EIS EUROPA IMAGING SYSTEM

High-Resolution, 3-D Insight into Europa's Ice Shell and Potential for Current Activity

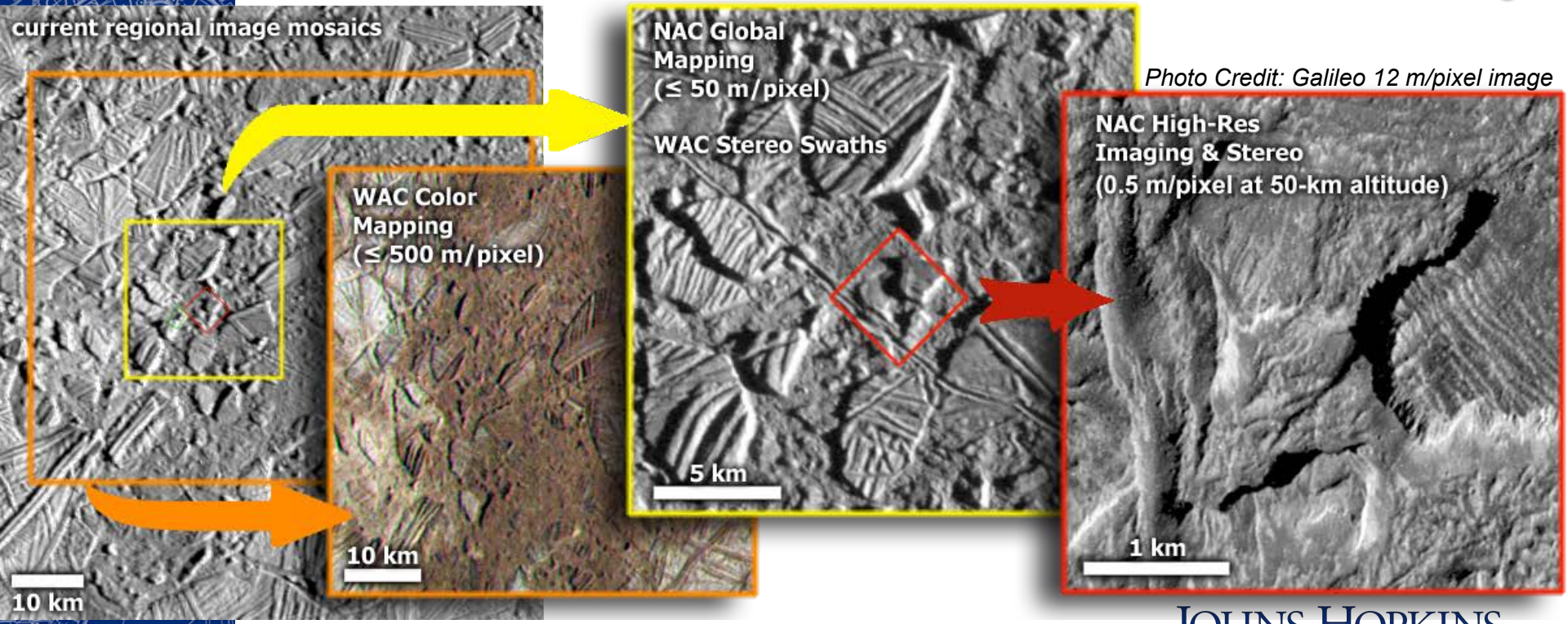

Photo Credit: Galileo 12 m/pixel image

24 August 2015

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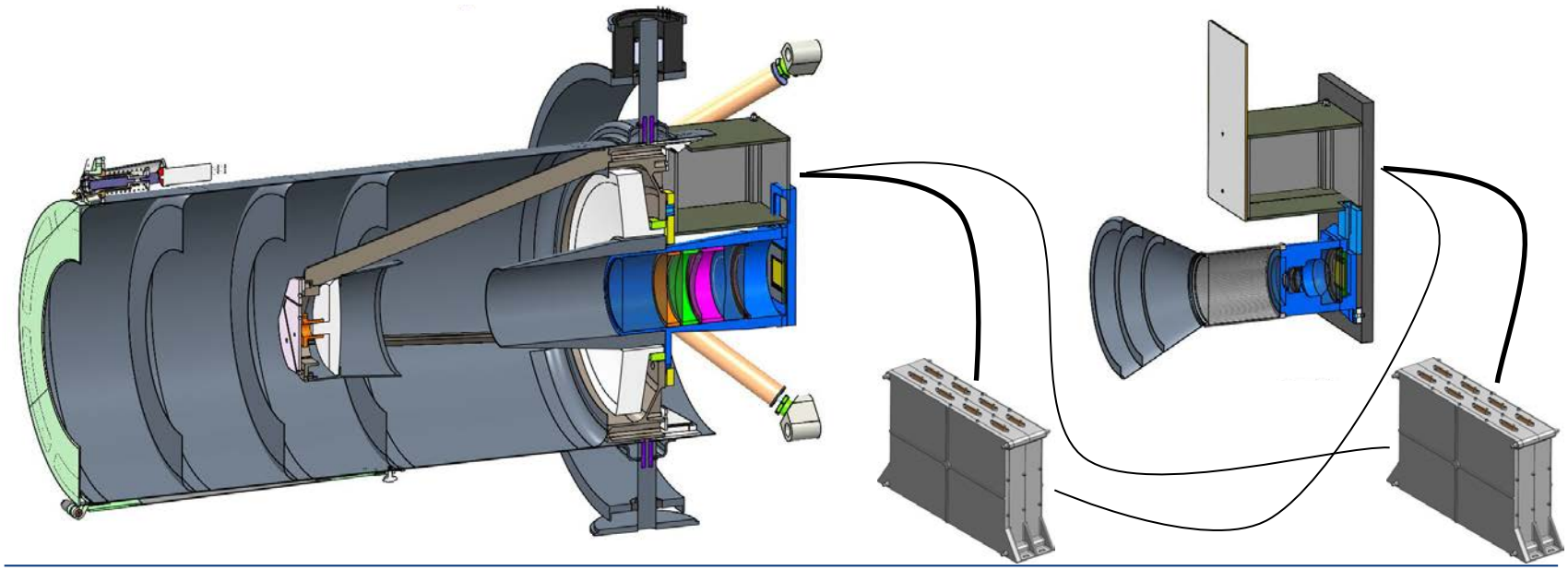
Science & reconnaissance objectives

- **A. Ice Shell and Ice-Ocean Interface**
  - **A.1 Constrain the thickness and nature of the ice shell.**
  - **A.2 Correlate surface features and subsurface structure to investigate surface – ice shell – ocean exchange processes and recent activity.**
- **B. Geologic Structures and Processes**
  - **B.1 Characterize endogenic structures, surface units, and relationships to Europa's subsurface and potential subsurface water, and identify recent geologic activity.**
  - **B.2 Constrain formation processes, 3D structures, and history of Europa's diverse geologic landforms**
- **R. Characterize Scientifically Compelling Landing Sites and Hazards**

Dual-camera imaging system

- **Narrow-Angle Camera (NAC)**
  - FOV: 2.3° cross-track x 1.2°along-track
  - IFOV: 10 µrad
  - Aperture: 152 mm
  - Focal length: 1000 mm
  - Targeting capability: 2-axis ±30° gimbal
- **Wide-Angle Camera (WAC)**
  - FOV: 48° cross-track x 24° along-track
  - IFOV: 218 µrad
  - Aperture: 8 mm
  - Focal length: 46 mm
  - Color capability: 6 stripe filters



Dual-camera imaging system

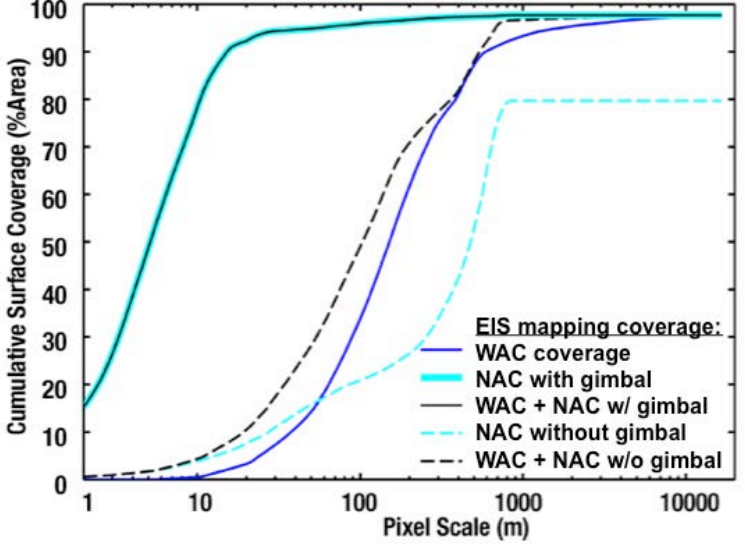
- Narrow-Angle Camera (NAC) provides very high-res, stereo reconnaissance
  - 2-km-wide swaths at 0.5-m pixel scale during flybys at 50-km altitude
- 2-axis gimbal enables independent targeting without s/c pointing:
  - Near-global mapping at ≤50-m pixel scale
  - Regional and high-resolution stereo imaging
  - High-phase-angle observations for plume searches
- Wide-Angle Camera (WAC) field of view designed to acquire along-track pushbroom stereo swaths: 32-m/DTM pixel, 4-m vertical precision @ 50 km
- WAC supports characterization of cross-track clutter for radar sounding
- WAC pushbroom color imaging with 6 filters (350-1050 nm) to map surface units and correlations with geologic features and topography
- Identical 4096 cross-track x 2048 along-track CMOS detectors
  - Rad-hard, eliminating significant charge-transfer efficiency degradation
  - Fast readout, framing & pushbroom – flyby, minimize radiation-induced noise
- Identical rad-hard DPUs, cross-strapped for redundancy

Dual-camera imaging system to achieve Decadal Survey Europa science & recon goals

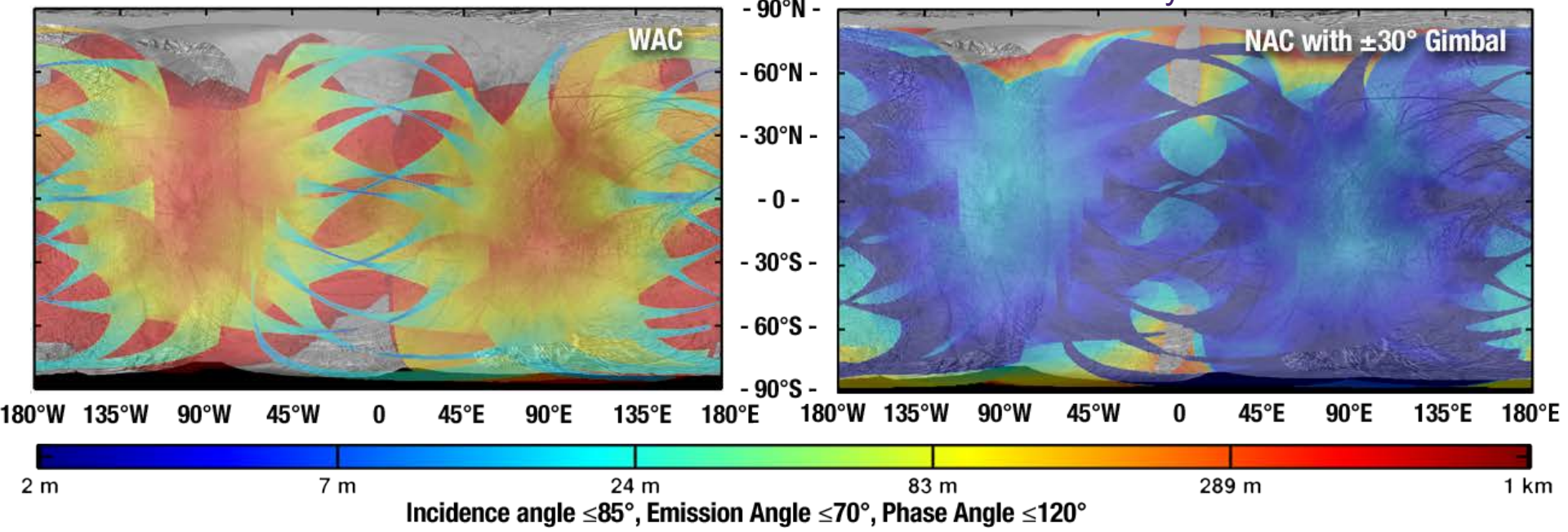
- **Understand formation of landforms and potential for current activity**
  - Near-global mapping at ≤50 m/pixel to characterize endogenic landforms and global cross-cutting relationships
  - High-resolution (0.5-25 m/pixel) imaging and stereo of key features
  - Topographic swaths to characterize clutter for ice-penetrating radar
  - Color photometry (surface and potential plumes) and high-resolution imaging to identify sites of current or recent activity
- **Characterize ice shell and ice-ocean interface**
  - Geodesy to constrain ice-shell thickness & ice-ocean interface
- **Perform reconnaissance**
  - Targeted ≤1-m/pixel images and stereo; ≤11 m/pixel stereo/color context

Observation highlight

- **Understand formation of landforms and potential for current activity**
  - **Near-global mapping at ≤50 m/pixel to characterize endogenic landforms and global cross-cutting relationships**

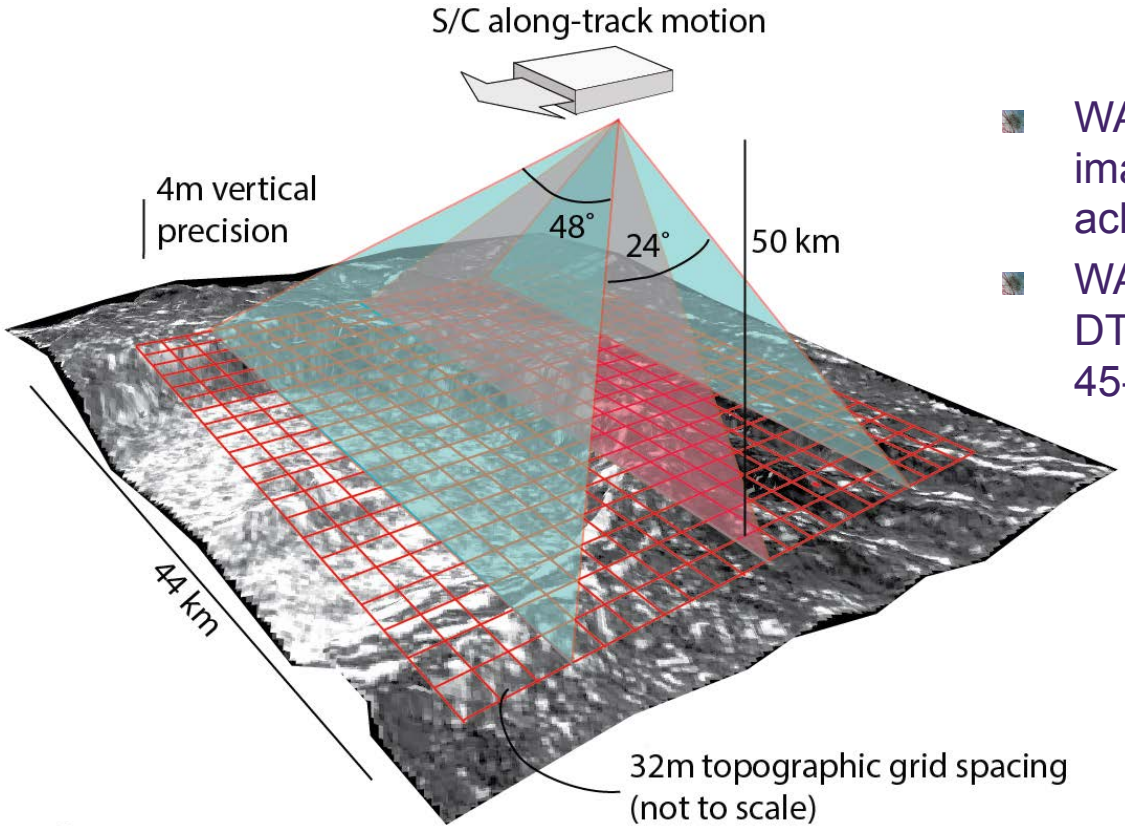


- WAC ground-track coverage (tour 13F7) including pushbroom stereo and color
- NAC maps >95% of Europa at ≤50 m/pixel
- NAC with 2-axis gimbal can image a 2.3° swath within and beyond WAC 48° FOV



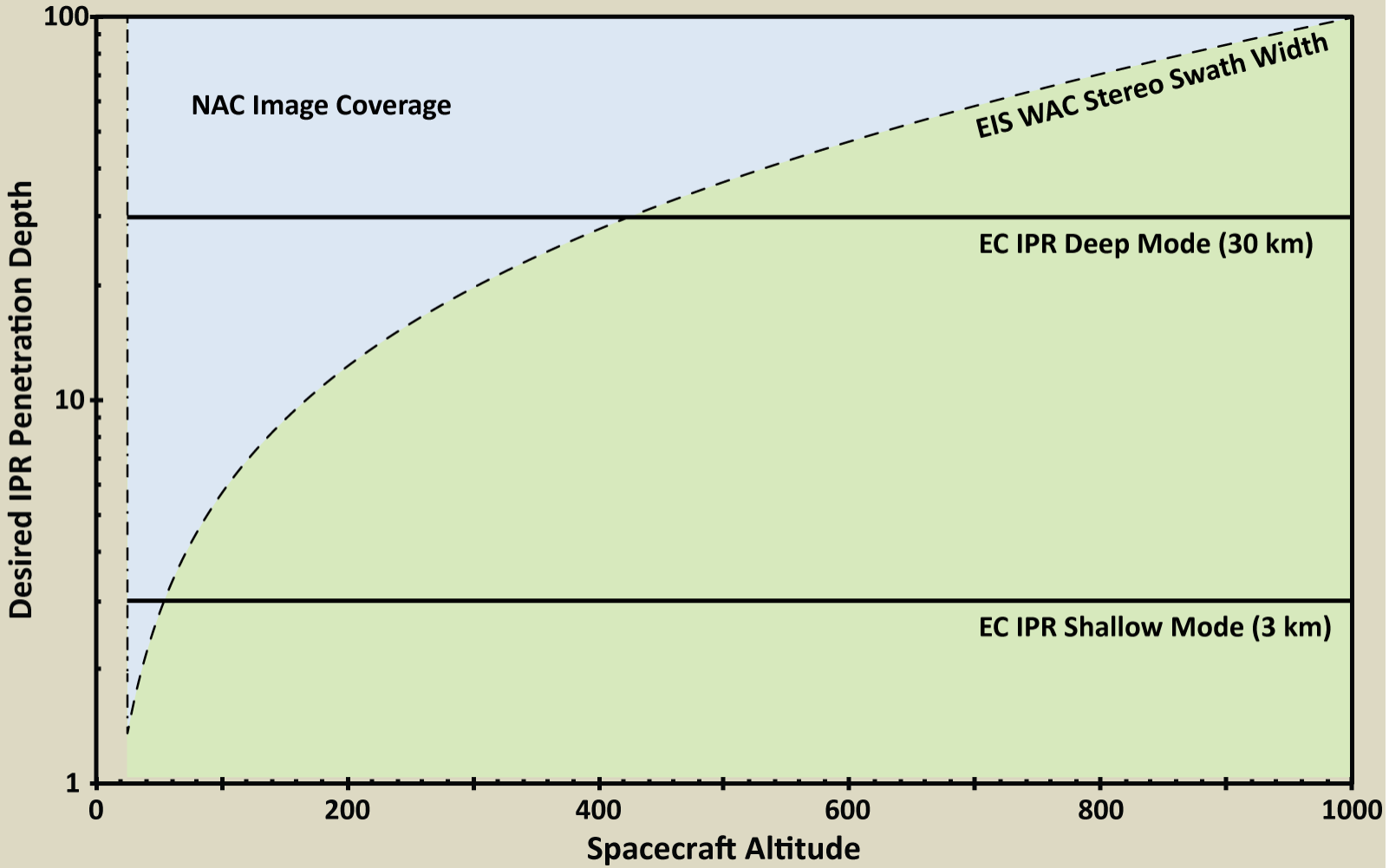
Observation highlights

- **Understand formation of landforms and potential for current activity**
  - **High-resolution (0.5-25 m/pixel) imaging and stereo of key features**
  - **Topographic swaths to characterize clutter for ice-penetrating radar**
- **Perform reconnaissance**
  - **Targeted ≤1-m/pixel images and stereo; ≤11 m/pixel stereo/color context**



- WAC performs 3-line pushbroom stereo imaging, with 24° along-track FOV to achieve stereo convergence angle
- WAC DTMs along ground tracks: 32-m/DTM pixel, 4-m vertical precision, and 45-km swath width at 50-km altitude

EIS and ice penetrating radar (IPR)



Maximum penetration depth d (km) for which EIS characterizes surface clutter as a function of s/c altitude (km) compared to penetration depths of EC IPR deep and shallow modes (n=1.78).

Observation highlights

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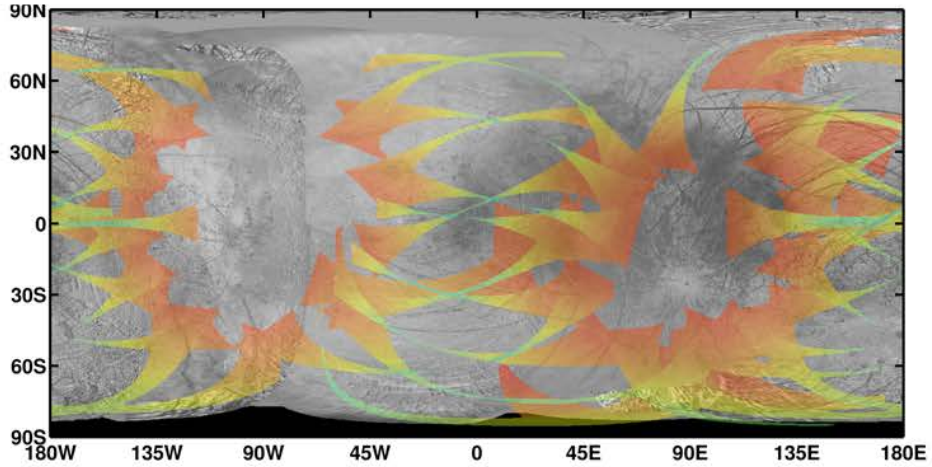
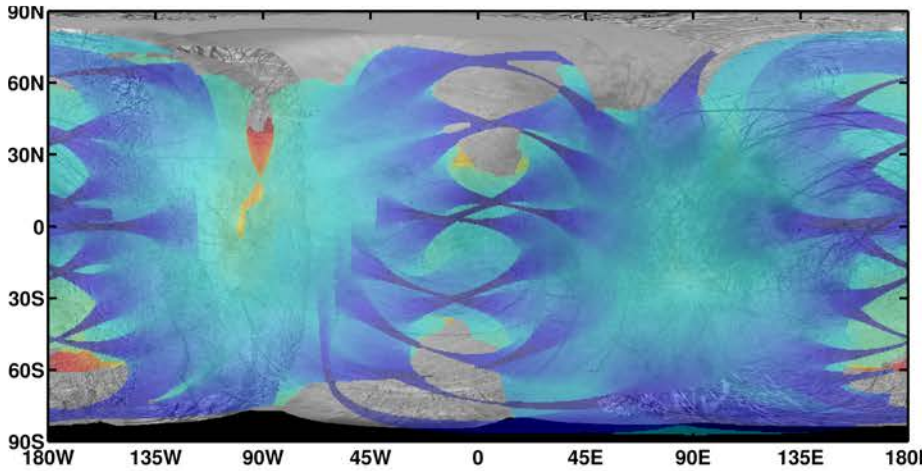
  - **High-resolution (0.5-25 m/pixel) imaging and stereo of key features**
  - **Topographic swaths to characterize clutter for ice-penetrating radar**
- **Perform reconnaissance**
  - **Targeted ≤1-m/pixel images and stereo; ≤11 m/pixel stereo/color context**

- WAC ground-track stereo coverage (tour 13F7), color coded by vertical precision



- Areas accessible (tour 13F7) for NAC stereo imaging, color coded by vertical precision

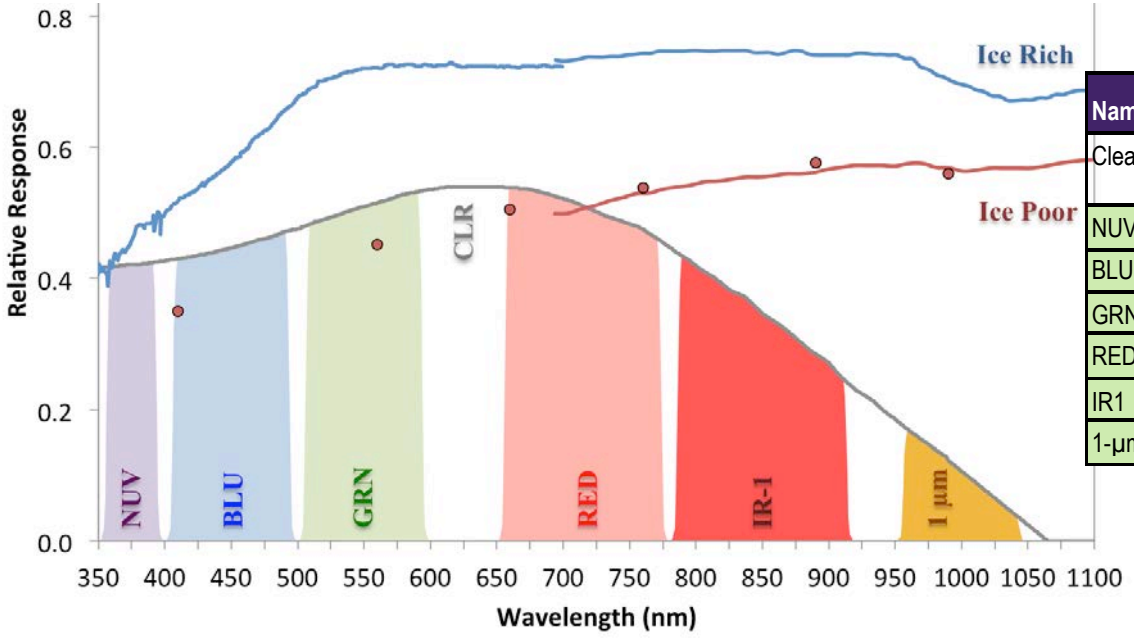


Space APL

Observation highlights

- **Understand formation of landforms and potential for current activity**
  - **Color photometry (surface and potential plumes) and high-resolution imaging to identify sites of current or recent activity**

- WAC performs color pushbroom imaging along ground tracks: 11 m/pixel across 45-km swath width at 50-km altitude
- EIS response functions under system response curve, with Europa spectra: ice-rich ≤700 nm (Spencer et al. 1995); ice-poor ≤700 nm (B. Clark et al. 1998); ≥700 nm (Carlson et al. 2009; McCord et al. 2010)



Name	λ (nm)	Key Purposes
Clear*	350-1050 (NAC, WAC)	Surface observations, stereo, context imaging, best SNR for faint targets (e.g. plume searches)
NUV	350-400	Surface color; plumes with Rayleigh scattering
BLU*	400-500	Surface color; Rayleigh scattering (with NUV), *Galileo*
GRN*	500-600	Surface color; airglow (eclipse, nightside); *Galileo*
RED*	650-780	Surface color; *Galileo*
IR1	780-920	Surface color; continuum for H_2O band
1-µm*	950-1050	Surface color, coarse-grained ice H_2O band; *Galileo*

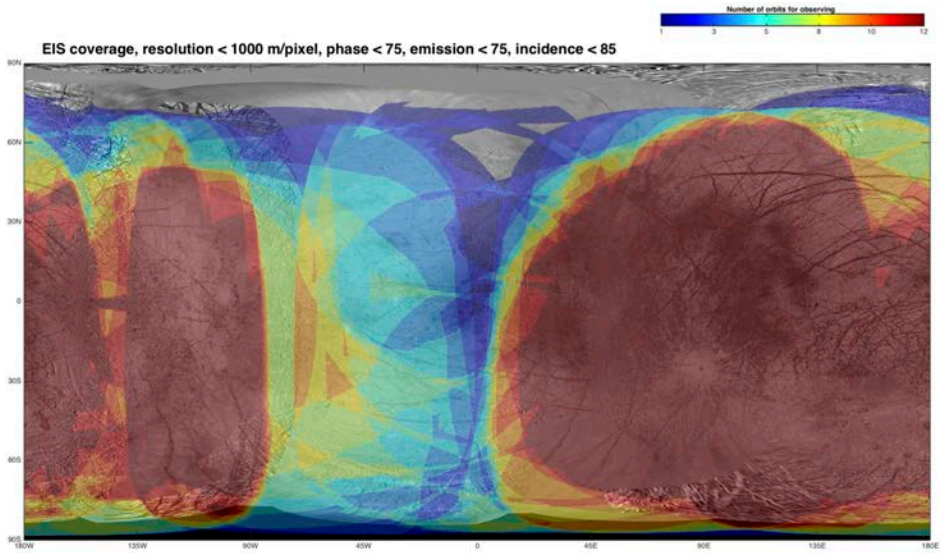
- EIS bandpasses; *Comparable filter on *Galileo* SSI (Belton et al. 1992) for change detection

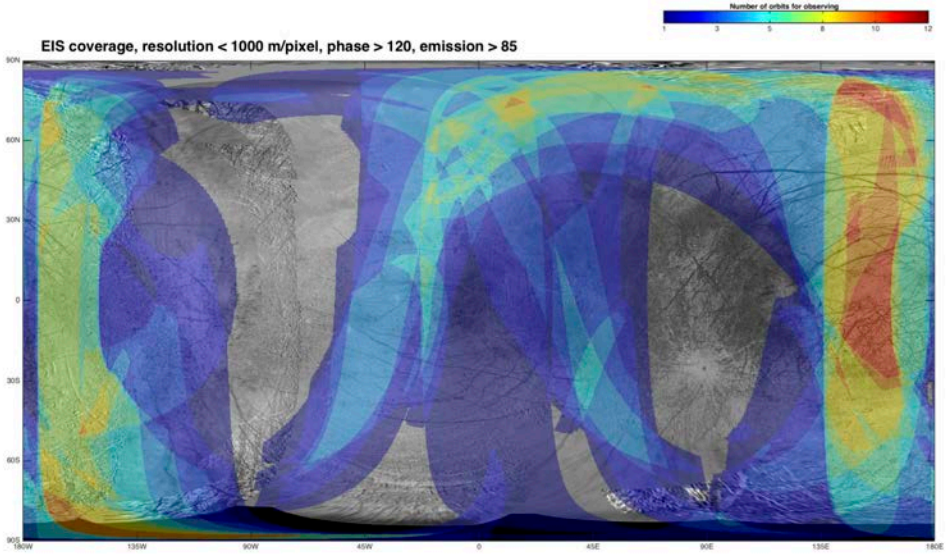
Observation highlights

- **Understand formation of landforms and potential for current activity**
  - **Color photometry (surface and potential plumes) and high-resolution imaging to identify sites of current or recent activity**

- Areas accessible (NAC & WAC) under different viewing geometries, color coded by repeat coverage opportunities (tour 13F7).
- Pixel scale <1000 m, incidence <85°
- Left: emission <75°, phase <75°

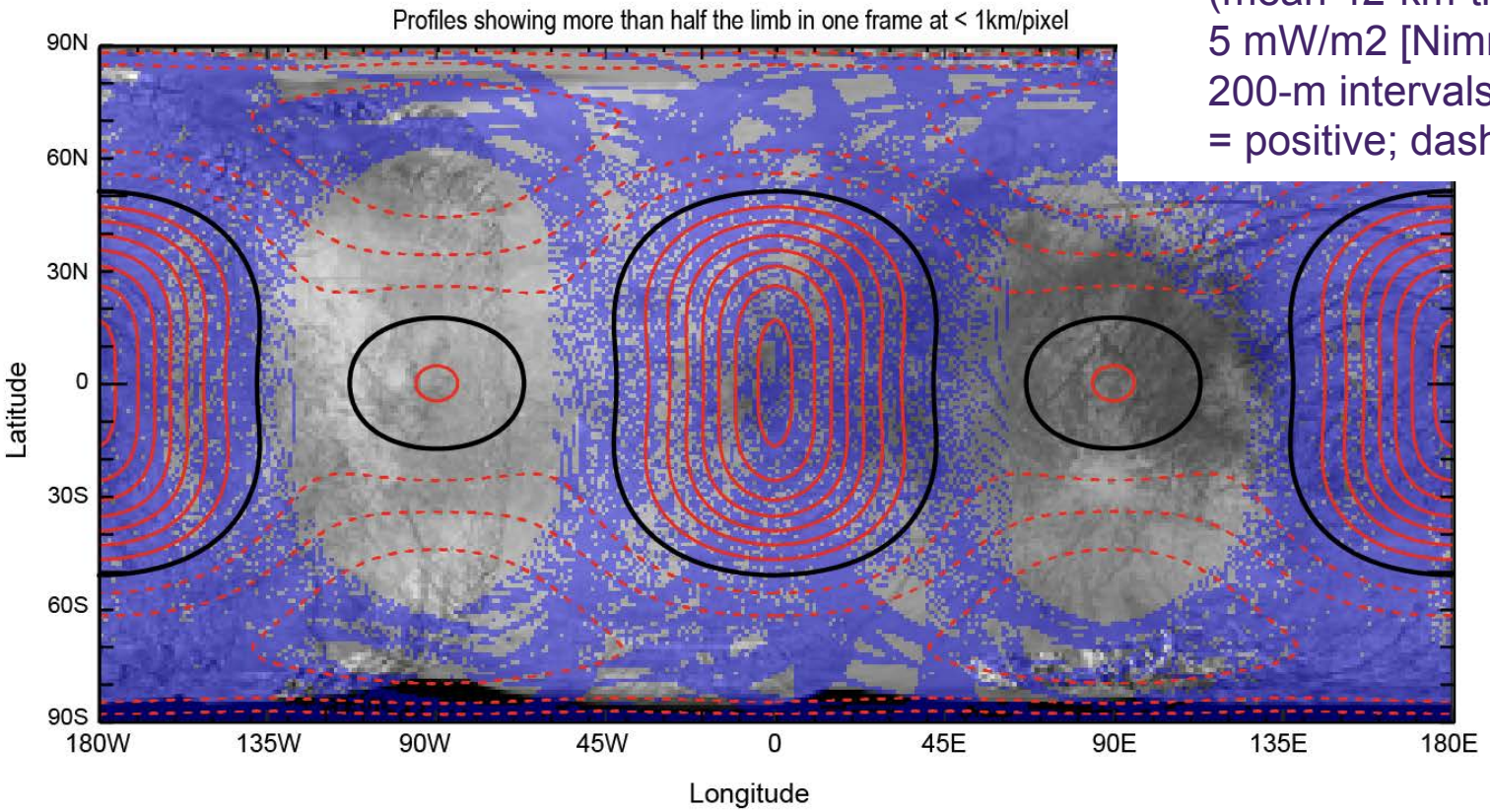
Right: emission >85°, phase >120°





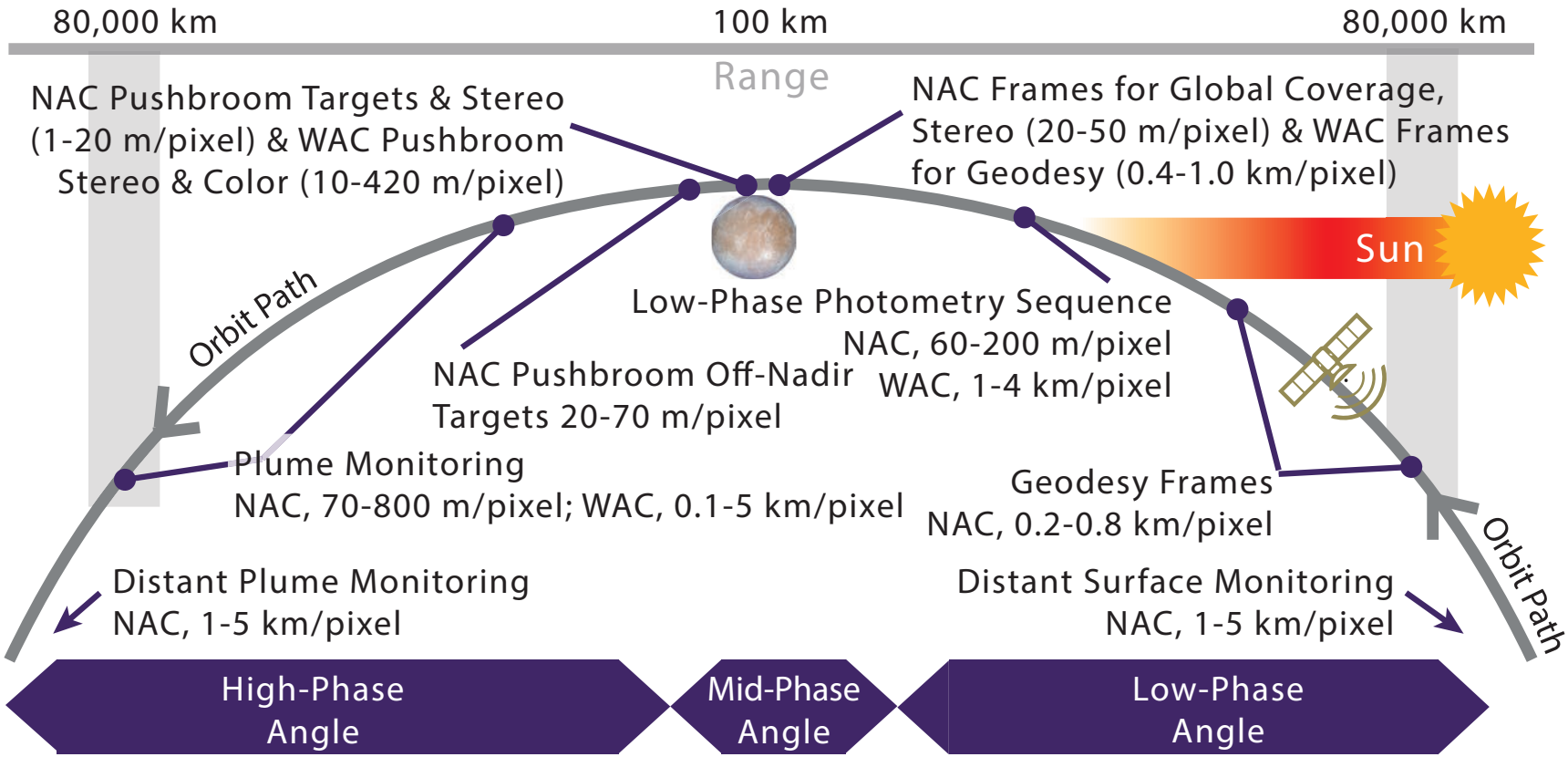
Observation highlights

- **Characterize ice shell and ice-ocean interface**
  - **Geodesy to constrain ice-shell thickness & ice-ocean interface**



- EIS limb-profile visibility (blue shading, tour 13F7) provides excellent long-wavelength topography at 0° & 180°.
- Contours illustrate modeled topography for thickness variations (mean 42-km-thick, basal heat flux 5 mW/m2 [Nimmo et al. 2007]): 200-m intervals; black = zero; solid = positive; dashed = negative.

Streamlined flyby observation planning



- **EIS observations for example encounter: tour 13F7 orbit 31E24 approaches at low phase angles (4-20°), passes closest to Europa at moderate phase angles (20-130°), then departs at very high phase angles (130-170°).**

Streamlined flyby observation planning

- Key EIS observations (blue = NAC; green = WAC; white = both cameras)
- Total compressed raw data volume = 487 Gb for EC, average ~11 Gb/flyby
  - *Flyby coverage & data volume depend on geometry/coverage opportunities*
- Decompression (~3 bpp to 16 bpp) expands data to ~2.6 Tb
- Derived data products expand by ~10x, for total PDS archives of ~26 Tb

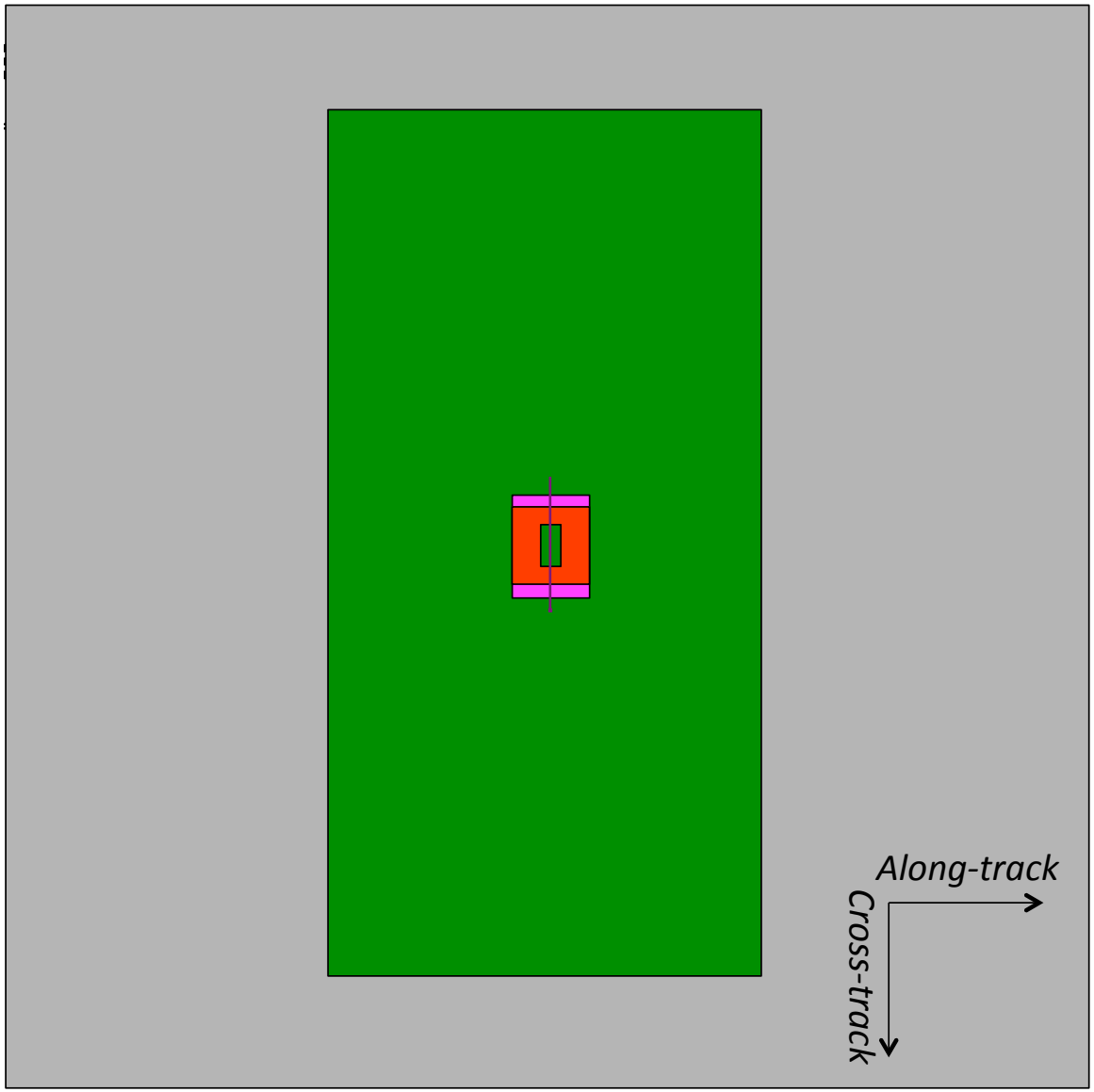
Range (km)	Approx. Time from C/A	NAC/WAC	Observation	Coverage	EIS Objective	Pix Scale/DEM Precisions	Colors/Stereo	Data Vol (Gb)
Distant	Varies, >6 hrs	NAC	Plume/surface monitor	Limb (high phase)	A, B	≤10 km	Clear	2
≤80,000	≤5:30	N/W	Plume searches	Limb (high phase)	A, B	≤0.8 km	Clear	30
≤80,000	≤5:30	N/W	Geodesy/rotation	Limb & terminator	A	0.05-1 km	Clear	45
≤5,000	≤0:30	NAC	NAC global mapping	>95%	A, B, R	≤50 m	Clear	70
100-2,600	0:02-0:15	WAC	WAC pushbroom color	>70%	A, B	≤1 km	3-6 colors	60
100-2,600	0:02-0:15	WAC	WAC pushbroom stereo	>70%	B, R	32-630 m/DTM pixel; 4-80 m vert. precis.	Stereo (clear)	60
≤2,000	≤0:13	NAC	NAC regional stereo (framing)	~45%	A, B	≤50 m/DTM pixel; ≤15 m vert. precis.	Stereo (clear)	75
≤100	≤0:02	WAC	High-res color and stereo	>600,000 km^2	R	≤21 m/pixel, ≤64 m/DTM pixel; ≤8-m vert, precis.	3-6 colors; Stereo	20
≤100	≤0:02	NAC	Very high res	>3000 km^2	R	≤1 m	Clear	60
≤100	≤0:02	NAC	Very high res stereo	>3000 km^2	R	2-m/DTM pixel; 0.2-m vert. precis.	Stereo (clear)	60
Varies	Varies	N/W	Calibrations	N/A	all	N/A	N/A	5
							Total	487

Coordinated Europa Science

- **Geologic structures and processes, exchange, recent activity**
  - Controlled global maps, including DTMs and color – MISE (near-IR overlap) E-THEMIS Europa-UVS REASON Gravity – surface expression (or not) of subsurface structures
  - High-res & high-res stereo – landing site characterization – REASON MISE E-THEMIS
  - Plume search, color photometry, high-res texture, change detection, surface irradiation → sites of current or recent activity – REASON MISE E-THEMIS Europa-UVS ICEMAG MASPEX SUDA PIMS
- **Interior**
  - EIS limb profiles for long-wavelength topography complement REASON altimetry and Gravity Science
  - EIS control network, colocated with REASON altimetry, to measure obliquity and forced librations complements Gravity Science (cf. Park et al., 2015)
- **REASON – EIS supports surface clutter characterization**
  - Coincident WAC pushbroom stereo, nightside imaging via Jupitershine
  - NAC global mapping
- **E-THEMIS – EIS albedo map, Jupitershine imaging**

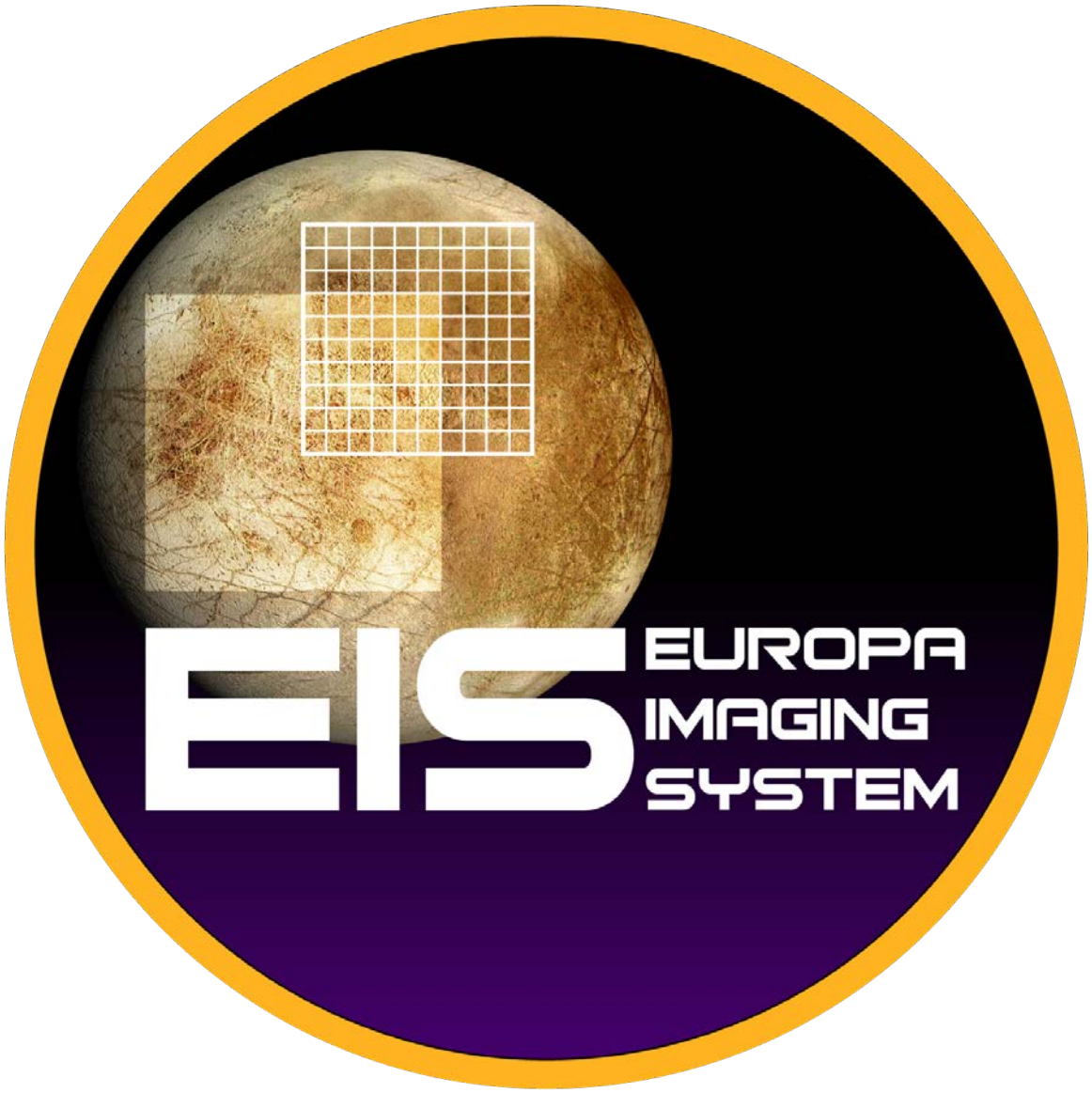
Europa remote-sensing fields of view

- 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°
- EIS NAC targeting:
  2-axis ±30°



Data products

Standard Products (bold = threshold) [*APL = EIS data processing pipeline*] All products follow IAU coordinate-system and USGS mapping conventions	
Raw data [*APL*]	
SPICE kernels (NAIF node) [*APL*]	
Radiometrically calibrated images [*APL*]	
Derived data products [*APL, Science Co-Is (Sec. E.5)*]:	
• **Geometrically projected images** and co-registered color image cubes. **Including jitter corrections as needed with updated C-matrix [*McEwen*]**	
• **Uncontrolled regional mosaics, monochrome** and color ***[APL, McEwen]***	
• **Controlled regional mosaics, monochrome** and color ***[APL, McEwen]***	
• **Controlled global mosaics, monochrome** and color ***[APL, McEwen]***	
• Topographic products [*Kirk, Hayes*]. **WAC** and NAC **regional and high-resolution DTMs**	
• **Supplementary data products [*APL, Humm, Turtle, Soderblom*]; calibration data and algorithms; documentation for data and data reduction**	
Special Products (derived data products)	
• Shape models [*Nimmo*] • Geologic maps [*Patterson, Collins, Soderblom, Hayes*]	• Plume search database [*Hurford, Quick, Hansen*] • Photometric data products [*Thomas*] • GIS products [*Hayes, Collins*]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