Early Science Operations Analysis for the Jupiter Icy Moons Explorer (JUICE) mission

Encuentro Español de Ciencias Planetarias y Exploración del Sistema Solar
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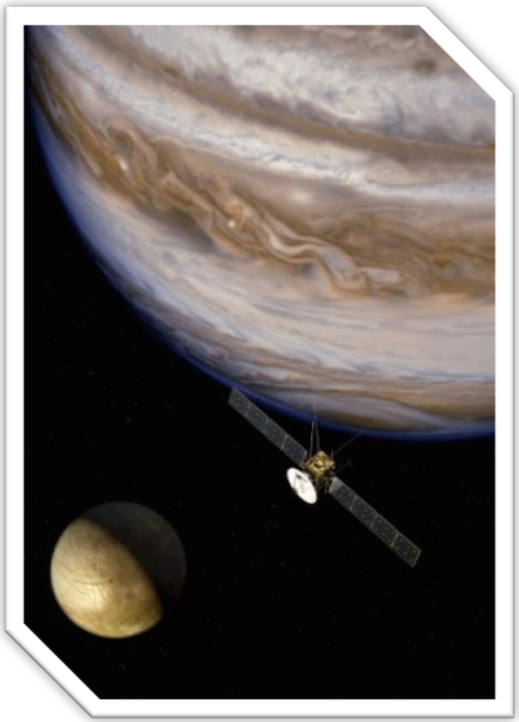
Present science started long ago…

Rosetta (1990's –)2004->2015

Future science starts now!
JUICE (2000's…)2022→2033

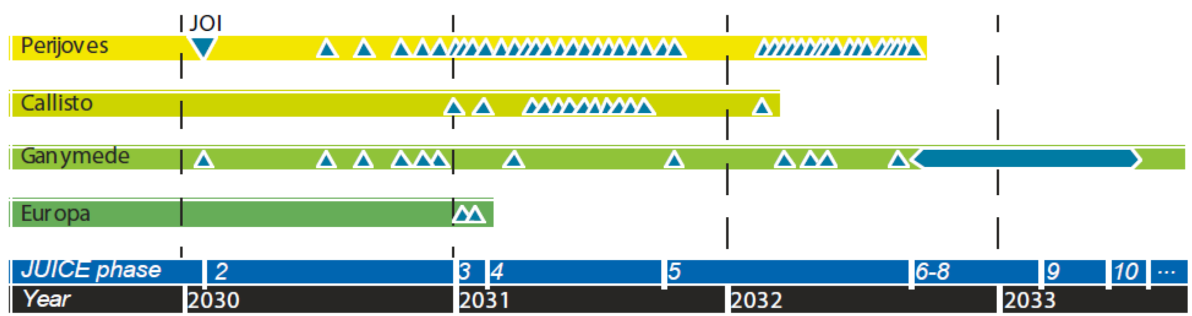
SCIENCE GOAL: Emergence of habitable worlds around gas giants; Jupiter as an archetype for gas giants

- First Large-class mission in ESA's Cosmic Vision 2015-2025 programme
- Launch in 2022, nominal science mission 2030-2033.
- Total mission duration 11 years: 7.6 years cruise + 3.5 years in Jupiter system.



Mission phases:

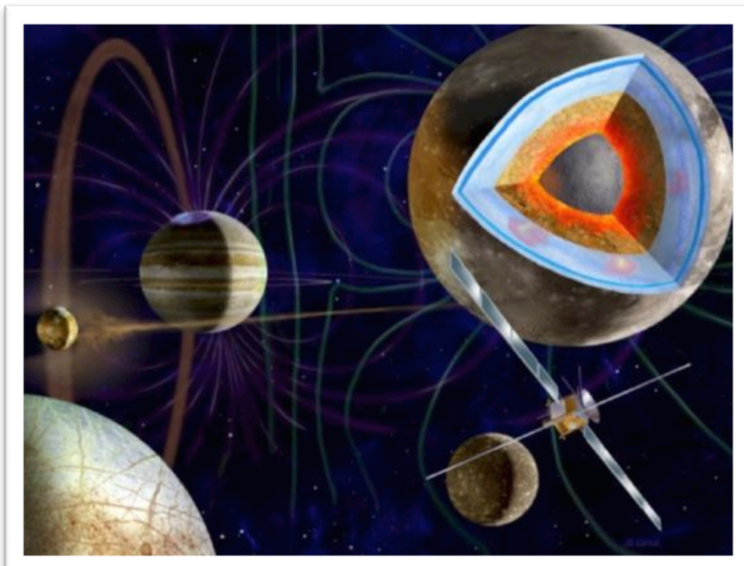
1. Launch and cruise (7.6 years)
2. JOI, and energy reduction for transfer to Callisto (11 months)
3. Europa flybys (36 days)
4. Jupiter High Latitude Phase (200 days)
5. Transfer to Ganymede (11 months)
6-10. Ganymede science phases: (282 days)
Elliptic, GCO 5000km, Elliptic, GCO 500km, GCO 200km



The JUICE mission
Mission Drivers

esa

Spacecraft design drivers:
- Long distance to Jupiter → **DATA BUDGET LIMITATION**
- Only solar electric power → **PAYLOAD POWER LIMITATION**
- High ΔV requirement.
- 3-axis stabilized spacecraft
- Radiation protection



Science Payload (11 instruments):
- Remote Sensing :
  - JANUS (Imager)
  - MAJIS, UVS, SWI (spectrometers/imagers)
- Geophysics:
  - GALA (Laser Altimeter)
  - RIME (Radar Sounder)
  - 3GM (Radio Science)
  - PRIDE (Very-Long Baseline Interferometry)
- In-situ :
  - PEP (Particle detectors)
  - JMAG (Magnetometer)
  - RPWI (Radio and plasma waves)

The JUICE mission

Feasibility Assessment: Sizing Cases

Two specific science cases identified for critical sizing constraints:

DATA BUDGET LIMITATION
PAYLOAD POWER LIMITATION

Mission phases:

1. Launch and cruise (7.6 years)
2. JOI, and energy reduction for transfer to Callisto (11 months)
3. **Europa flybys** (36 days)
4. Jupiter High Latitude Phase (200 days)
5. Transfer to Ganymede (11 months)

6-10. Ganymede science phases: (282 days)
Elliptic, GCO 5000km, Elliptic, **GCO 500km**, GCO 200km

Two Europa flybys
All instruments observing simultaneously

Ganymede Circular Orbit 500km,
Long term plan covering various science objectives

an Space Agency

JUICE SciOps Analysis
Basic ESAC support so far

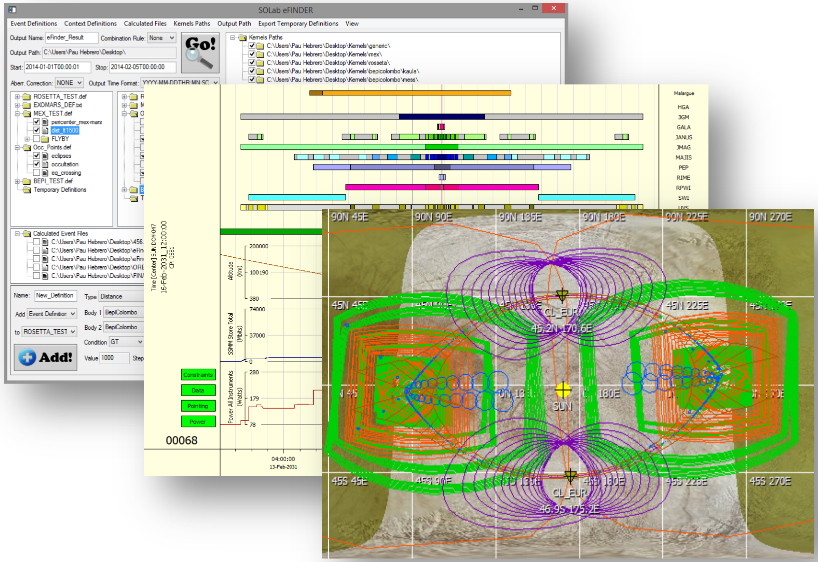
Science Operations support not foreseen for JUICE in early stages

Since January 2015: ESAC involved with very limited resources

Time before CA	-60 min to - 45 min	-45 min to -32 min	-32 min to - 30 min	-30 min	-17 min	-13 min	-7 min
Time after CA	+45 min to +60 min	+32 min to +45 min	+30 min to +32 min	+30 min	+17min	+13 min	+7 min
	1st medium resolution slew	2nd medium resolution slew	Transition to "true" nadir pointing				
Altitude (km)	12,000 to 10,000	9000 to 6000	6000 to 5700	5700	4300	2000	1000
Pointing mode	4.2° W to E In 600 s, 4.5° offset to the N (along Z)	8° E to W in 780 s, 0.5° offset to the N (along Z)	Slew along Y and Z to nadir pointing	Nadir pointing, Push-broom	Nadir pointing, push-broom	Nadir pointing, push-broom	Nadir pointing, push-broom
JANUS (excluding RIME-requested DTM)	-60 min: Mode: SCIENCE-EFB-CA1 35.5W, 390 kbps -50 min: STBY, 28.7 W	-45min: Mode: SCIENCE-EFB-CA2 35.5W, 600 kbps	STBY, 28.7 W	Mode: SCIENCE-EFB-CA3 35.5W, 660 kbps	Mode: SCIENCE-EFB-CA1 35.5W, 390 kbps	Mode: SCIENCE-EFB-CA4 35.5, 1080 kbps	Mode: SCIENCE-EFB-CA5 35.5 W, 4000 kbps
MAJIS	Surface scan Duration: 600 s	-50min to -45min (exosphere observations):	Mode: STBY 18.9W, o kbps	Surface Push-broom MODE1x1_1sec_RE	Surface Push-broom -17 min …+17 min:	Motion compensation initiated	Surface Push-broom -17 min …+17 min

INPUTS
- Mission and Payload Science/Technical documentation
- High level concept and basic operations scenarios
- Interaction with Project Scientist and Science Working Team

BASIC DEVELOPMENT AT ESAC:
- Small SciOps team with multi-mission experience
- Setup "recycled" systems from other missions
- Preliminary modeling for spacecraft and payload
- Preliminary geometric analysis for the mission



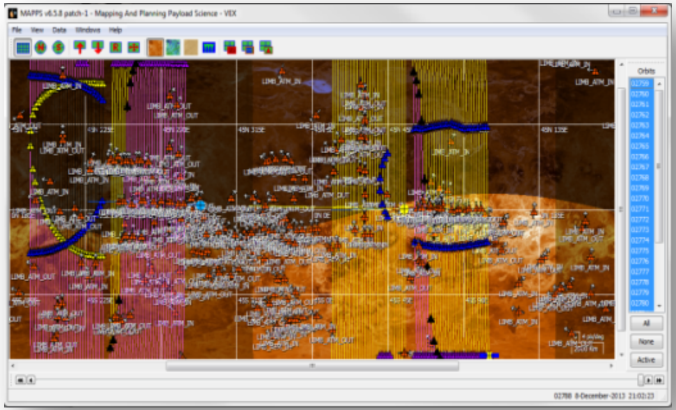
OUTPUT:
- Science Opportunity Analysis
- Operational analysis of science scenarios
- Assessment of science goals

Science Operations Tools

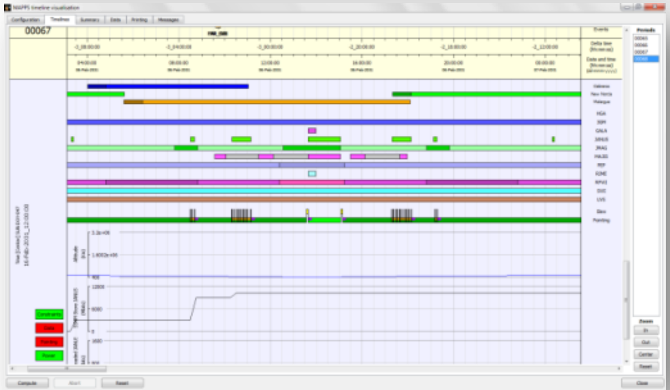
MAPPS/EPS

MAPPS/EPS

- Mission Analysis and Payload Planning System: simulation and visualization.
  - Geometry computation for Spacecrafts, Instruments and Targets
  - Visualization of multiple parameters and overlays in 2D
  - Simulation of events and operational timelines



- Experiment Planning System: payload commanding modelling.
  - Payload and spacecraft resources, sequences and transitions.
  - Generation of command level sequences
  - Payload planning files



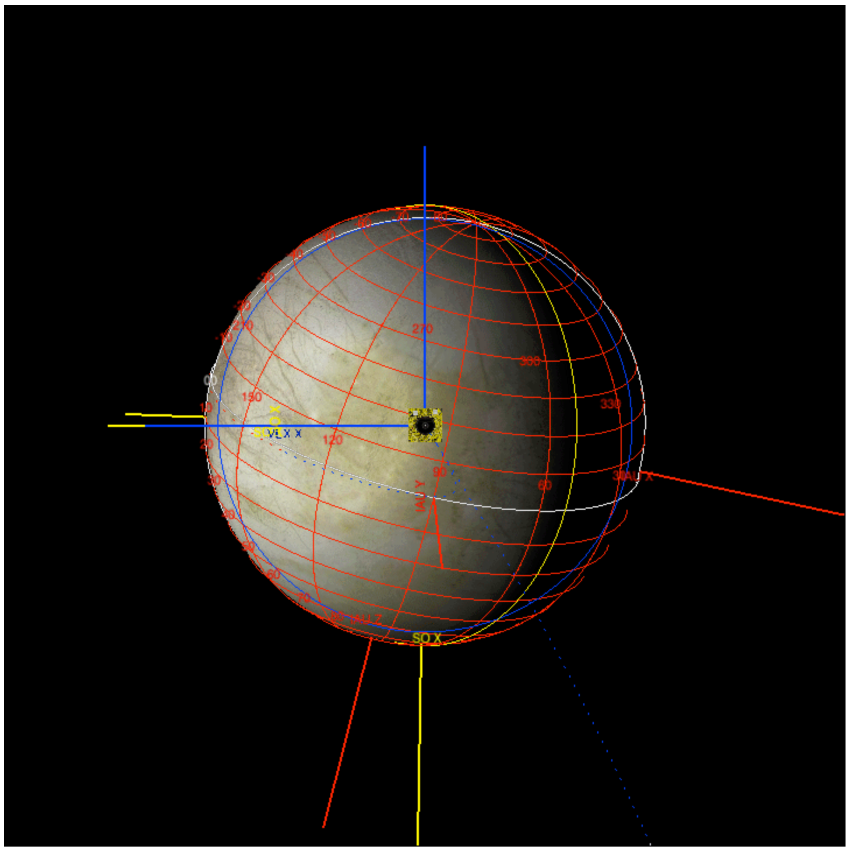
- Used operationally by all ESA planetary missions:
  - SMART-1, VEX, MEX, Rosetta, BepiColombo, Solar Orbiter, Exomars

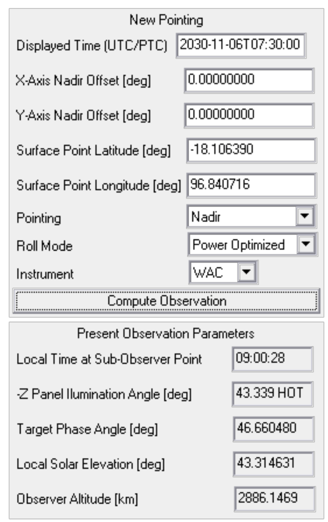
Science Operations Tools

SOLab / eFinder

SOLab (Solar System Science Operations Laboratory):

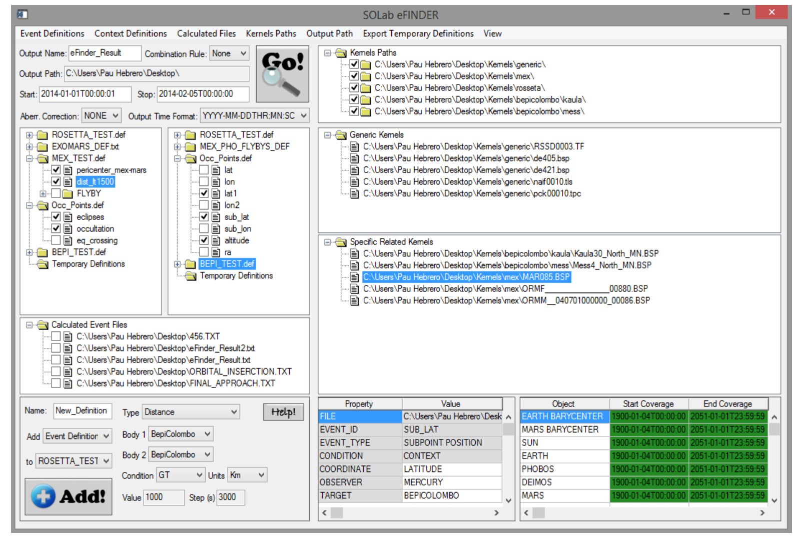
- Research project for geometry computation
- Quick analysis and 3D visualization of observations
- Used by most ESA planetary missions: VEX, MEX, Exomars, JUICE

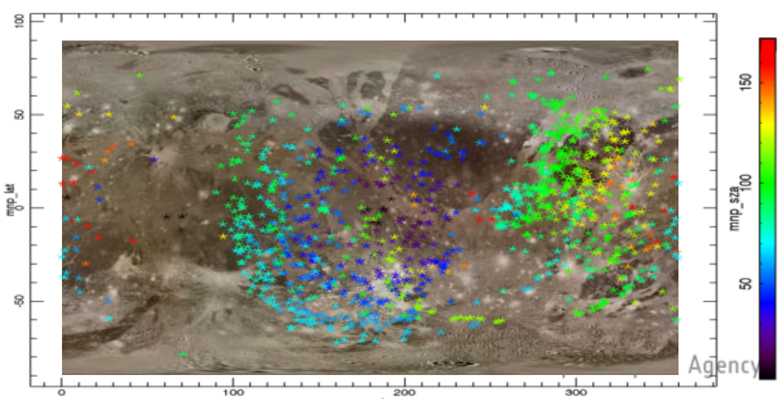




SOLab eFinder:

- Science Opportunity Analysis





Europa Fly-by analysis

Scientific and Operational Feasibility assessment

esa

Input High Level Scenario Definitions (from ESA Technical Note)

Time before CA	-60 min to - 45 min	-45 min to -32 min	-32 min to - 30 min	-30 min	-17 min	-13 min	-7 min	+7 min to + 60 min
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	1st medium resolution slew	2nd medium resolution slew	Transition to “true” nadir pointing					
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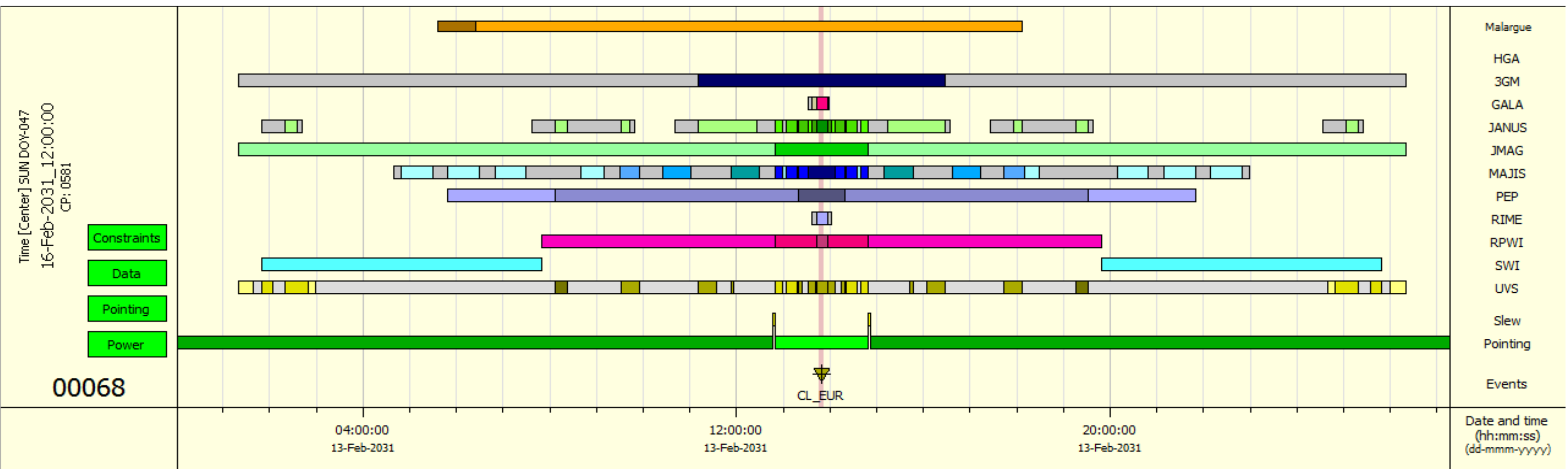
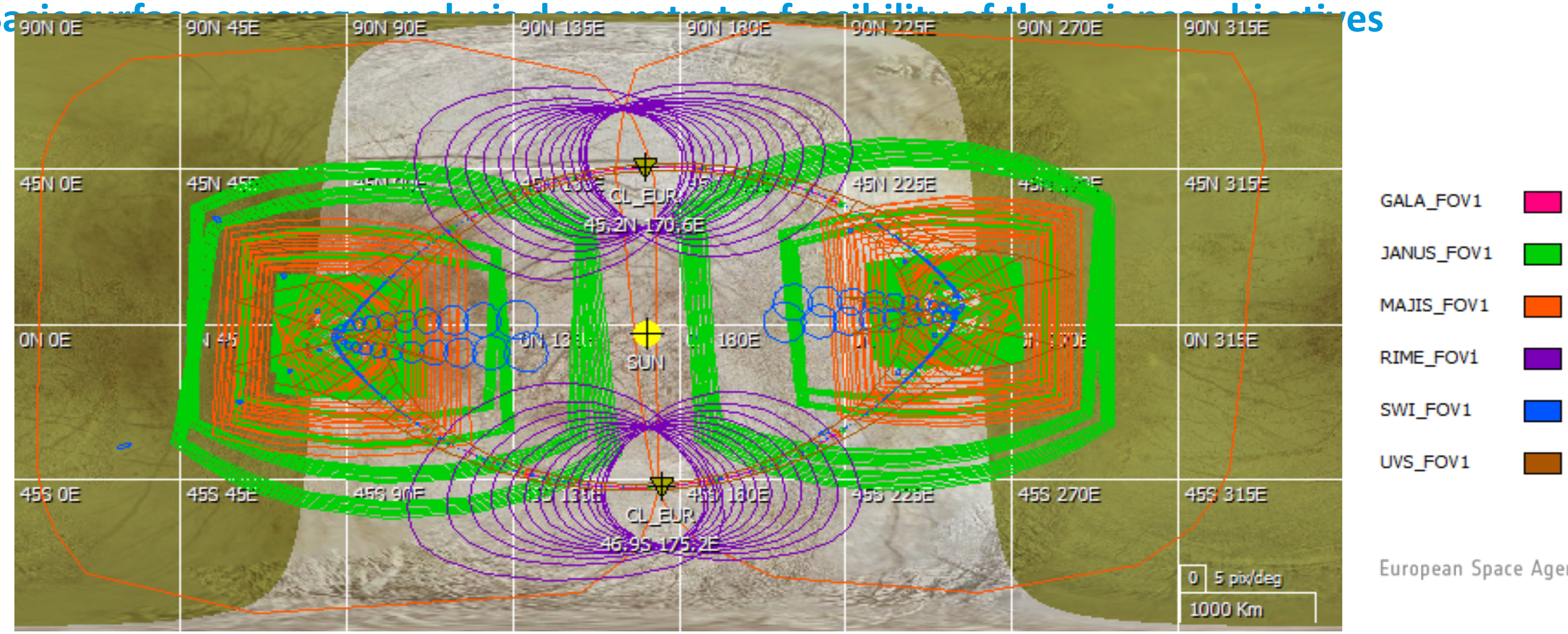
Output Scientific and Operational feasibility analysis



Europa Fly-by Analysis

Conclusions of Feasibility Assessment

- **Simulations confirm feasibility of the proposed observation scenarios for both fly-bys**
  - Payload data simulation predicts <u>73Gbit of science data</u> for each fly-by scenario.
  - Downlink simulation requires at least <u>3 months to download</u> all fly-by data
  - Payload power simulation predicts <u>consumption of 180Watts</u> in average (peaks up to 275W)
  - Accumulated energy required is <u>4500Wh for each fly-by</u> (input for SC battery assessment)
  - **Basic surface coverage analysis demonstrates feasibility of the science objectives**



GCO500 Sizing Case analysis
(old) Preliminary Study for Yellow book (2013)

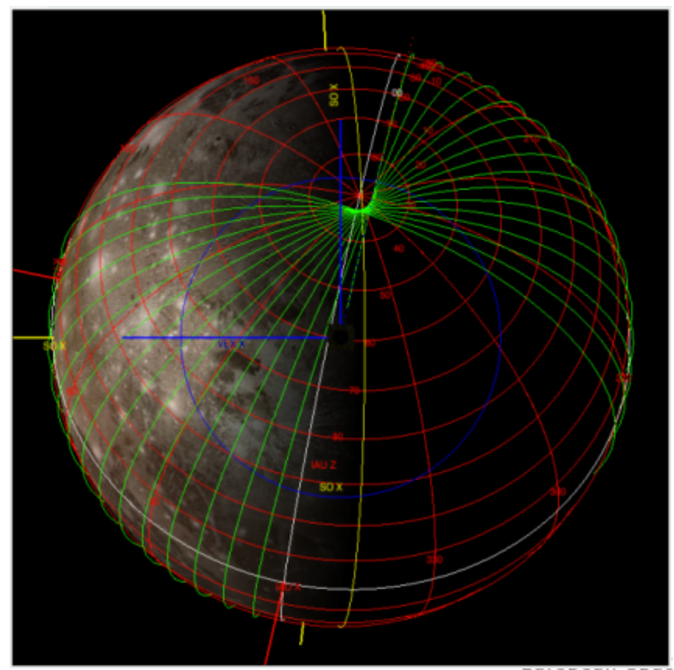
SAME INPUTS FOR SCIENCE OPERATIONS STUDY

- High level concept and basic operations scenarios
- Mission and Payload Science/Technical documentation
- Interaction with Project Scientist and SWT representatives

JMAG	Mode Name	Off	Grad			14	1. **Grad mode** only- close to continuous - 16 hours / day (when no D/L). Remark: Strategy to be discussed within WG#3 in future steps.
	Datarate (Mbps)		0,002413				
	Power (W)	2,48	7,11				
MAJIS	Mode Name	Survival	Standby	Mode 1x1		33	1. **Mode 1x1** observations on ROI only : duration = 86 s observation. 493 Mbits/cube compressed for science. Remark: the plan is one acquisition of 86 s every 12 orbits (averaged) in order to not exceed the total data volume allocation . If possible, operation on day side only and limited to low latitudes (say <50 deg). Switch-on procedure - 10 minutes
	Datarate (Mbps)			5,74			
	Power (W)	6,12	14.25	24,3			
PEP	Mode Name	Survival	Standby	Low	High	11,8	1. **Low mode** close to continuous when no D/L (15 hours/day) 2. **High mode** randomly when no D/L (1 hour/day). Remark: Strategy to be balanced within WG#3 in future steps.
	Datarate (Mbps)			0,0016	0,0081		
	Power (W)	8	8	34,5	51		

VERY DIFFERENT SCIENCE OPERATIONS CONSIDERATIONS

- LONG TERM SCIENCE ANALYSIS:
  - Several months of observations
  - 3 different science campaigns (Geophysics/Remote/In-Situ)
- SPECIFIC PAYLOAD REQUIREMENTS:
  - Illumination conditions (JANUS,MAJIS),
  - Jovian radio noise (RIME)
- RESOURCE CONSTRAINTS:
  - Data Volume (<147Gbit, 1.4Gb/day)
  - Data Downlink 8h/day on Malargue ground Station
  - Payload Power Consumption <170W



SIMILAR OUTPUT:

- Operational feasibility analysis of science scenarios (MAPPS)
- Assessment of science goals

GCO500 Sizing Case Analysis
Long Term Planning (~100days)

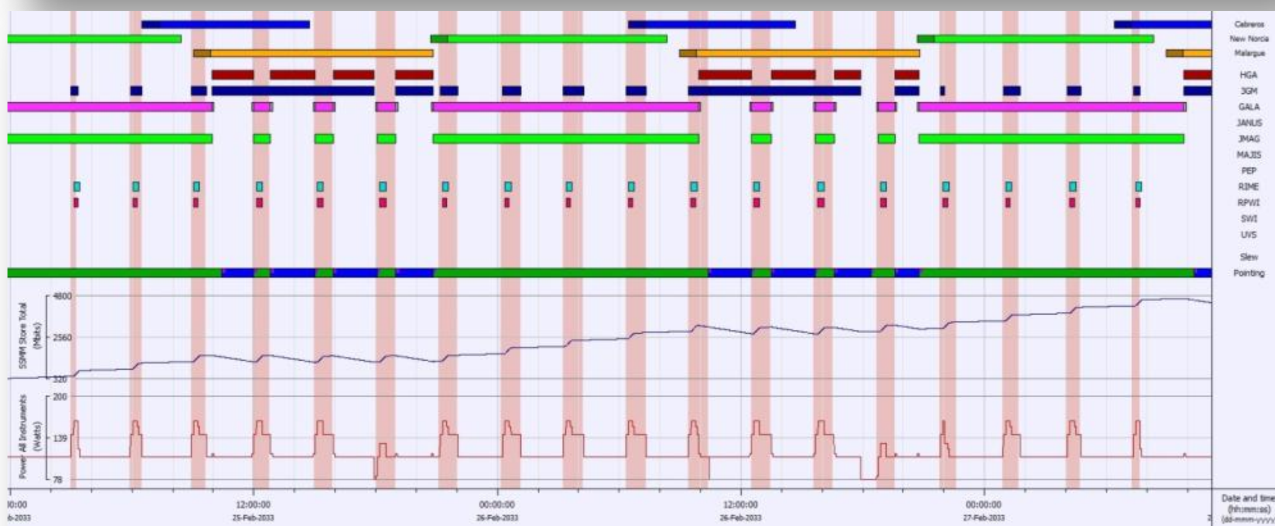
Simulations confirm feasibility of the proposed Long Term Plan

- **3 science cases separated:**
  Remote Sensing, In Situ, Geophysics

- **Event driven operations:**
  illumination, Jupiter occultations, …

- **Payload resource computation:**
  data volume, power, comms, …

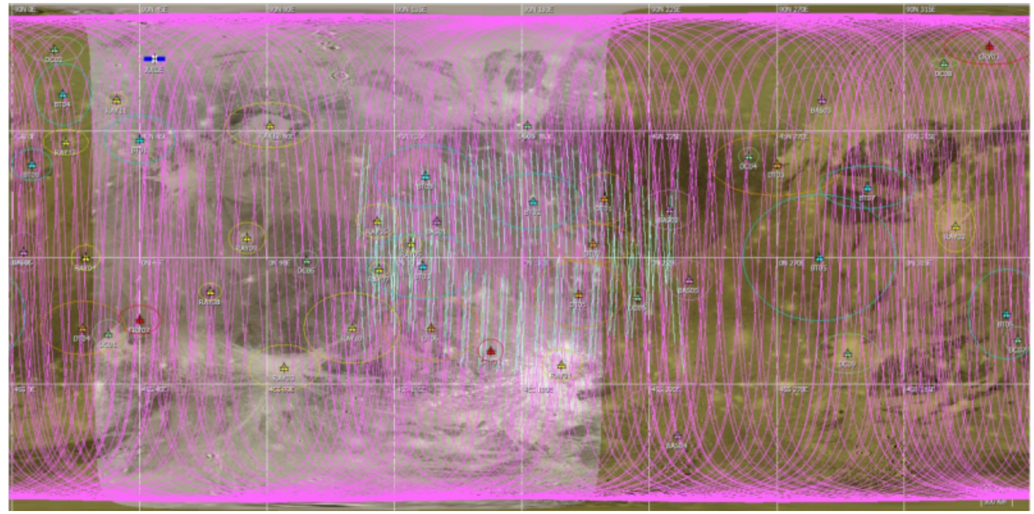
- **Science and Resource Optimization:**
  coverage, data volume, etc



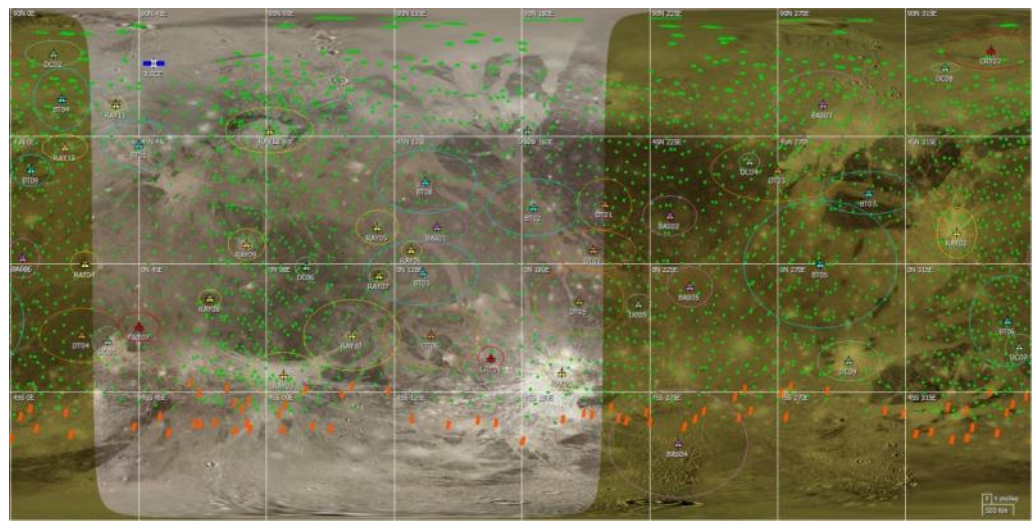
GCO500 Sizing Case analysis
Surface coverage analysis for GCO500

Surface coverage analysis demonstrates feasibility of the science objectives

- MAPPS simulation of geophysics observations.
  - GALA coverage in purple.
  - RIME coverage in blue



- Basic simulation of remote sensing coverage.
  - JANUS (green) ~2% surface coverage *
  - MAJIS (orange) <1 % surface coverage *



Conclusions

- **Science Operations Team at ESAC useful support to JUICE study/definition phases**

- **Early science operations analysis is needed!**
  - To demonstrate feasibility of mission science objectives
  - To estimate the adequacy of spacecraft and payload resources
  - To provide useful input to industry for the sizing of the spacecraft

- **Demonstrated that existing multi-mission systems and expertise can be easily reused**
  - Successful implementation with minimal resources!

  - We encourage:

re-use of expertise,
multi-mission involvement,
in-house development

Thanks for your attention