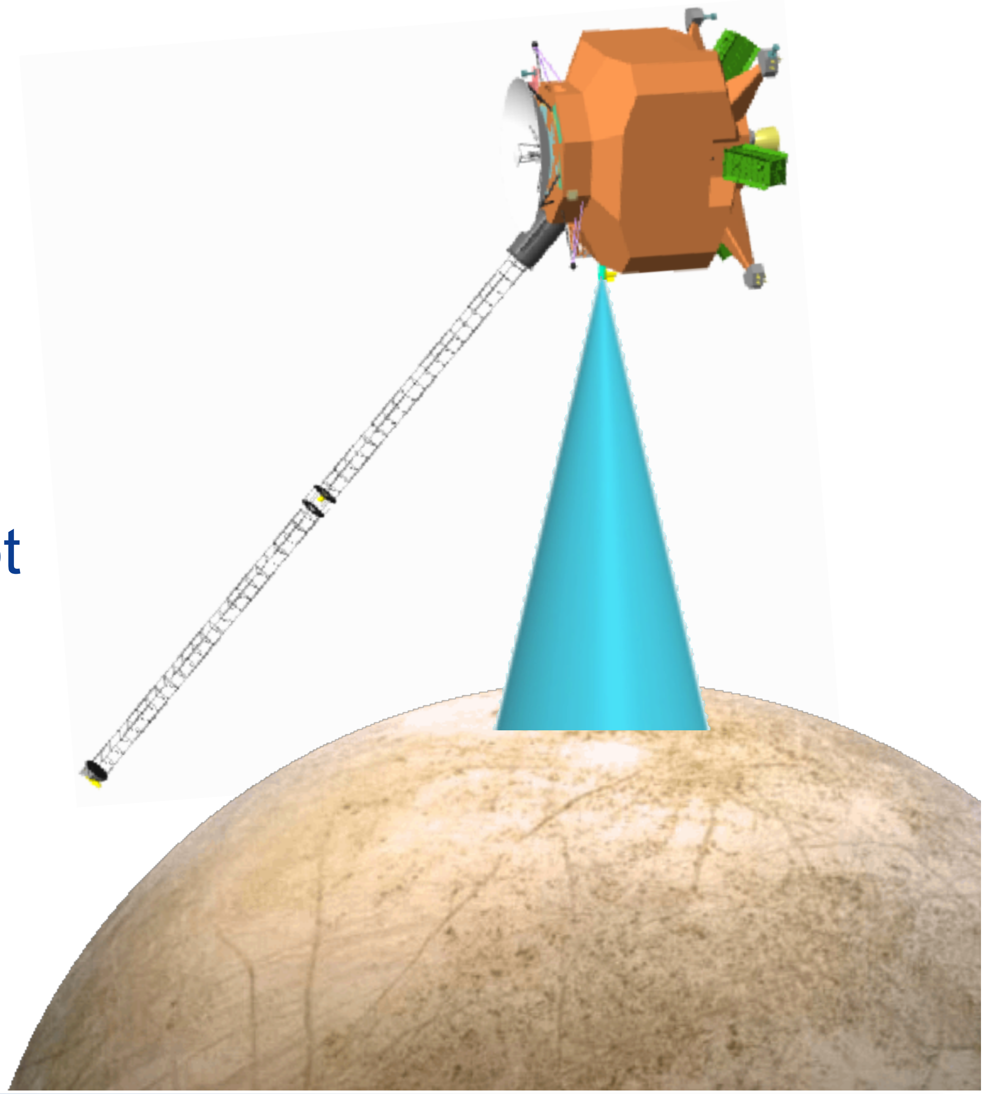
Goal	Objective	Investigation	Measurement	Example instrument	Mission constraints/ requirements	Notional Instrument Specifications	Notional Mission Type
Explore Europa to investigate its habitability.	Characterize the extent of the ocean and its relation to the deeper interior.	Determine the amplitude and phase of gravitational tides.	Measure degree two time dependent gravity field, to recover k_2 amplitude at Europa's orbital frequency to 0.003 absolute accuracy, and the phase to 1 degree.	Radio sub-system	(1) Low altitude (~100+ km), circular, near-polar (within 5° to 10° of the pole) orbit, for at least 30 days (baseline), 18 days (floor); (2) Range-rate measurements with an accuracy better than 0.1 mm/s at 60 sec integration time to determine spacecraft orbit to better than 1-meter (rms) in radial direction over several tidal cycles; (3) Several "unperturbed" days for the data arcs (preferably at least one rotation of Europa) for gravity-limit spacecraft momentum dumping or thrusting to an interval of 3 to 4 days, if possible.	Ka and X, both up and down (closed-loop)	Orbiter

Key Science Drivers & Requirements

Instrument(s)	Key Accommodation Requirements	Element
Radio Subsystem + Laser Altimeter	Low altitude (~100+ km), circular, near-polar orbit, for at least 30 days. Unperturbed orbital arcs (no thrusting) of at least 3 days.	Orbiter
Magnetometer + Langmuir Probe	Low altitude (~100+ km), circular, near-polar orbit, for at least 30 days. Cover approximately 12 hours of Europa local time.	Orbiter
Mapping Camera	Low altitude (~100+ km), ≥ 80% global coverage under near uniform lighting conditions, solar incidence angle > 45° (70° preferred).	Orbiter
Ice Penetrating Radar	≥ 800 km tracks in 11 of 14 globally distributed regions, intersected by at least 1 other track, with track lengths measured from ≤ 400 km alt. ~25–100 km closest approach at ≤ 6 km/s.	Flyby
ShortWave IR Spectrometer	≥ 70% coverage at ≤ 10 km per pixel. Ability to target specific geologic locations with a wide range of surface locations, lighting between 9:00am and 3:00pm. Attitude stability < ½ IFOV over integration time, flyby speed < 6 km/s.	Flyby
Topographical Imager	High resolution stereo imagery aligned with IPR coverage; lighting conditions solar incidence angle > 20° (70° preferred).	Flyby
Ion and Neutral Mass Spectrometer	Low altitude (< 200 km with lower altitudes desired) at ≤ 7 km/s; long integration times and low altitudes (≤ 100 km) preferred.	Flyby

Orbiter Model Payload: Outline

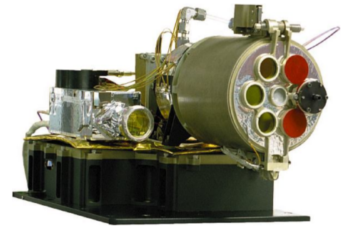
- Model payload instruments
  - Radio Subsystem (RS)
  - Laser Altimeter (LA)
  - Magnetometer (MAG)
  - Langmuir Probe (LP)
  - Mapping Camera (MC)
- Science operations concept
- Example coverage



Orbiter Model Payload Instruments

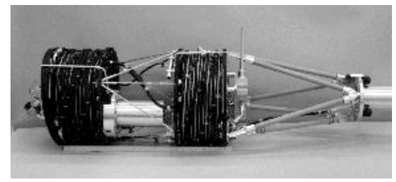
Similar instruments

- Radio Subsystem (RS)
  - X-band up and down; Ka-band down only
  - Ka Transponder
- Laser Altimeter (LA)
  - Nadir view, co-boresighted with camera on 2-axis gimbal platform



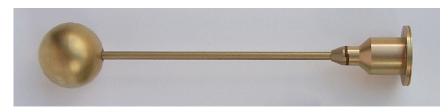
NEAR NLR

- Magnetometer (MAG)
  - Dual 3-axis fluxgate
  - Sensors on boom 5 m and 10 m from S/C



Galileo MAG

- Langmuir Probe (LP)
  - Two 5 cm diameter spheres mounted on 1 m long booms pointed > 90° from each other



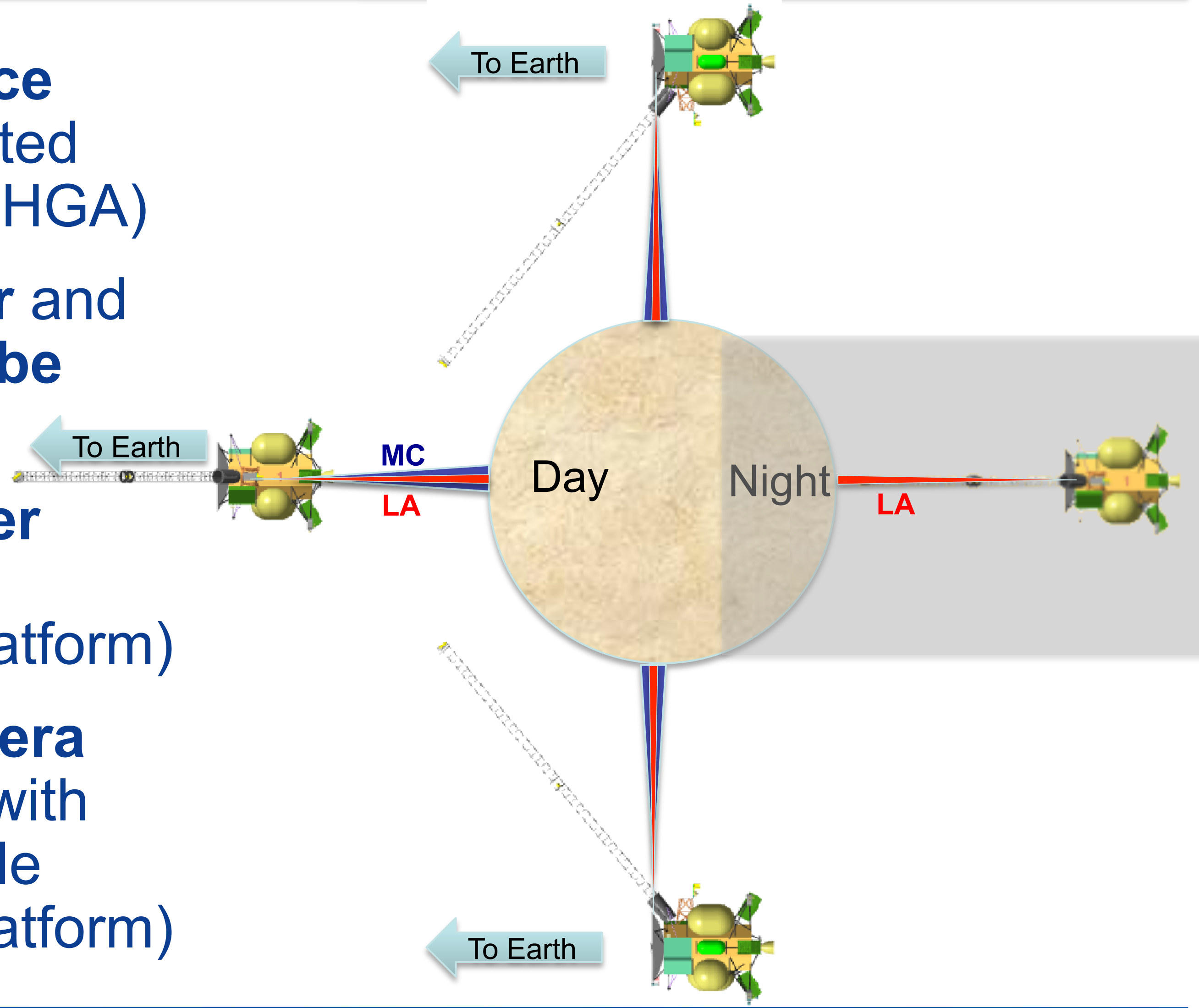
Rosetta LAP

- Mapping Camera (MC)
  - Pushbroom imager; 1024 pixel CMOS or CCD line array
  - 5 separate line arrays in focal plane (radiation shielded)
    - 4 nadir viewing: panchromatic + 3 color bands (color for E/PO)
    - 1 panchromatic viewing ~40° forward or aft for stereo
  - Nadir view, co-boresighted with LA on 2-axis gimbal platform

MPL/MSL MARDI

Orbiter Science Operations Concept

- **Gravity Science** while not occulted (Earth-pointed HGA)
- **Magnetometer** and **Langmuir Probe** on all the time
- **Laser Altimeter** on all the time (2 axis scan platform)
- **Mapping Camera** on during day with ~45% duty cycle (2 axis scan platform)



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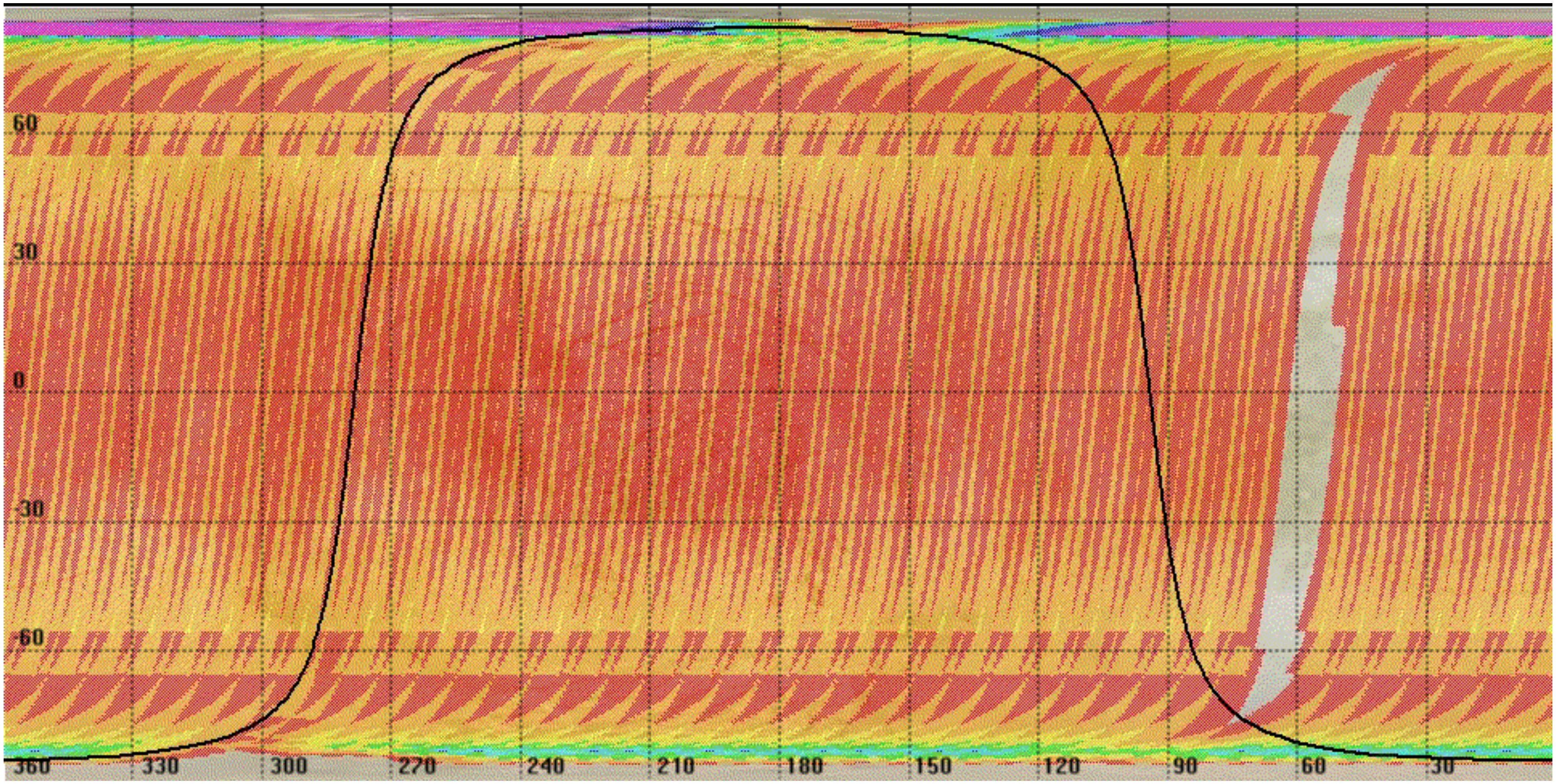
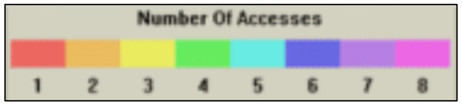
Mapping Camera

Global Stereo Map in 3 Eurosols (<11 days)

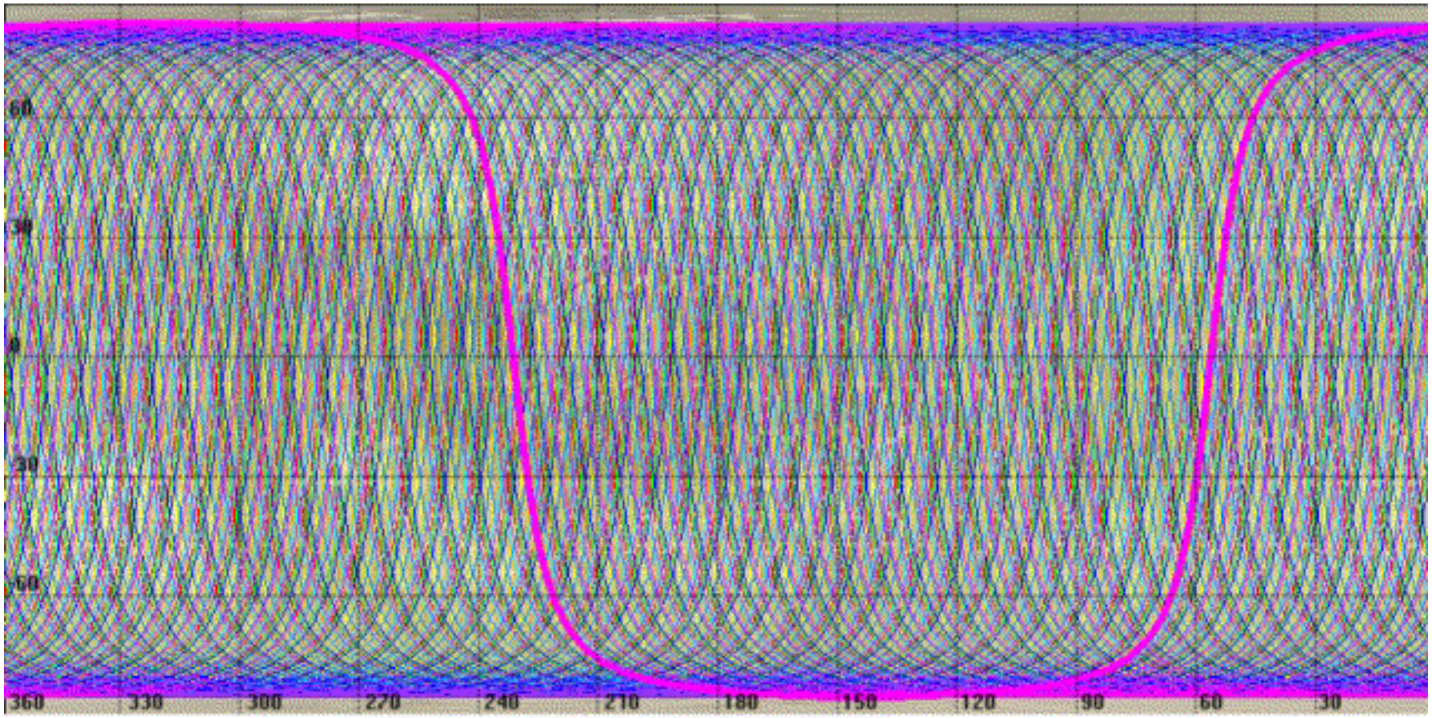


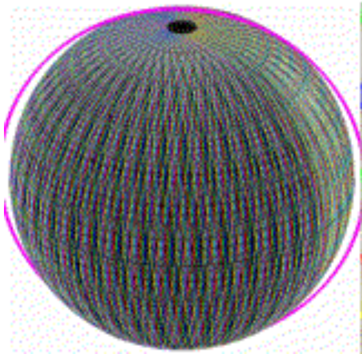


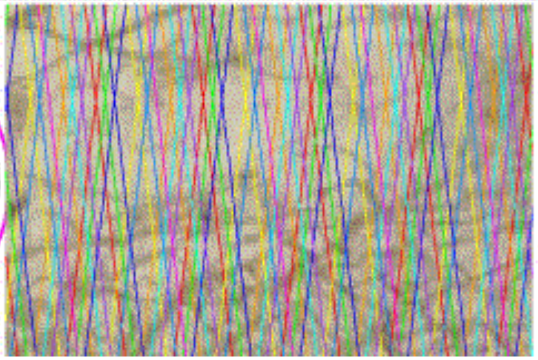
- **10% side-to-side swath overlap**
- **Orbit altitude of 103 km permits ground track near-repeat**
- **1024-pixel line width ~100 m/pixel average resolution across FOV**
- **Wide gap is due to Jupiter occultation; It could be filled through off-nadir pointing**

Laser Altimeter Nadir Track

Each color is 1 eurosol (3.55 days)



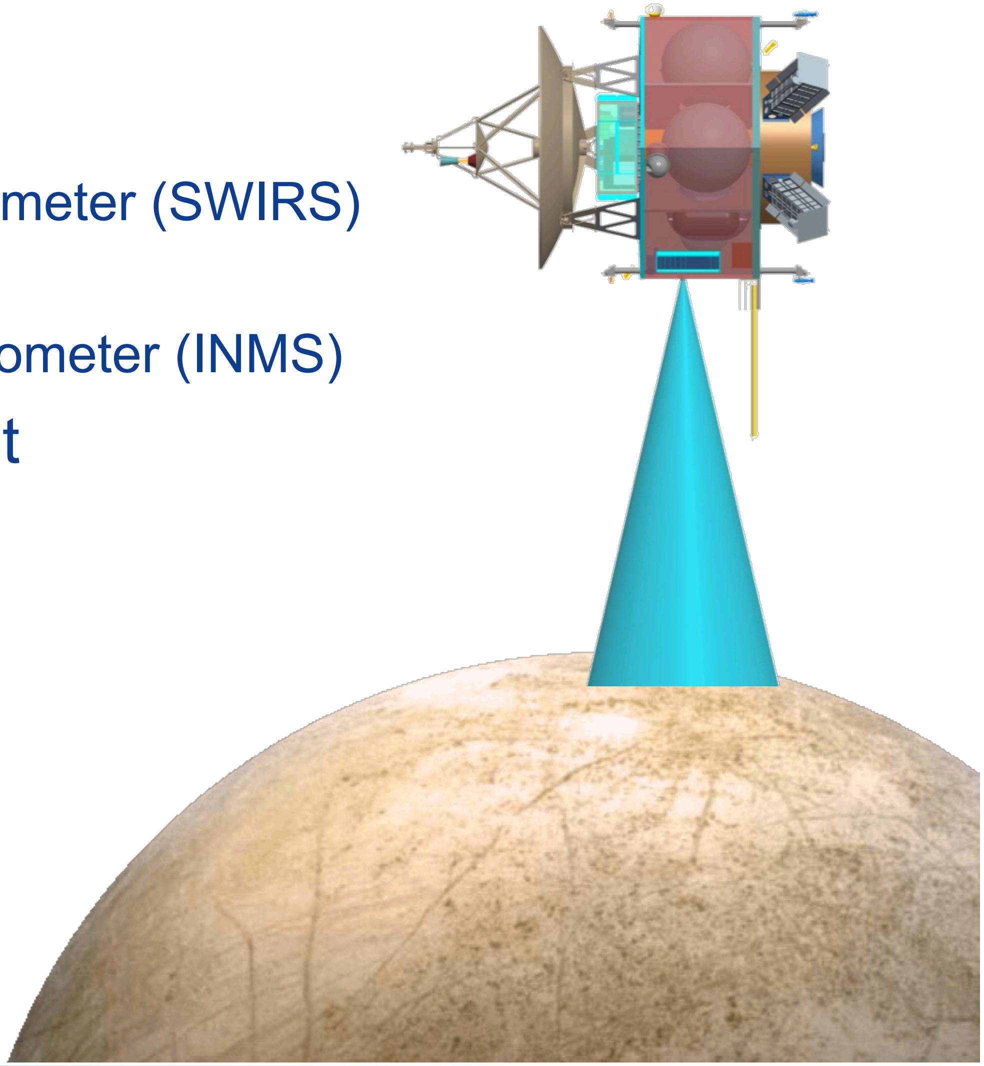




~25 km equatorial spacing of laser profiles after 30 days

Flyby Model Payload: Outline

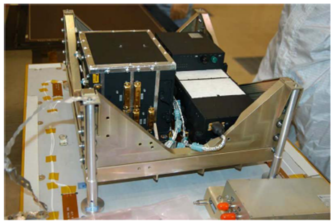
- Model payload instruments
  - Ice Penetrating Radar (IPR)
  - ShortWave InfraRed Spectrometer (SWIRS)
  - Topographical Imager (TI)
  - Ion and Neutral Mass Spectrometer (INMS)
- Science operations concept
- Example coverage



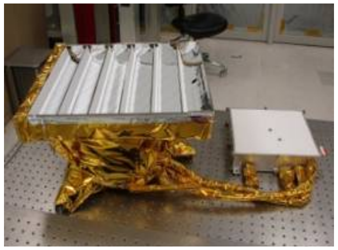
Flyby Model Payload Instruments

- Ice Penetrating Radar (IPR)
  - Dual-frequency sounder
    - 60 MHz with 10 MHz bandwidth (shallow)
    - 9 MHz with 1 MHz bandwidth (deep)
  - Deployed dipole antenna array on 15 m boom
- ShortWave InfraRed Spectrometer (SWIRS)
  - Spectral Range 0.85 – 5.0 µm; Spectral Resolution 10 nm
  - Single optic, single grating spectrometer & HgCdTe detector
  - Scan mirror for Target Motion Compensation
- Topographical Imager (TI)
  - Pushbroom, 4096 pixels width
  - Stereo obtained through along-track overlap
- Ion and Neutral Mass Spectrometer (INMS)
  - Mass Range 1 – 300 Da; Mass Resolution > 500; Sensitivity 10 particles/cm^3

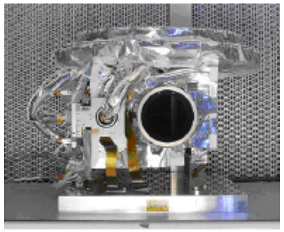
Similar instruments



MRO SHARAD



LRO M^3

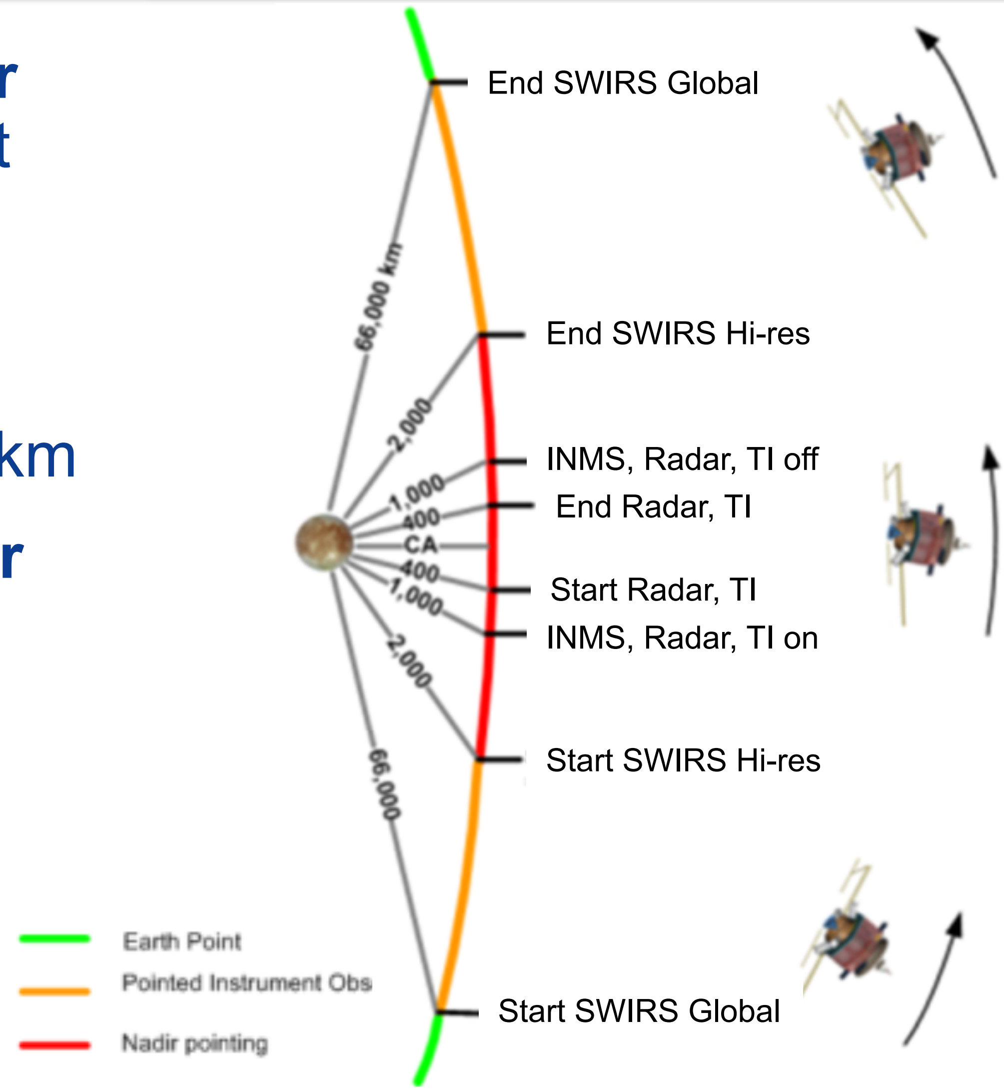


New Horizons Ralph/MVIC

Cassini INMS

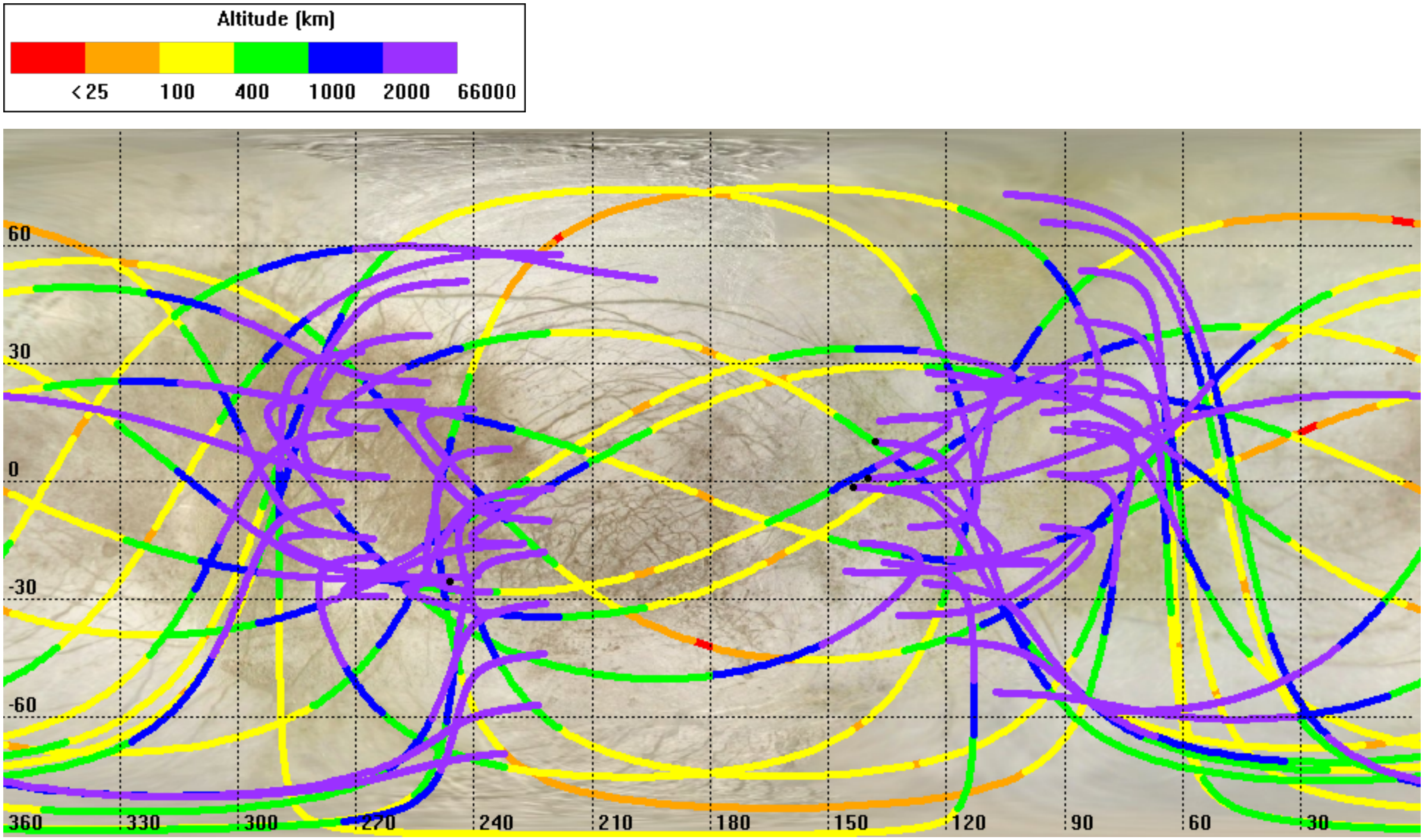
Flyby Science Operations Concept

- **Ice Penetrating Radar** obtains primary data at ≤ 400 km
- **ShortWave InfraRed Spectrometer** obtains data ≤ 66,000 km
- **Topographical Imager** obtains stereo images ≤ 1,000 km
- **INMS** obtains data ≤ 1,000 km, including several ~25 km flybys



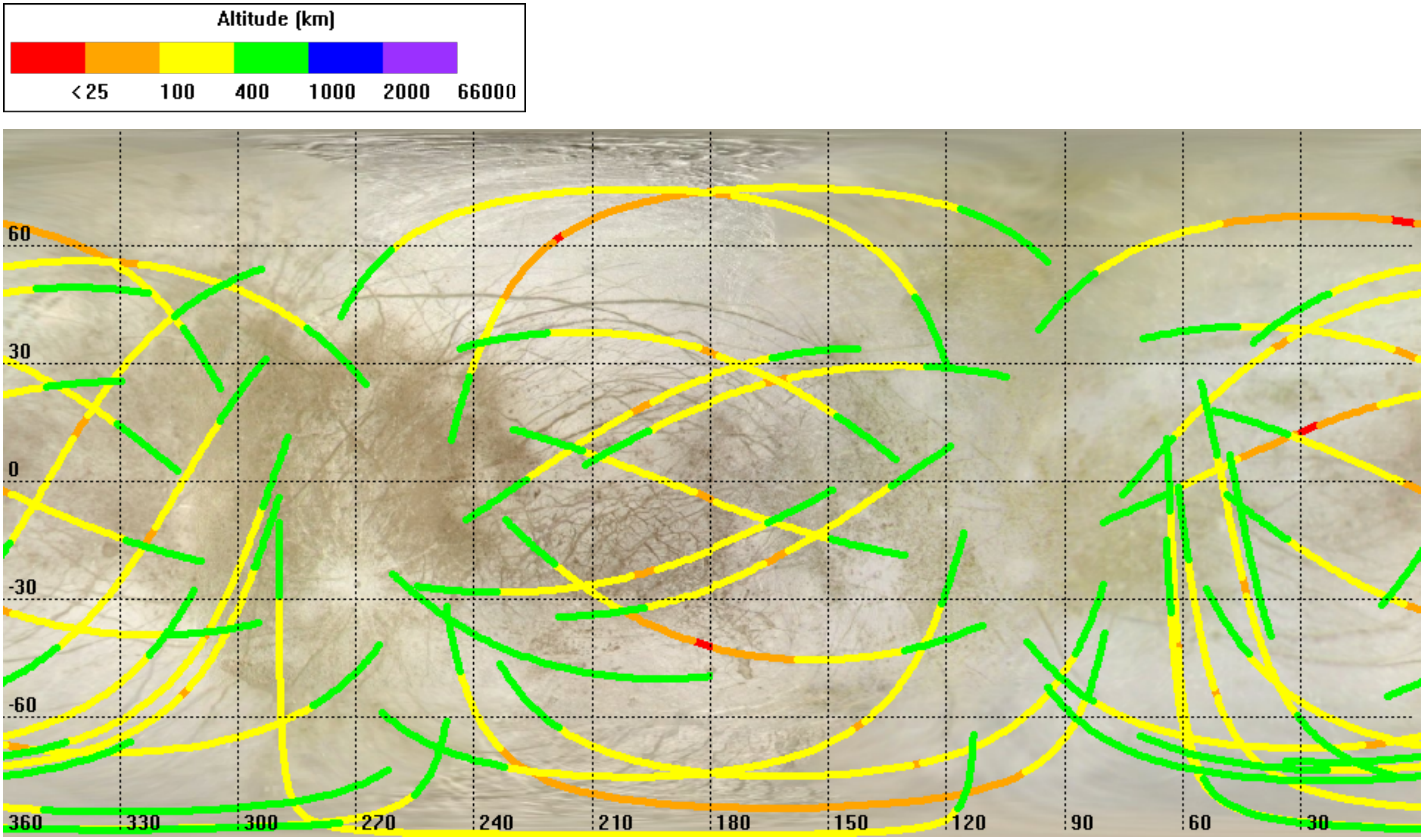
Flyby Ground Tracks

Altitude 25 km – 66,000 km



Flyby Ground Tracks

Altitude < 1,000 km



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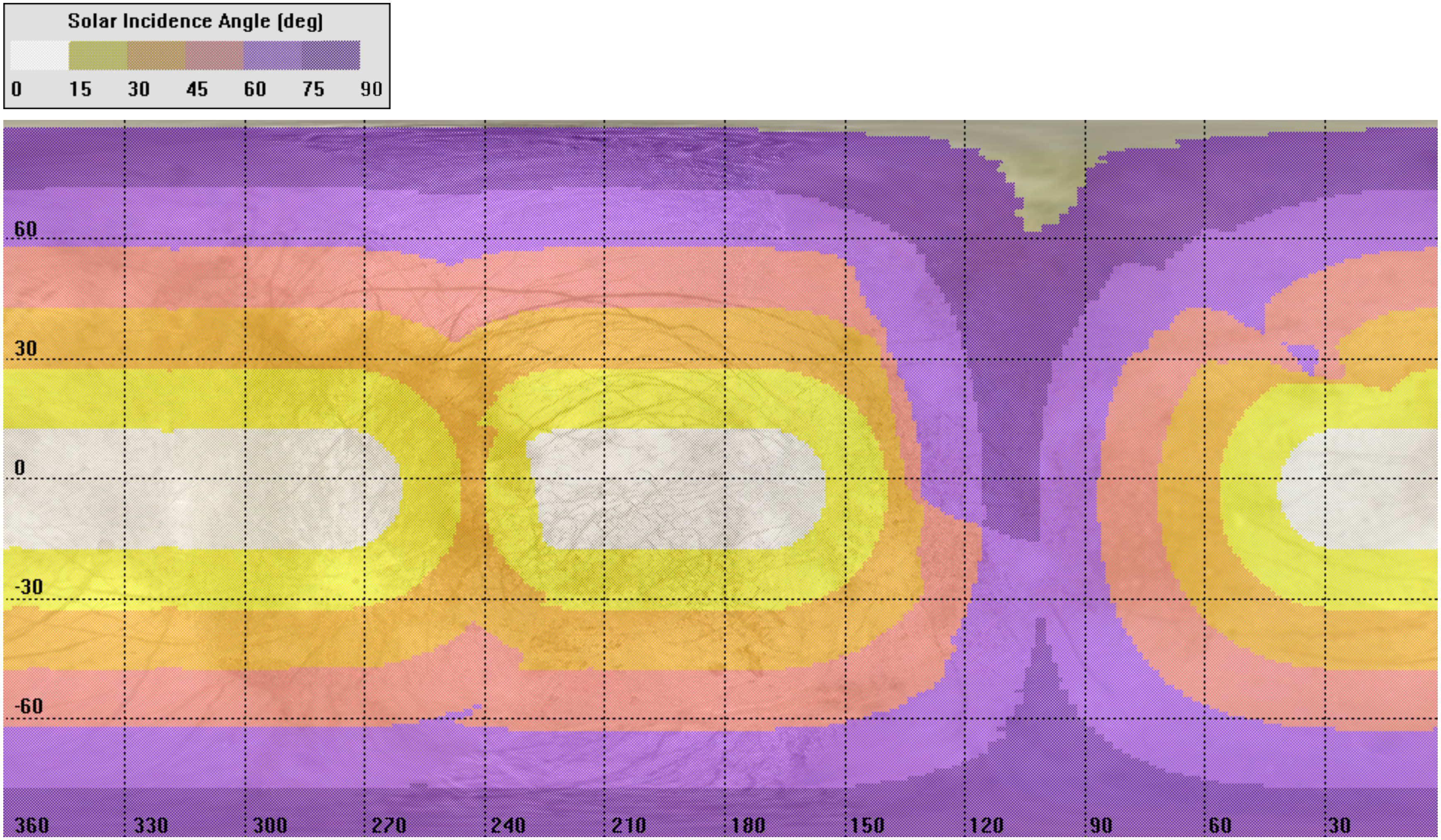
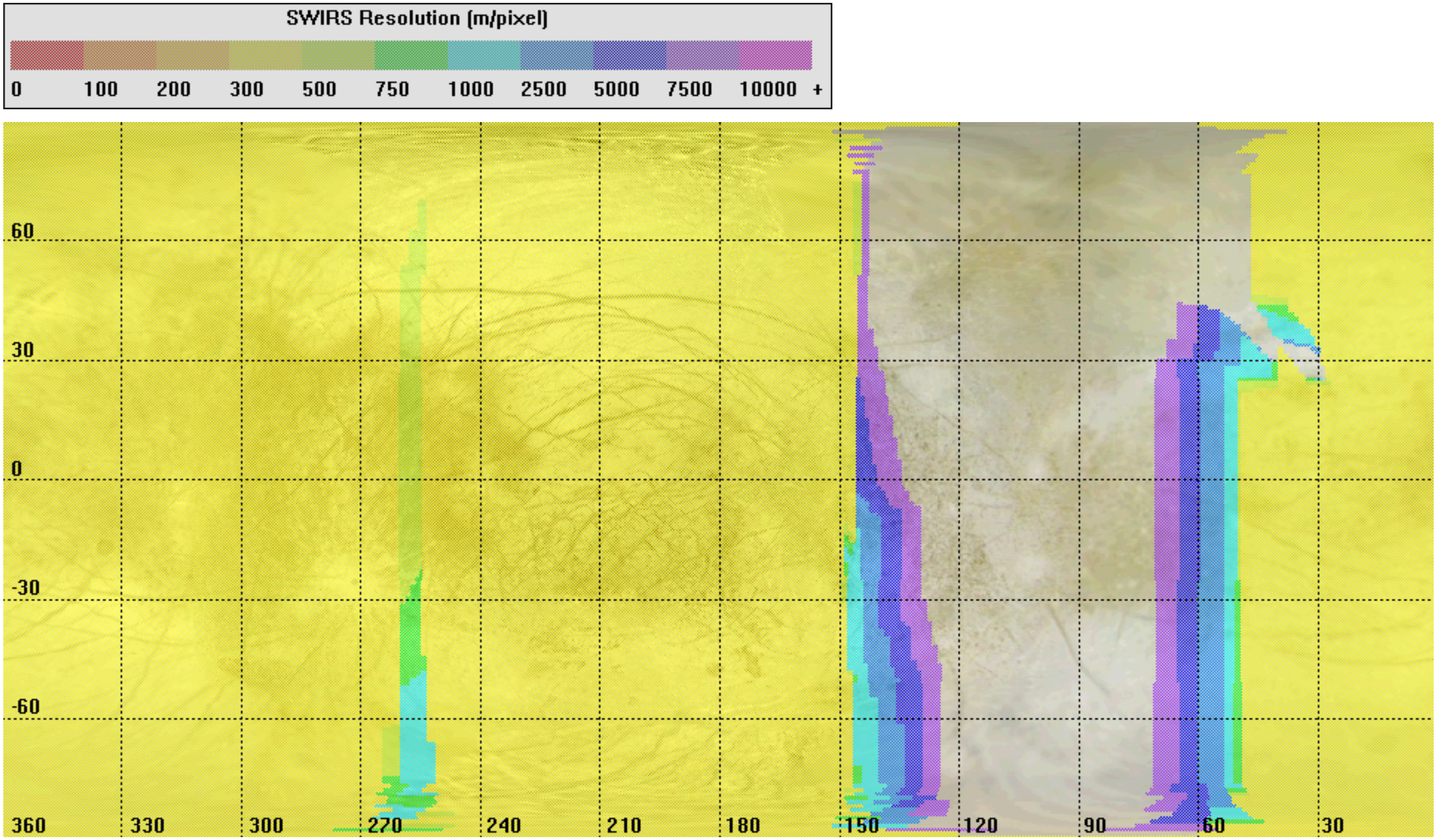
SWIRS Coverage

Solar Incidence Angle, Altitude 2,000 km – 66,000 km



SWIRS Low Resolution Coverage

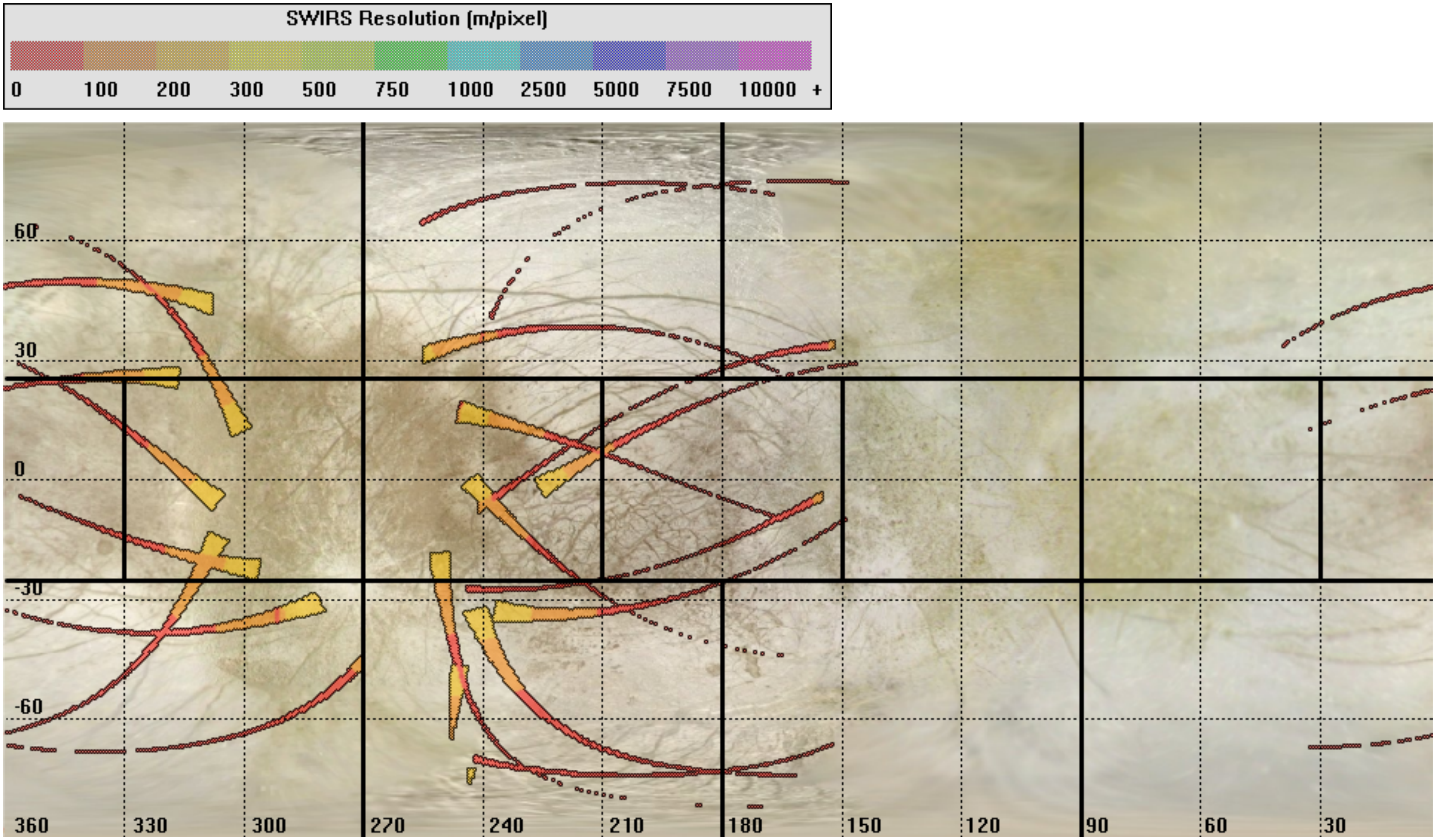
Altitude 2,000 km – 66,000 km



Coverage shown for local true solar times between 9:00am and 3:00pm

SWIRS High Resolution Coverage

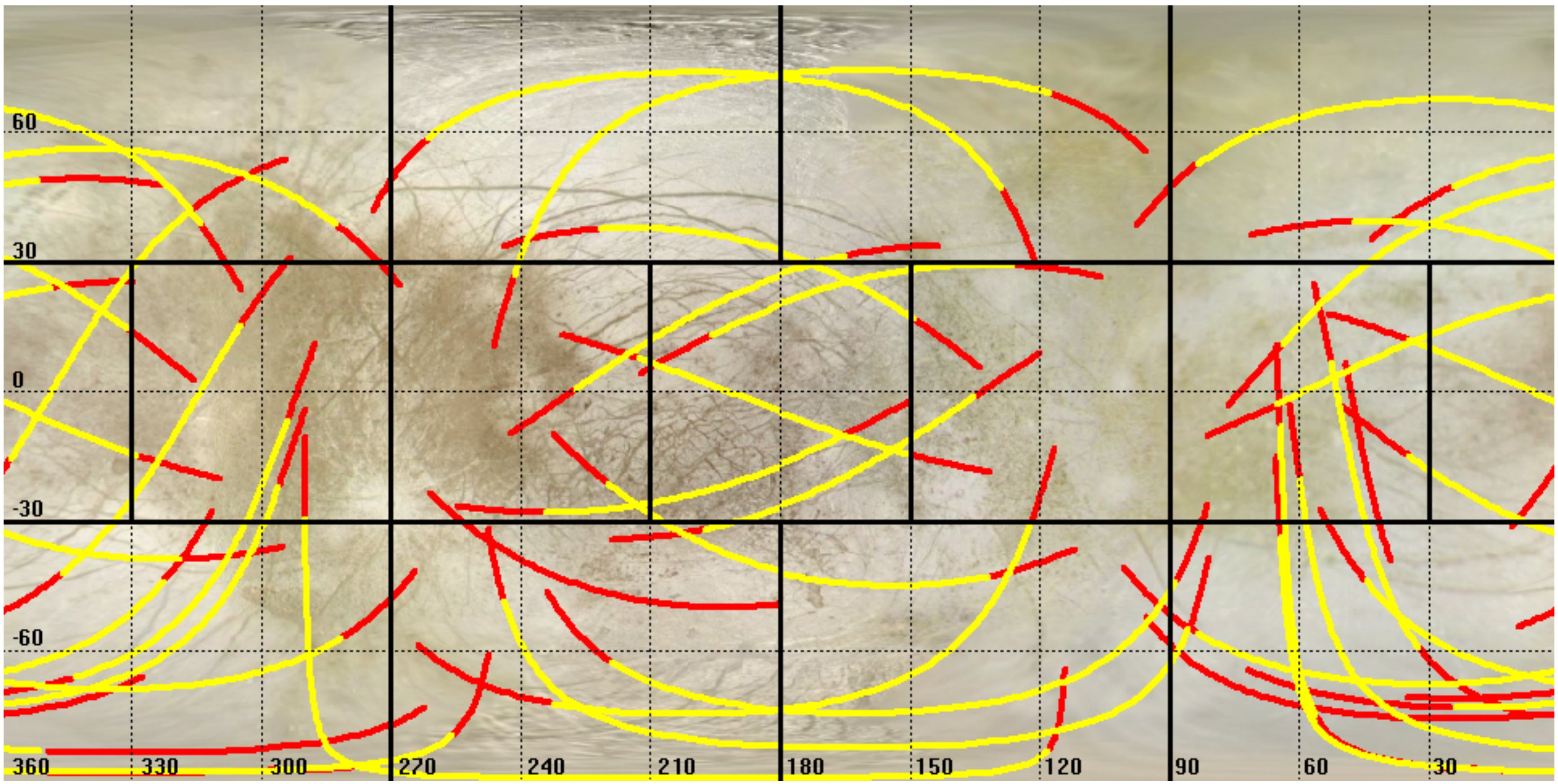
Altitude ≤ 2,000 km



Coverage shown for local true solar times between 9:00am and 3:00pm

IPR Ground Coverage

(yellow line)	25 – 400 km	(primary data collection)
(red line)	400 – 1,000 km	(extended data collection)



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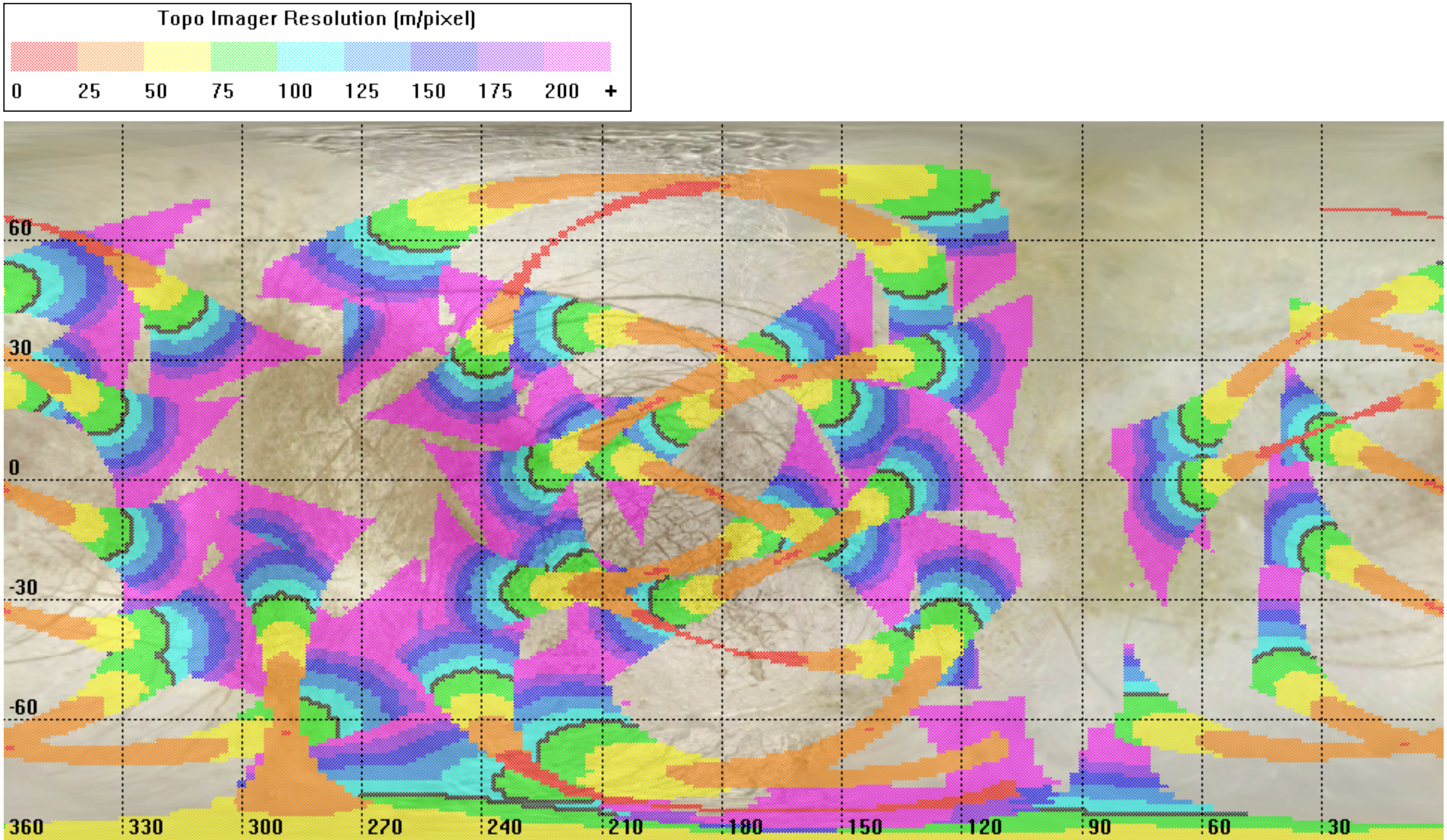
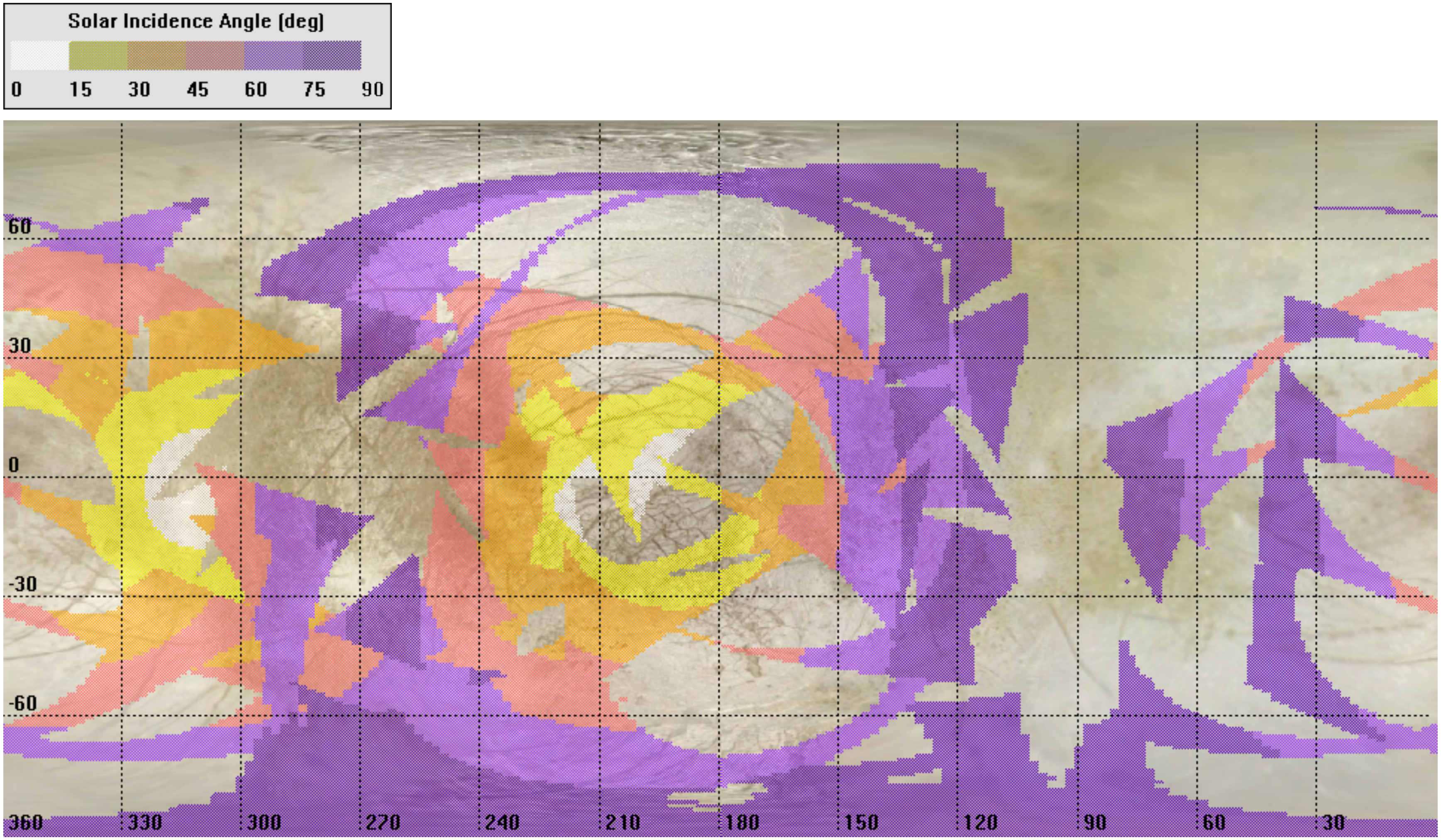
Topo Imager Coverage

Resolution for Altitude ≤ 1,000 km



Topo Imager Coverage

Solar Incidence Angle for Altitude ≤ 1,000 km



Science as a Driver of Mission Architecture

Science traceability leads to a <u>two element</u> mission concept:

***<u>Orbiter Element:</u>* Geophysical measurements that can be achieved only from <u>orbit</u>**

- Science focused primarily to address "Ocean" objective:
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  - Magnetometer (MAG)
  - Langmuir Probe (LP)
  - Mapping Camera (MC)
- Have readily accommodated those instruments that are:
  - Less massive
  - Lower power
  - Lower data rate

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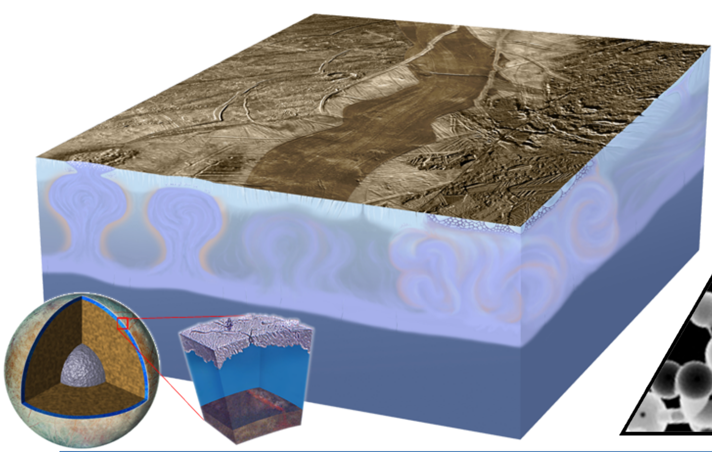
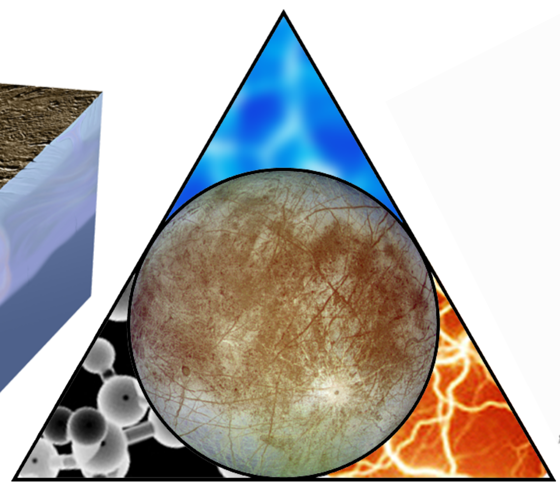
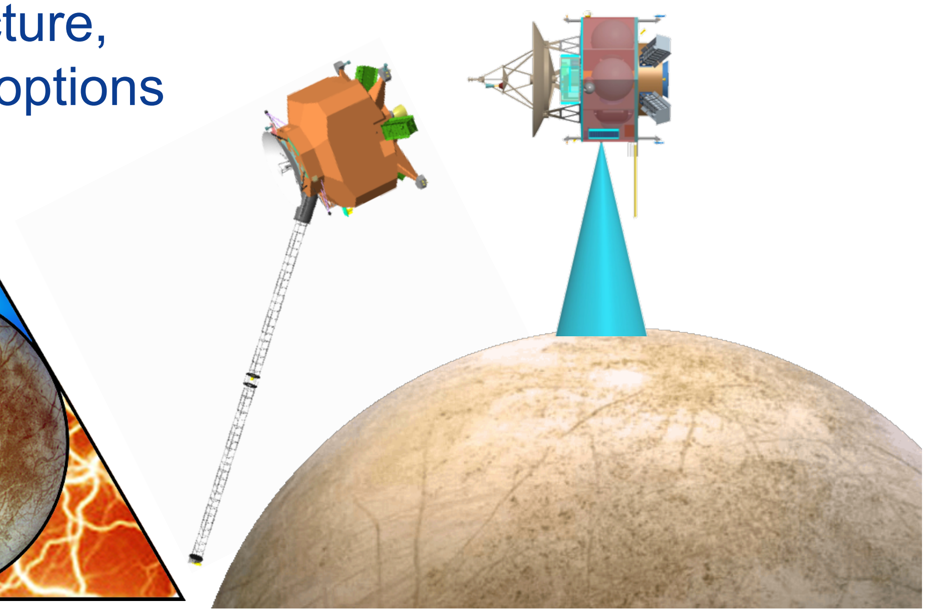
  - Higher data rate

A Pragmatic Path to Europa Exploration

- Pragmatic two-element architecture would fulfill the highest-priority Europa science objectives
  - Orbiter element concentrates on the "Ocean" objective
  - Multiple-flyby element concentrates on the "Chemistry" and "Energy" themes
- Each element has very high science value on its own
- Directly responsive to Decadal Survey's recommendation for Europa
- Scientific priorities drive the architecture, permitting low-cost Europa mission options

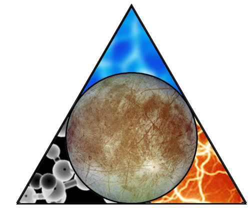






Backup Slides:
Science

Europa Exploration Addresses Decadal Survey Themes



Decadal Survey Theme and Key Questions:			Building New Worlds	Planetary Habitats		Workings of Solar Systems
✓= good, ✓✓= very good, ✓✓✓= excellent			Q2: Planet and satellite accretion and migration	Q4: Organic sources and synthesis	Q6: Modern habitats and life	Q10: Solar system processes and evolution
Goal	**Europa Objective**					
Explore Europa to investigate its habitability	Ocean	Characterize the extent of the ocean and its relation to the deeper interior.	✓	✓✓	✓✓✓	✓✓✓
	Ice Shell	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.		✓✓	✓✓✓	✓✓✓
	Comp'tn	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.		✓✓	✓✓✓	✓✓✓

Europa Science Definition Team

Subgroup Structure

Objectives subgroups:

- **Ocean & Ice:**
  - **Bills**, Barr, Blankenship*, Connerney, Senske, Smith
- **Composition**:
  - **Blaney**, Bagenal, Hoehler, Hand, Shock*, Brinckerhoff, Vance
- **Geology**:
  - **Moore**, Kurth, McGrath, Mellon, Patterson, Prockter*

Cross-Cutting subgroups:

- **Astrobiology**:
  - **Hoehler**, Blankenship, Hand*, McGrath, Senske, Shock
- **Instrumentation**:
  - **Mellon**, Bills, Blaney, Brinckerhoff*, Connerney, Kurth
- **Landing Sites**:
  - **Prockter**, Bagenal, Barr*, Moore, Patterson, Smith, Vance

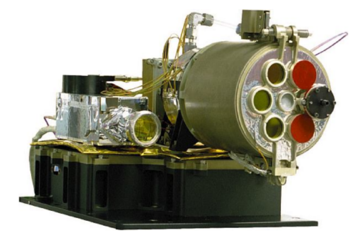
Bold = Lead; * = Deputy Lead

Orbiter: Laser Altimeter
(LA)

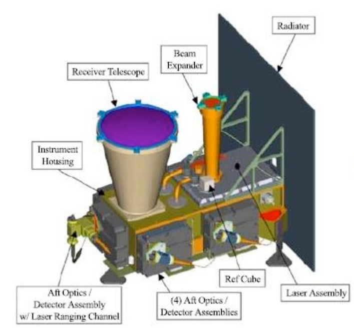
- **Primary Science Investigations**
  - Europa global topography and tidal deformation, rotation state, landform topography
- **Measurement Requirements**
  - Topographic differences to 1 m vertical accuracy at globally distributed crossover points at varying Europa orbital phases; implies surface ranging to 10 cm accuracy
  - Simultaneous ranging with stereo imagery desired
  - Near-polar near-circular orbit at ≤ 200 km altitude
- **Configuration for Model Payload**
  - Time-of-flight rangefinder
  - Transmits 2.7 mJ pulses at 1.064 μm
  - 50 m laser spot from 100 km altitude
  - Receiver telescope aperture of 12.5 cm diameter provides good SNR from 100 km altitude
  - Avalanche photodiode detector (radiation shielded)
  - 26 Hz pulse rate yields 50 m spot spacing
  - Nadir view co-boresighted with camera; minimize thruster contamination
  - Mounted on 2-axis gimbal platform (assuming simultaneous ranging and downlink over fixed-mounted HGA from mid-afternoon orbit)

Similar instruments

MESSENGER MLA



NEAR NLR



LRO LOLA

Orbiter: Radio Subsystem
(RS)

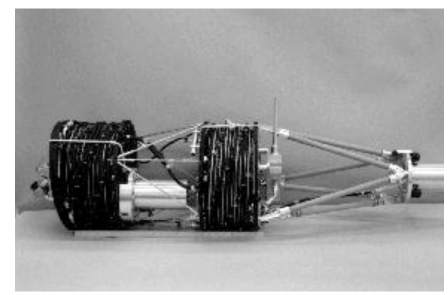
- **Primary Science Investigations**
  - Europa static gravity field and gravitational and tides
- **Measurement Requirements**
  - Degree-2 time-dependent gravity field, to recover k_2 amplitude at Europa's orbital frequency to ≤ 0.003 absolute accuracy and phase to ≤ 1°
  - Europa position wrt Jupiter to ≤ 10 m throughout orbital mission
  - Europa static gravity field resolved to degree and order 30
    - Range-rate to < 0.1 mm/s at 60 s integration time
    - S/C orbit determination about Europa to accuracy of < 1 m (rms) in radial direction
  - Near-polar near-circular orbit at ≤ 200 km altitude for ≥ 30 days
  - Data arcs over several "unperturbed" days
  - Range-rate measurements over several Europa tidal cycles
- **Configuration for Model Payload**
  - X-band up and down; Ka-band down only
  - Ka Transponder/Hybrid Diplexer
  - USO not required

Orbiter: Magnetometer
(MAG)

- **Primary Science Investigations**
  - Europa magnetic induction response
- **Measurement Requirements**
  - 3-axis magnetic field components at 8 Hz, 8 vectors/s
  - Sensitivity of 0.1 nT
  - Near continuous measurements
  - Near-polar near-circular orbit at ≤ 200 km altitude for ≥ 30 days
- **Configuration for Model Payload**
  - Dual 3-axis fluxgate
  - Sensitivity 0.1 nT
  - Maximum sampling rate 32 Hz; sampling resolution 0.01 nT
  - Sensors on boom 5 m and 10 m from S/C
  - Spacecraft cleanliness of 0.1 nT desired, 0.5 nT required at outboard sensor
  - Periodic S/C slow spins about two orthogonal axes for calibration

Similar instruments

MESSENGER MAG

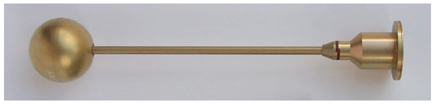


Galileo MAG

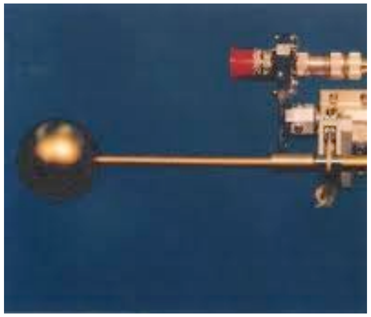
Orbiter: Langmuir Probe
(LP)

- **Primary Science Investigations**
  - Europa ionospheric plasma effects on magnetic induction response
- **Measurement Requirements**
  - Local plasma density, temperature, and flow
  - Electric field (near DC to 3 MHz)
  - Electron temperature
  - Ion currents
  - 4π coverage
  - Map approximately 12 hours of Europa local time
  - Near-polar near-circular orbit at ≤ 200 km altitude for ≥ 30 days
- **Configuration for Model Payload**
  - Two 5 cm diameter spheres mounted on 1 m long booms
  - Booms pointed > 90° from each other, desire one always free of S/C wake
  - Electronics (including pre-amp) in S/C vault < 3 m from sensors
  - EMI/EMC cleanliness like Rosetta and/or Cassini

Similar instruments



Rosetta LAP

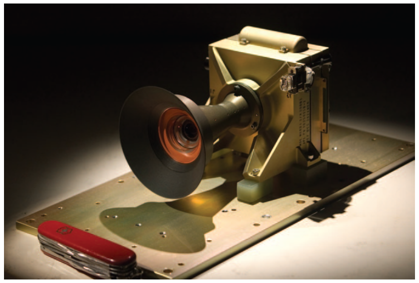


Cassini RPWS

Orbiter: Mapping Camera
(MC)

- **Primary Science Investigations**
  - Landform mapping, Europa rotation state, and surface/subsurface material exchange
- **Measurement Requirements**
  - ≥ 80% global mapping at ≤ 100 m/pixel
  - 30 m vertical resolution topo, ≤ 300 m horizontal footprint resolution
  - Incidence angle > 45° (70° preferred)
  - Near-polar near-circular orbit with consistent lighting
- **Configuration for Model Payload**
  - Pushbroom imager; 1024 pixel CMOS or CCD line array
  - 5 separate line arrays in focal plane (radiation shielded)
    - 4 nadir viewing: panchromatic, 0.56, 0.76, 0.99 μm bands
    - 1 panchromatic viewing ~40° forward or aft for stereo
  - IFOV = 0.85 mrad; FOV = 50°
    - 85 m/pixel at nadir from 100-km orbit altitude
    - 94 km wide swath (~3.4° of longitude at the equator)
    - 63 ms for 1 pixel of smear in 100 km orbit, providing good SNR
  - Can elect to operate color and stereo bands, or not
  - Loose pointing requirements (~2° accuracy; 5 mrad/s stability)
  - Mounted on 2-axis gimbal platform (permits simultaneous imaging and HGA downlink)
  - Small radiator with view to dark space

Similar instruments



MRO MARCI

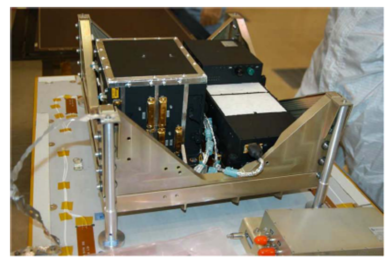
MPL/MSL MARDI

Flyby: Ice Penetrating Radar
(IPR)

- **Primary Science Investigations**
  - Characterize distribution of shallow subsurface water and structure of ice shell
  - Search for an ice-ocean interface
  - Correlate surface features, subsurface structures, and geological processes
- **Measurement Requirements**
  - Shallow Mode: 10 m vertical resolution; 100 m to 3 km depth
  - Deep Mode: 100 m vertical resolution; 1 km to 30 km depth
  - Globally distributed intersecting and adjacent swaths, in 11 of 14 “panels”
  - Supporting requirements:
    - Nadir altimetry, 10 m vertical resolution
    - Cross-track surface topography (stereo imaging), 100 m vertical res
- **Configuration for Model Payload**
  - Dual-frequency sounder
    - 60 MHz with 10 MHz bandwidth (shallow)
    - 9 MHz with 1 MHz bandwidth (deep)
  - Deployed dipole antenna array on 15 m boom
  - Range compression, pre-summing, Doppler filtering, data averaging, resampling in S/C electronics

Similar instruments

Mars Express MARSIS



MRO SHARAD

Flyby: ShortWave InfraRed Spectrometer
(SWIRS)

- **Primary Science Investigations**
  - Characterize surface composition for representative landforms
  - Characterize exogenic materials
- **Measurement Requirements**
  - Spectral Range — 850 nm – 5.0 µm
  - Spectral Resolution — 10 nm
  - Spectral Channels — 420
  - Spatial Resolution — 300 m @ 2000 km (IFOV = 150 µrad)
  - Image Width — 480 pixels (4.2°)
  - Signal to Noise — ~ 100 at 5 µm (TMC 8), 18 at 5 µm (TMC 1)
  - Exposure time — ~ 1 s / row (TMC 8) [7.7 min for full image], 0.12 s / row (TMC 1)

Similar instruments

LRO M^3

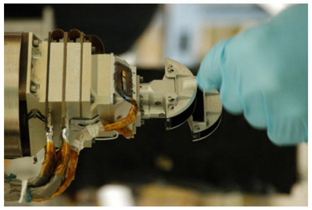
- **Configuration for Model Payload**
  - Implementation of 4 scans for each flyby: 2 @ 10 km/pixel (s/c slew) and 2 < 300 m/pixel (scan mirror, s/c tracking nadir)
  - Single optic, single grating spectrometer & HgCdTe detector; TMC (scan mirror)
  - Passive detector and spectrometer cooling
  - Detector radiation noise (for TMC 8, 4% pixels are hit @ 9.5 cm tantalum shielding; for TMC 1, 4% pixels are hit @ ~3 cm Ta); calculation for worst case 0° inclination

Flyby: Topographical Imager
(TI)

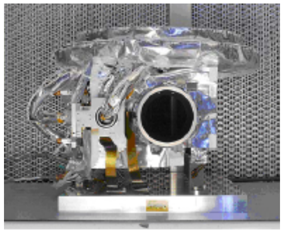
- **Primary Science Investigations**
  - Removal of radar returns from off-nadir surface topography
  - High-resolution stereo imaging of landforms for geology
- **Measurement Requirements**
  - Spectral Range   visible
  - Spectral Bands   monochromatic
  - FOV   58° (for stereo separation)
  - Image Width @ C/A   100 km (matches width of radar swath)
  - Signal to Noise   ≥ 100
- **Configuration for Model Payload**
  - Pushbroom operation
  - Stereo obtained through along-track overlap with ~ 50 m vertical resolution
  - Image width   4096 pixels
  - Spatial Resolution   25 m @ 100 km alt (250 μrad iFOV) (6.2 m @ 25 km alt)
  - SNR   ~ 100 @ 100 km alt (can increase to ~400 using TDI)
    ~ 27 @ 25 km alt (with TDI, can get up to ~ 100)
  - Exposure times   5.5 ms for 1 pixel of smear @ 100 km alt
    1.4 ms for 1 pixel of smear @ 25 km alt
  - Radiation noise (% of pixels hit with electrons/1 cm Ta detector shielding) 0.5%

Similar instruments

MESSENGER MDIS



MRO MARCI

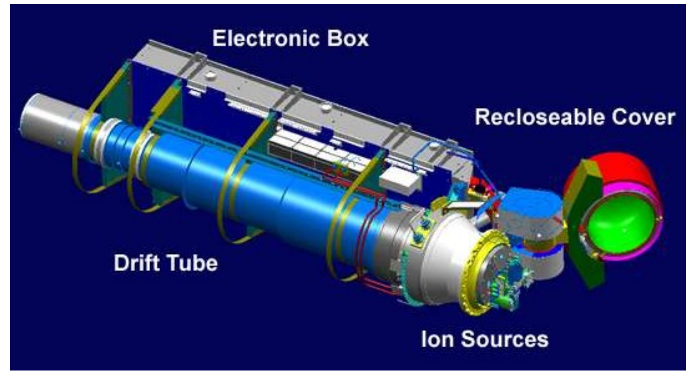


New Horizons Ralph/MVIC

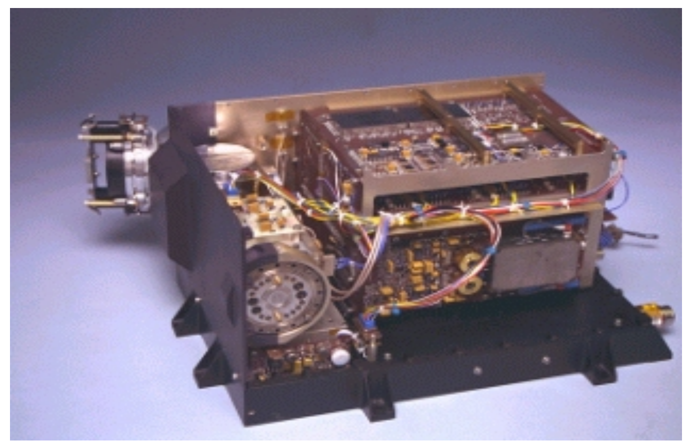
Flyby: Ion and Neutral Mass Spectrometer (INMS)

- **Primary Science Investigations**
  - Elemental, isotropic and molecular composition of Europa's atmosphere and ionosphere
- **Measurement Requirements**
  - Mass Range — 1 – 300 Daltons
  - Mass Resolution — > 500
  - Sensitivity — 10 particles/cm^3
  - Field of View — 60 degree clear input
- **Configuration for Model Payload**
  - Ram pointed inlet
  - Remote electronics
  - One-time opening cover
- **Note on Sensitivity and Resources**
  - We solicited input from INMS providers to understand the limits on sensitivity and detection of minor species during fast flybys

Similar instruments



Rosina RTOF



Cassini INMS