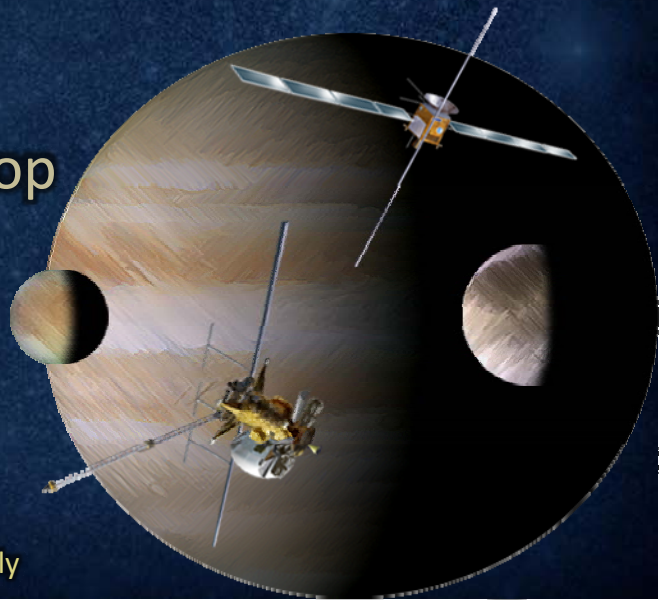
JEO Science Operations Concept

Rob Lock

JEO Pre-Project

EJSM Instrument Workshop

July 26 – 29, 2010



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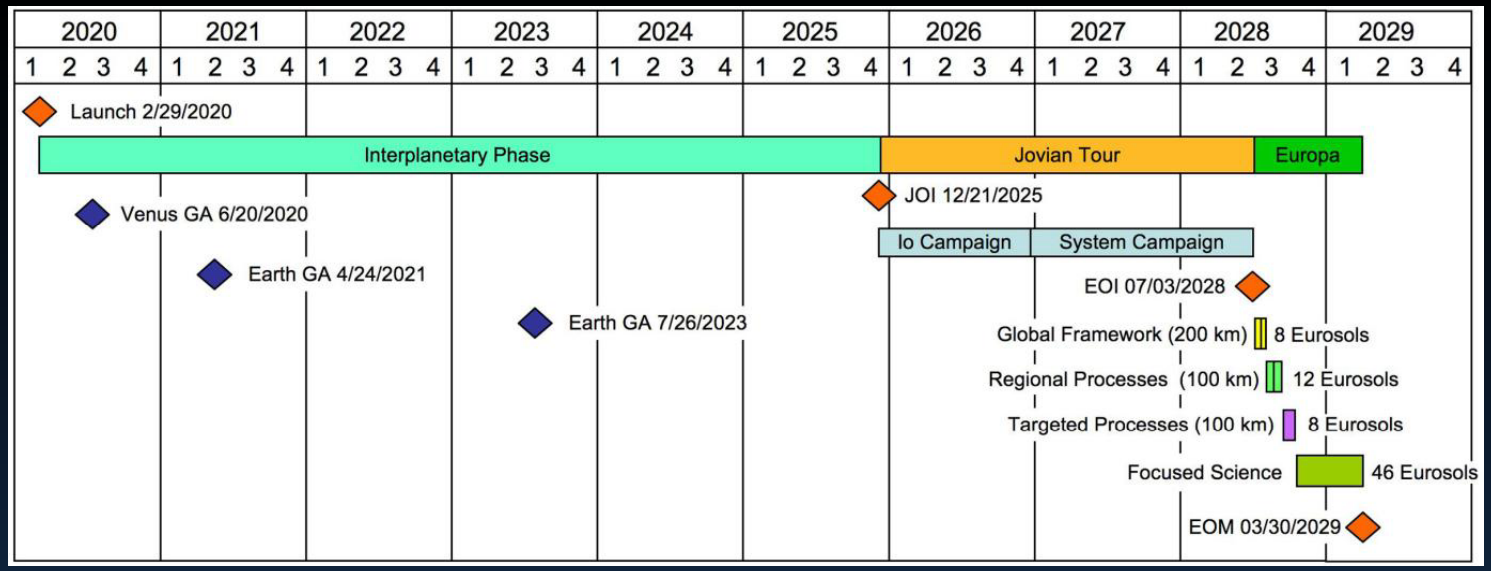
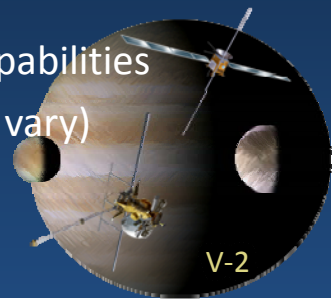
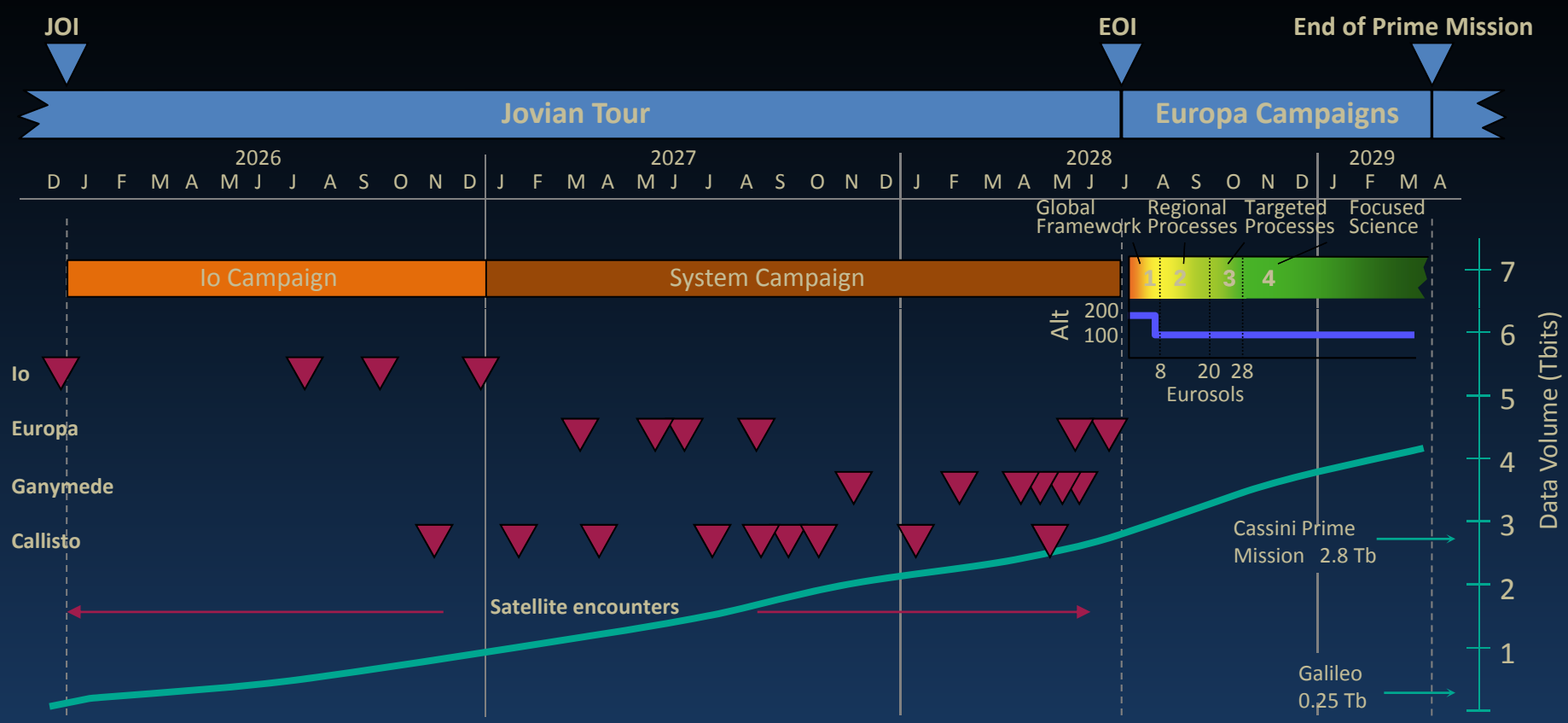
JEO Baseline Mission Timeline



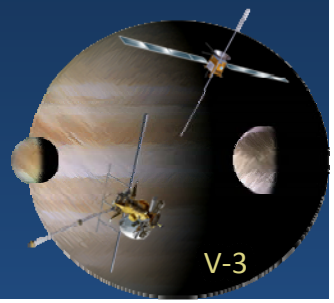
- Long Cruise to Jupiter
  - Challenges: Training, Skill Retention, Obsolescence
  - Opportunities: Process Improvement (methods, S/W, etc), IT infrastructure, ops approaches
- Two kinds of science missions
  - Tour: longer, slower, more diverse
  - Europa: Faster, more intense, more systematic and structured
  - Cruise: Specialized science not anticipated, calibrations and training use Tour capabilities
  - Need one system to meet all needs (process timelines and decision process can vary)



Baseline Science Mission Overview

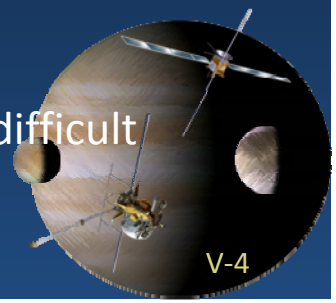


Required to reach Europa,
but also targets of Jupiter system science



Challenges to Operations

- Europa Science Phase
  - Radiation environment limits lifetime available for diverse science goals and objectives
    - System "Uptime" and flexibility in the face of anomalies are driving concerns
  - Radiation environment limits SSR size (hardened parts: availability, size, power consumption)
    - Constrains data collection and return, and science opportunities
  - Radiation degradation changes S/C behavior over time, eventually causing more frequent fault management and operations intervention
    - Limited life in orbit pushes on-board autonomous fault management, system flexibility, and operability design
  - Europa gravity field unknowns and 3rd body effect cause frequent orbit trim maneuvers and complicates science data collection
- Jupiter Tour phase
  - Target rich environment requires sharing of S/C resources (pointing direction, power, data volume, SSR capacity)
  - Europa orbit based instruments (e.g. line imagers) can be more difficult to operate (longer range, slew modes for imaging, etc)
- Mission Lifetime
  - Long mission makes training, skill retention, design knowledge more difficult

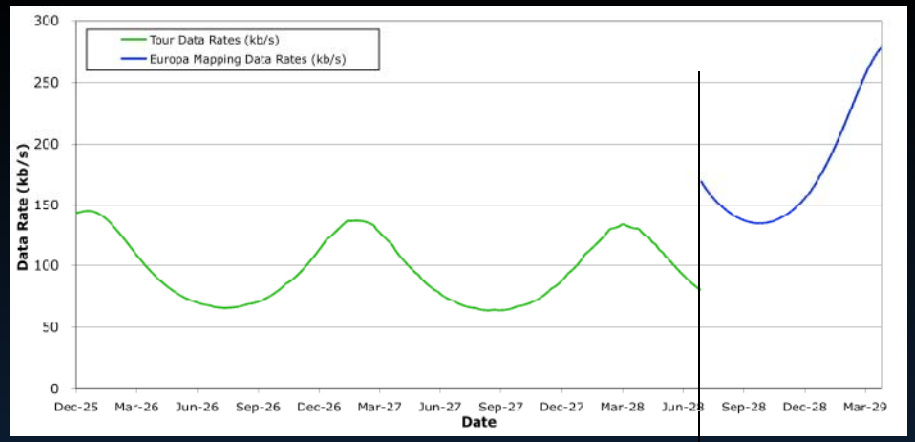


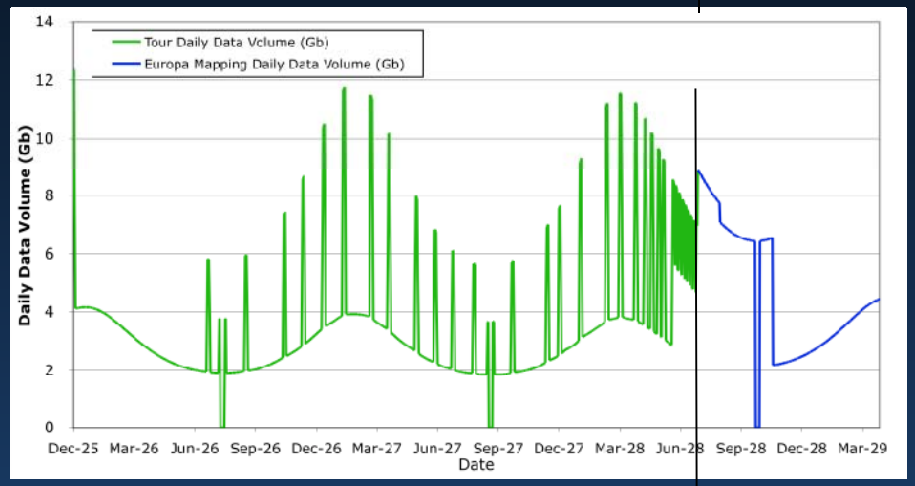
Data Acquisition Strategy

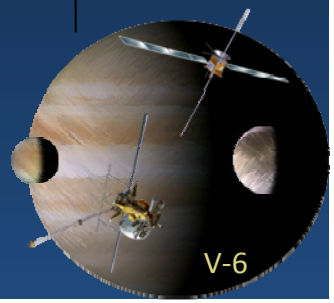
- Mission architecture and design of operations capabilities will be largely driven by the intense Europa science campaign needs
  - Some additional features will be added for Tour science needs
- In the current concept, Europa science sequences will be developed on a weekly basis with a one week development schedule
  - Basic sequences to include mapping activities, target tables, OTM and desats, downlink rates and times, and resource predictions
  - Targeted observations will be executed via on-board table
  - Ephemeris updates, Target updates and observation parameters might be updated a few times per week (to accommodate ephemeris updates)
- Tour sequences would use the same tools, teams and processes but will allow for more diverse activity types and likely have longer development schedules
  - 1-4 week sequence durations with 2-3 week development schedules
  - More time will be available for strategic activity planning prior to sequence development

Data Return Strategy

- Data rates tuned to support science scenarios
  - Ka-band provides desired rate levels
  - Power adjusted to achieve Europa scenario data volume requirements
  - Second Europa Science Campaign is sizing case
- DSN tracking schedule is moderate
  - Single 34m station per day for most of the science mission
  - Continuous 34m used for Launch, JOI, EOI, Flybys, 105 days at Europa to meet mission requirements
- Jovian Tour and Europa orbital data volumes are very large and meet Europa science objectives with margin

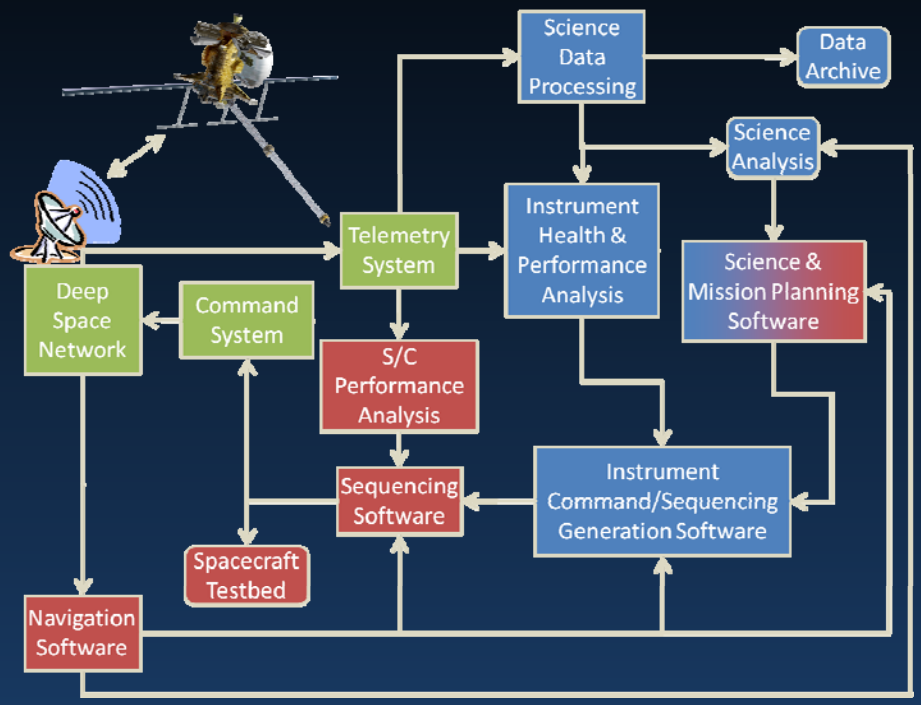


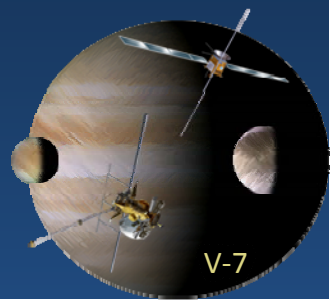




Approach to Operations

- MOS architecture employs proven approaches
  - Centralized command and control
  - Distributed science operations
  - Maximum use of NASA standard infrastructure
- Best operations techniques drawn from many missions for application to JEO
  - e.g., Cassini, MER, MRO, MESSENGER, New Horizons
- Flight/Ground operability is a major focus in the system architecture and is addressed early and often
- To date, no new capabilities have been needed to operate JEO efficiently and achieve the mission goals
- During development and flight, new capabilities may be incorporated to improve operability, system longevity, or cost





Key Operability Features

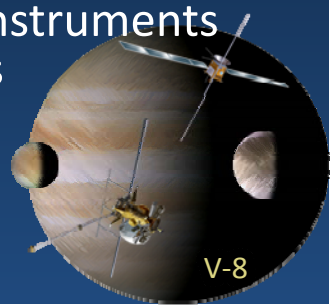
- Two studies were conducted in 2008 to capture relevant lessons learned from the past and present operational missions
  - Lessons Learned Study for The Next Outer Planets Flagship Mission
  - Outer Planets Flagship Mission Science Operations Concept Study Report
  - Many recommendations for S/C and MOS concepts were incorporated. A few key system concept features are noted below:

Spacecraft

- Large 17 Gb Hybrid Science SSR
- 2-axis HGA gimbal
- Co-boresighted instruments
- Onboard software emphasizes fault isolation and management, flexible instrument sequencing, and ephemeris driven pointing (allows MOS operability)

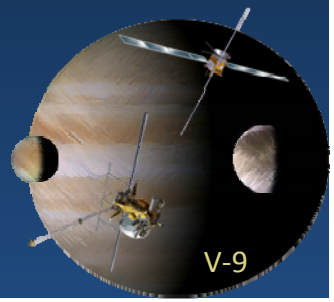
MOS

- On-board, target relative, pointing and slew control
- Standard, file based, communications protocols for end-to-end automated transfer of commands, telemetry, and science data
- Parallel commanding of instruments and engineering activities

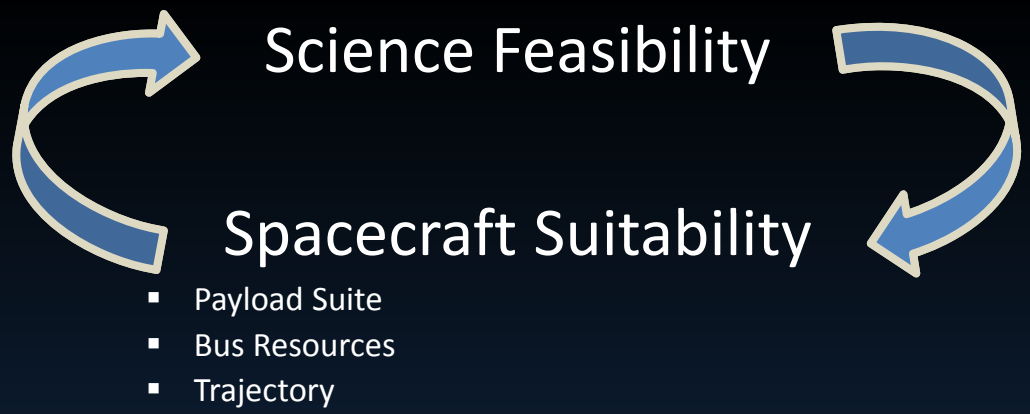


Instrument Operability Issues

- Instrument Operability
  - From a System perspective, instrument operability can be viewed as the trade between flexibility (many options under many conditions) and complexity (number of steps, preconditions, dependencies, etc)
  - The JEO system architecture approach considers operability across all aspects of the system
    - Needs to include instrument operability as early as possible
    - Trade operability solutions across the system (ground, s/c, payload, instrument) to balance risk, cost mission return, etc.
    - Increases capability to meet science objectives and risk
    - On-going process across the development phase
- Instrument operability characteristics (such as)
  - Power Modes • Data Modes • Operations Scenarios
  - Deep Diagnostic and Recovery Capability



Scenario Analysis & Evaluation

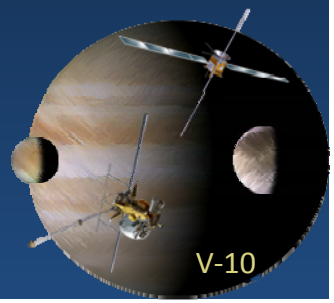


Approach:

- Iterative process
- Optimization of science and spacecraft

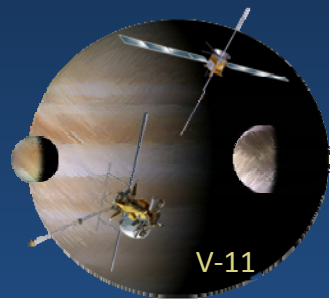
Characteristics:

- Open communication between scientists & scenario engineers
- Tool Set – Rapid, repeatable, highly-accurate analysis
- Standard Products – Quick, consistent evaluation



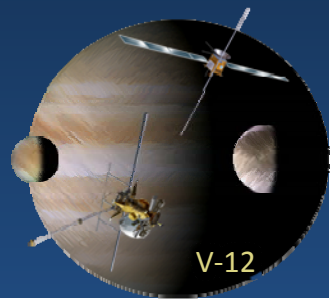
Scenario Tools & Products

- Spatial-Temporal Modeling & Analysis
  - Satellite Tool Kit (STK) by Analytical Graphics Inc. (AGI)
  - Post-processing: Microsoft Excel
- Spacecraft Resource Modeling & Analysis
  - Custom 'Scenario' Tool
  - More comprehensive system models and simulations will be coming on line in the next couple of years
- Products
  - Data acquisition & return profiles
  - Power generation & consumption profiles
  - Event & activity timelines
  - Contoured coverage maps
  - Vector / angle plots & time profiles
  - Animations



Key Instrument Parameters

- To perform scenarios analysis and system modeling, key instrument parameters and models will be needed:
  - Power Modes - off, standby, observing [1-N]
  - Observing Modes - data rates (science and housekeeping), reduction factors and acceptable range, data product size and size range
  - Operation Scenarios – observation modes and data for each objective, geometry and timing constraints, success criteria, coordination needs with other instruments



Scenario Analysis – Europa Mapping Example

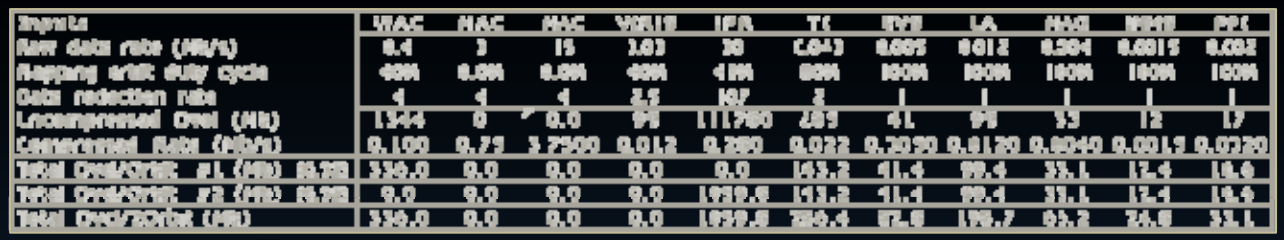
SDT
Instrument data rates
Reduction factors
Coverage needs
Duty cycles

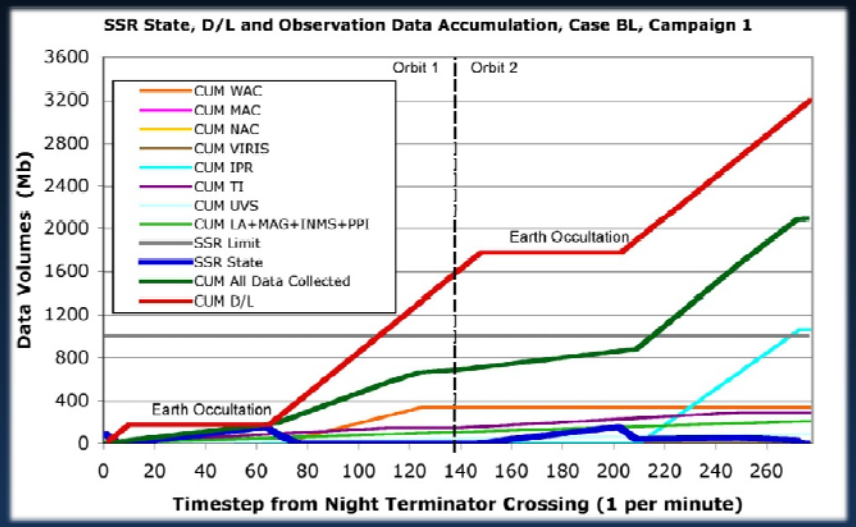
Constraints

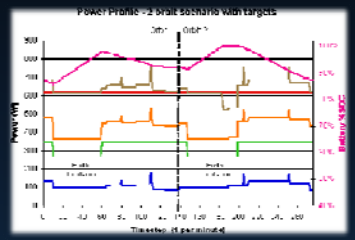
S/C:
3m HGA
25 W TWTA
1 Gb SSR

DSN:
34m Ka-band, 3/day

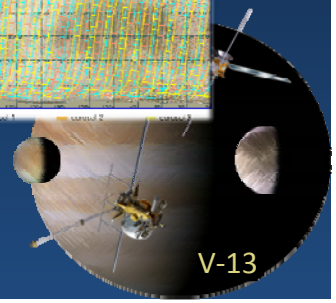
Operations:
Alternating orbit data collection
No retransmit
Most observations during D/L







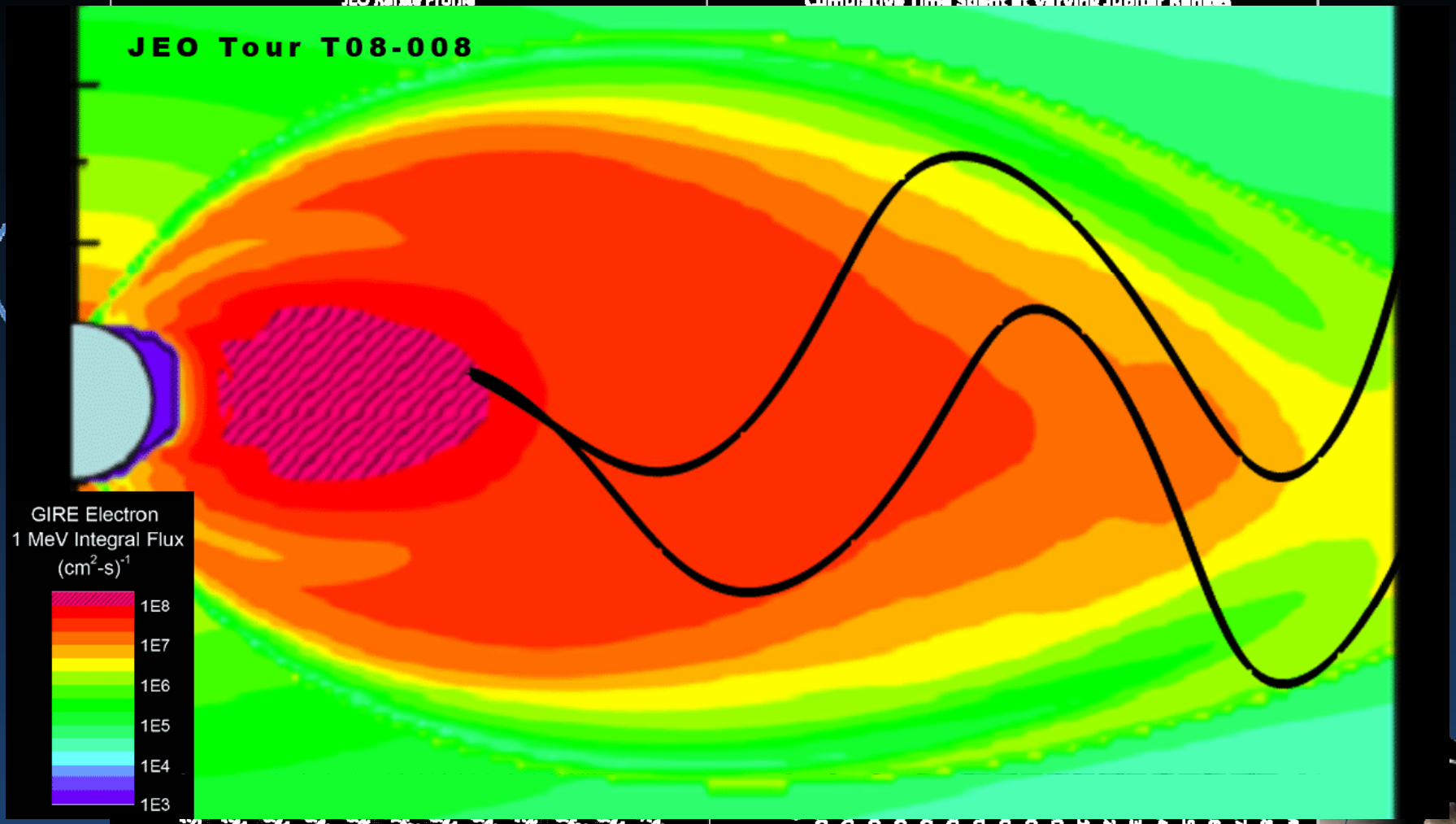
- Data flow simulator used to model observation strategies over 2 orbits
- Each campaign is evaluated with new rates and observation parameters
- Power profiles calculated from worst case observation scenarios



EJSM Operational Scenarios (To Date)

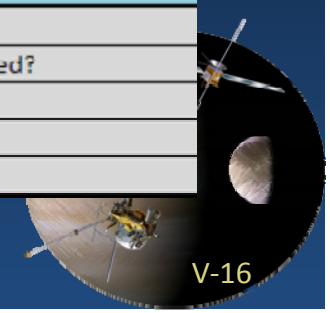
- Science Scenarios
  - Jovian Tour
    - Single Jupiter Orbit
    - Galilean Satellite Flybys
    - JEO-JGO Synergy
  - Europa Orbit
- Engineering Scenarios
  - Deployment
  - Jupiter Orbit Insertion
- Scenario Parameters
  - Science
    - Coverage
    - Resolution
    - Cadence (Frequency)
    - Geometry
  - Engineering
    - Telecom link margins & DSN resources
    - Attitude pointing & slew rates
    - Data rates, volume, & storage
    - Power consumption & storage
    - Configuration

Jovian Tour Scenario

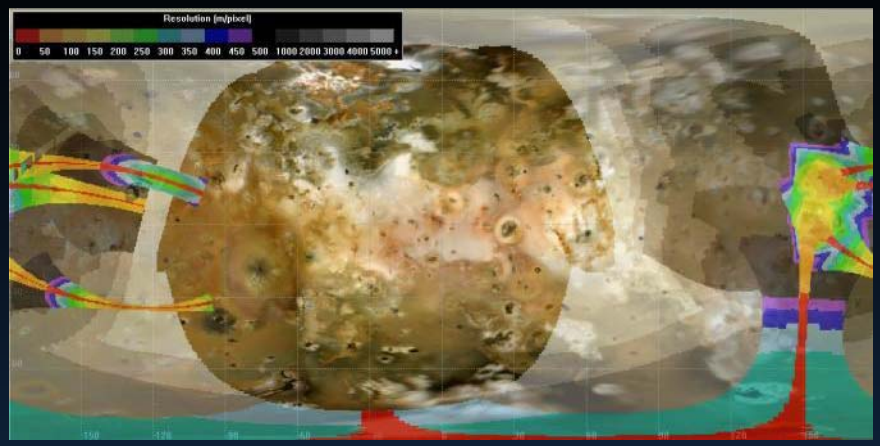


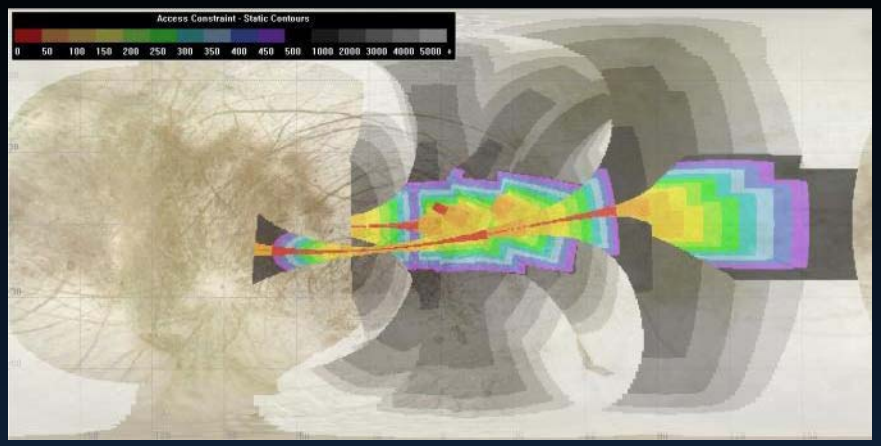
Jovian Tour – Single Orbit Scenario

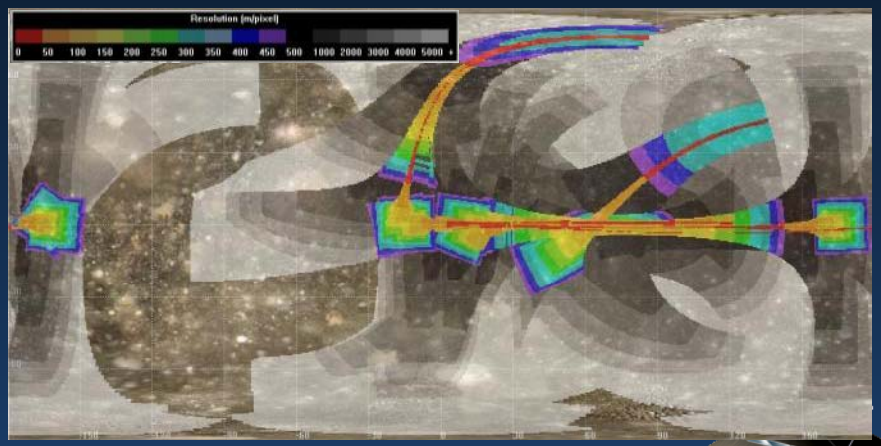
Category	Observations of Interest	Cadence	Instruments / Mode	S/C Attitude	Ops Concept
F&P / Mag Observing	From spinning s/c	1/ 2 days	MAG PPI	Earth Point	Do during 8hr DSN passes. Spin the s/c 2-3 times in 2 orthogonal directions and re-orient.
Jupiter Monitoring	Atmospheric Feature Monitoring (e.g. brown band)	1/wk (4-5/orbit)	VIRIS (long wavelength) TI UVS NAC MAC	Jupiter Point	Want 20 hrs of monitoring --> every 10 deg longitude. For each observation, make movie (72 images).
Io Monitoring	Io in Jupiter shadow	1/wk	NAC VIRIS UVS	Io Point	
	Io's dark side	1/wk			
	Io longitudinal grid	1-2/wk			Take image every ~5deg longitude (72 images) & look at limb.
JEO-JGO Synergy	S/C occultation	1-2/orbit	USO	JGO Point	Monitor for 1-2 hours before an event and 30 minutes after plus time to get back to Earth-pointed orientation.
Fly-By (Ganymede)	Areas not previously mapped by Galileo	~1/orbit	NAC WAC&MAC	Ganymede Point	
Other Observations	Galilean Moons		NAC, WAC&MAC		
	Small Moons		NAC, WAC&MAC		Jovian disc crossings desired?
	Rings				
	UV Stars		UVS		
	UV Aurora		UVS		

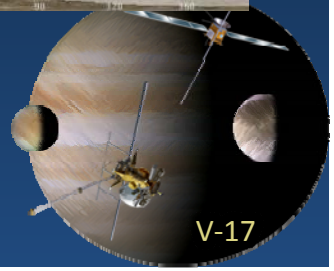


Satellite Flybys – FOV Contours









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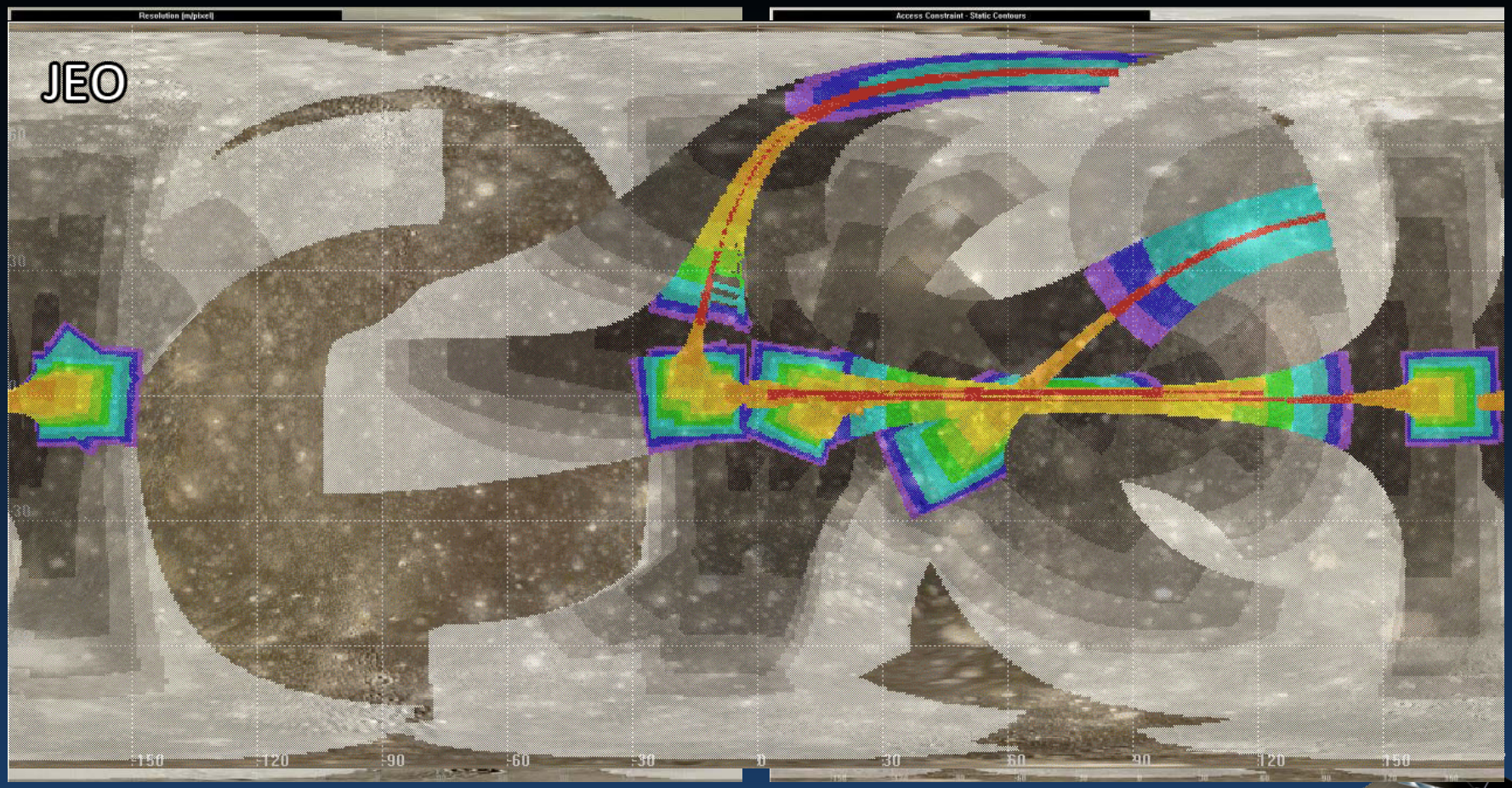
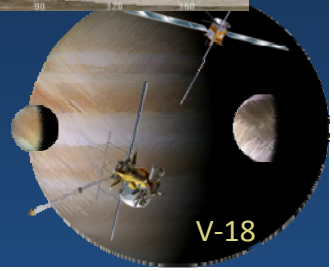
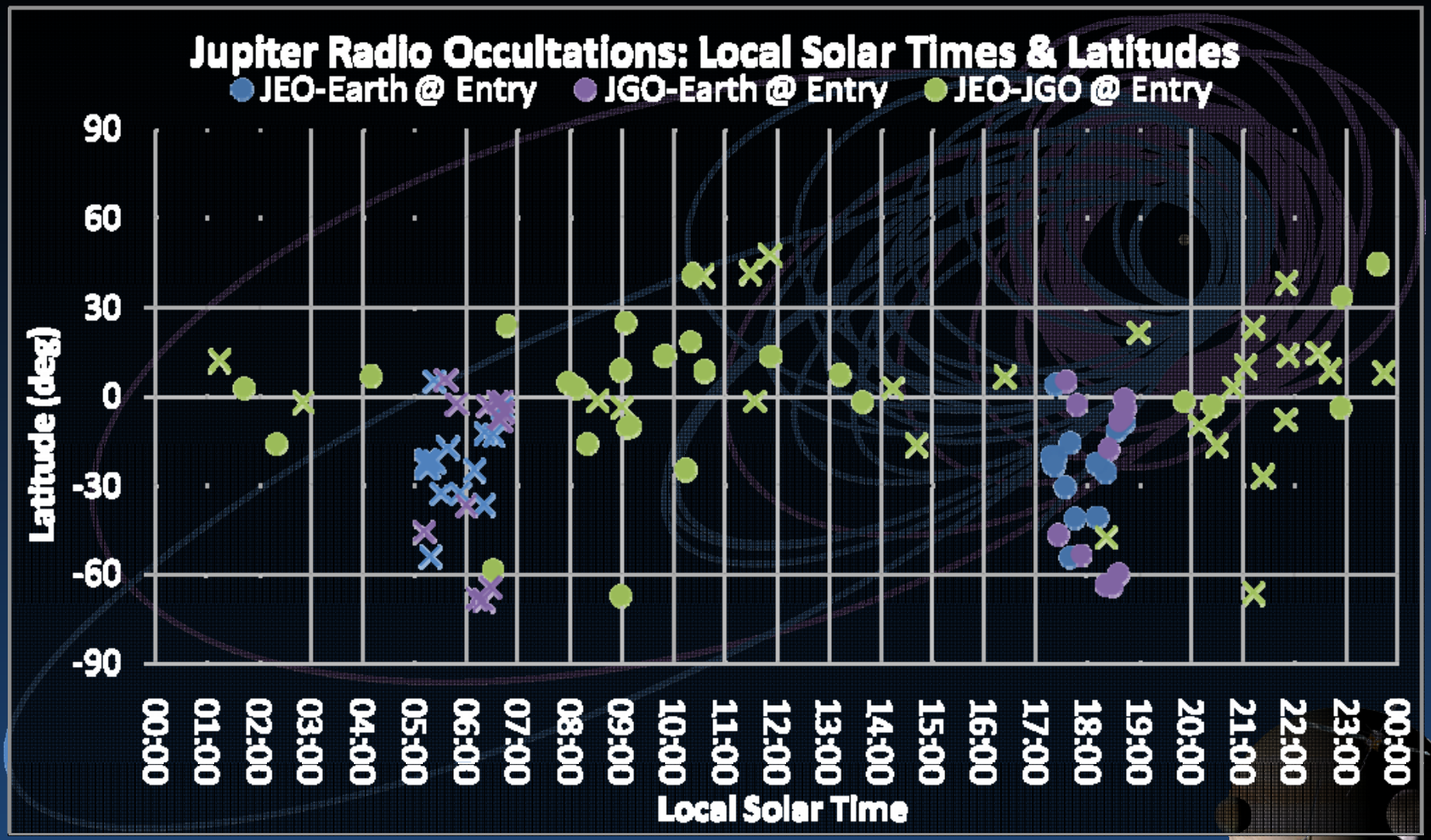
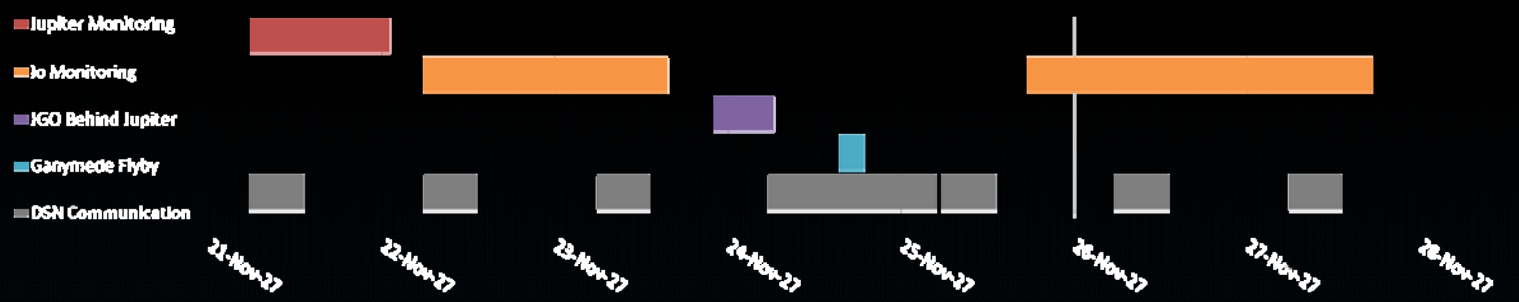


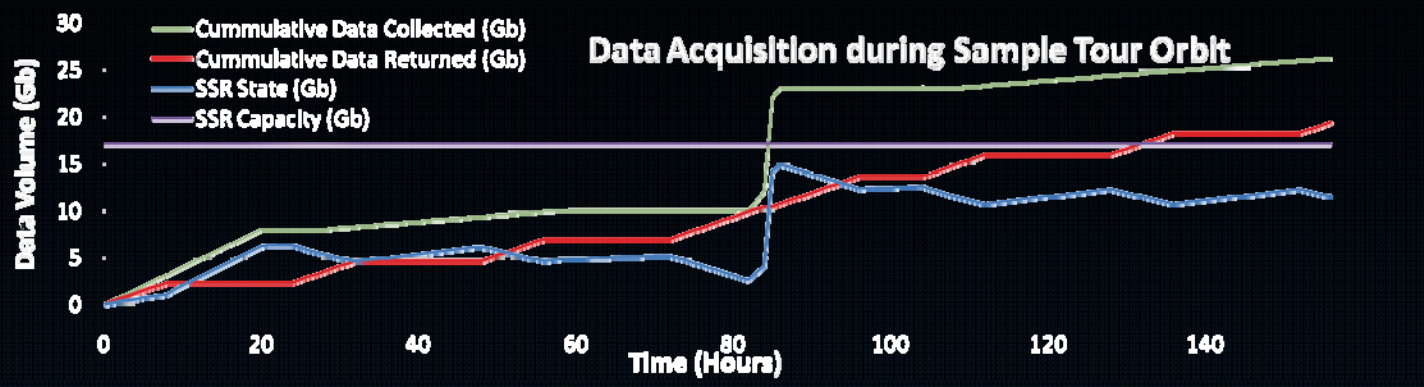


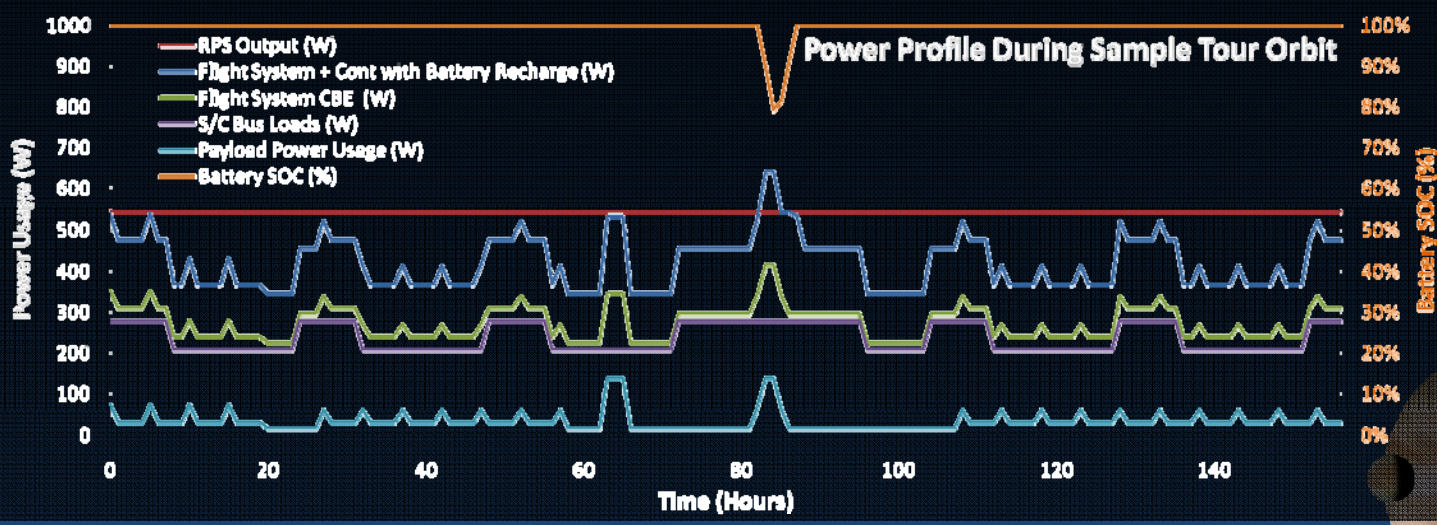
JEO-JGO Synergy Scenarios

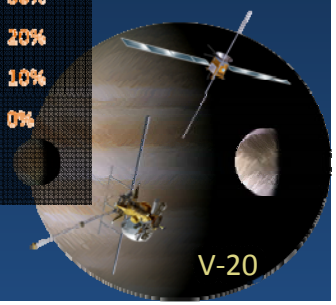


Jovian Tour Resource Analysis









Baseline Europa Science Campaign

JOI to EOI	Jul 2028	Aug 2028	Sep 2028	Oct 2028

Observing Strategies for Europa Campaigns 1–3

- Always on: LA, MAG, PPI, TI, INMS (50%)
- 2-orbit ops scenario permits power/data rate equalization:
  - Even orbits emphasize optical remote sensing:
  - Odd orbits emphasize radar sounding to locate water
- Targets collected with residual data volume

Satellite/Jupiter Science

Eng Assessment (6 d)

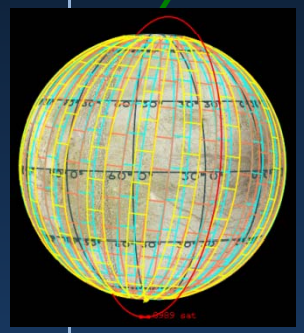
Europa Science Campaigns

1A | 1B | 2A | 2B | 3 | 4

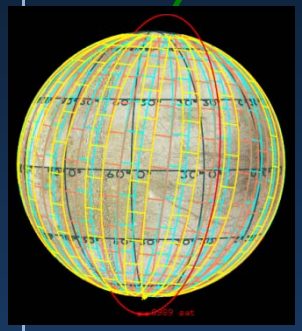
Initial Europa Orbit
Altitude: 200 km
Inclination: 95–100 deg (~85° N lat)
Lighting: 2:30 PM LST
Repeat: 4 Eurosols

After Campaign 1
Altitude: 100 km
Repeat: 6 Eurosols

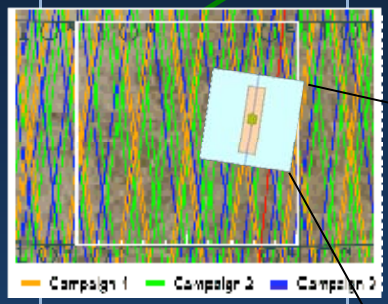
Europa Campaigns 1–3 total 99 days

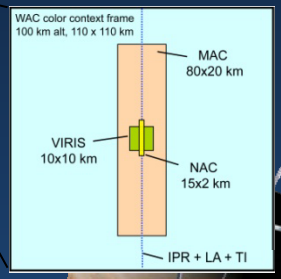


Global Framework
200 km altitude
(200 m/pixel WAC)
8 eurosols ≈ 28 days



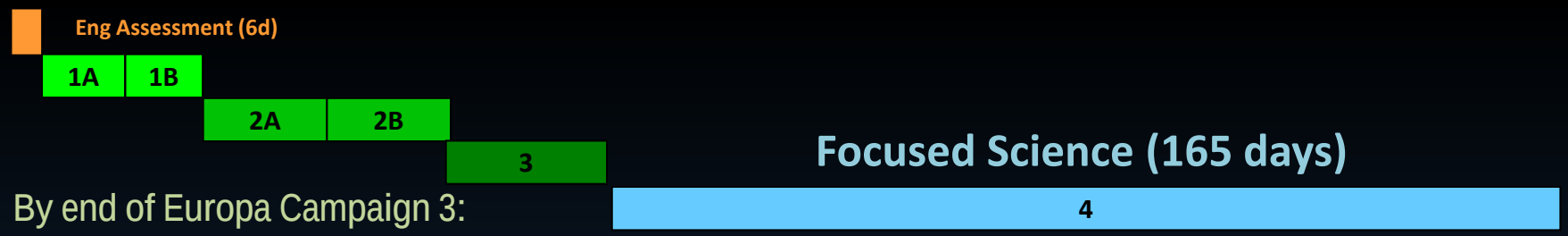
Regional Processes
100 km altitude
(100 m/pixel WAC)
12 eurosols ≈ 43 days





Targeted Processes
100 km altitude
8 eurosols ≈ 28 days

Baseline Europa Science Campaigns (cont.)

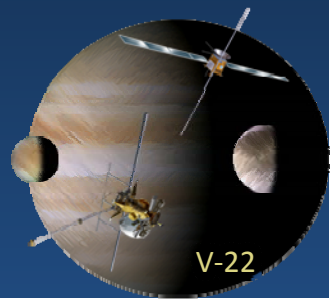


Focused Science (165 days)

By end of Europa Campaign 3:

99 days orbital science
4 global maps
- 2 @ 200 m Color + Stereo
- 2 @ 100 m Stereo

730 imaging and radar targets
18 km profile spacing for LA and TI
35 km spacing for IPR and VIRIS
400 UVS stellar occultations
700 Gb data return

- Follow up on discoveries
- Finer global and regional grid of profiling observations (IPR, VIRIS, TI)
- Continue gravity, laser altimetry, and fields and particles measurements
- Additional coordinated target sets
  - Investigate new discoveries and priorities
  - Characterize candidate future landing sites
- Off-nadir NAC stereo images
- Lower-altitude operations
- Monitor Io and Jupiter, 1 to 2 times per week
- Caution: Radiation margins will also be disappearing over this time period

Extended time in Europa orbit allows additional investigations and exploration