# Science Operations Support Activities for the Definition Phase of the Jupiter Icy Moons Explorer (JUICE)

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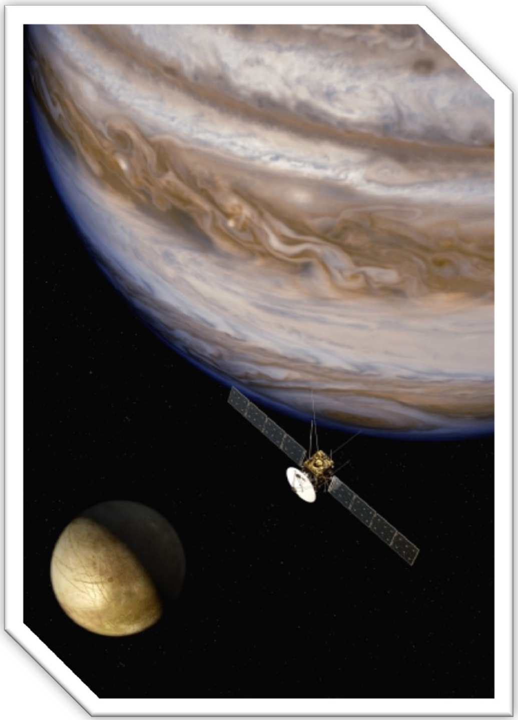
# Present science started long ago… Rosetta (1990's…)2004→2014


European Space Agency

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

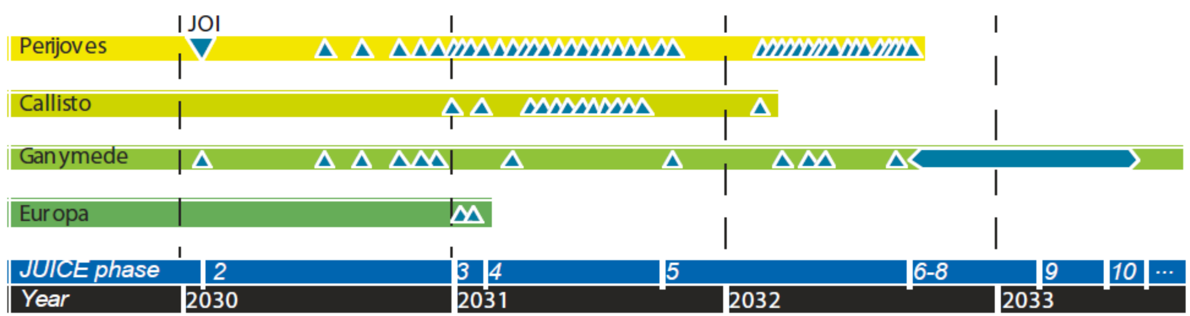
**SCIENCE GOAL: Emergence of habitable worlds around gas giants; Jupiter as an archetype for gas giants**

- 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:**

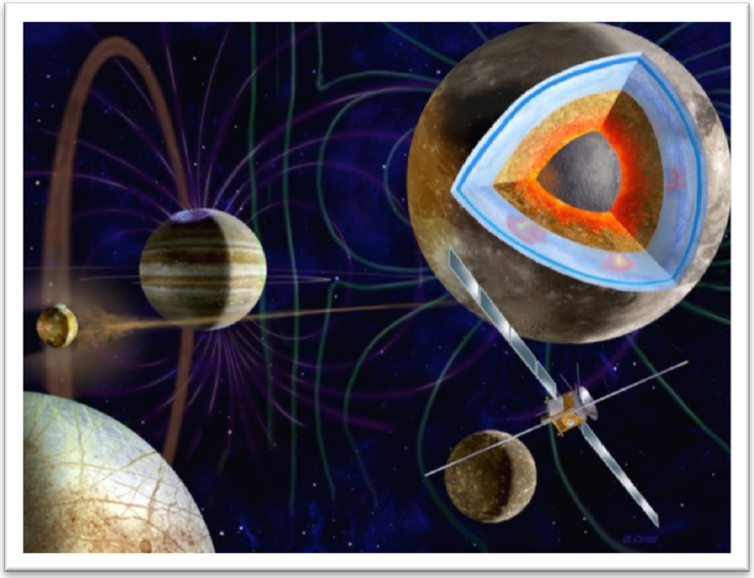
**1**. Launch and cruise (7.6 years)
**2**. JOI, and energy reduction for transfer to <u>Callisto</u> (11 months)
**3**. <u>Europa</u> flybys (36 days)
**4**. <u>Jupiter</u> High Latitude Phase (200 days)
**5**. Transfer to Ganymede (11 months)
**6-10**. <u>Ganymede</u> science phases: (282 days)
Elliptic,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



# The JUICE mission
## Bus & Payload

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

**DATA BUDGET LIMITATION**
**PAYLOAD POWER LIMITATION**



**Science Payload (11 instruments):**
- Remote Sensing :
  - JANUS (Imager)
  - MAJIS, IVS, SWI (spectrometers/spectro-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

# JUICE SciOps Analysis

## Basic Group and System setup

**Science Operations support not foreseen for JUICE in early stages!**
**Still… limited support is provided at ESAC**

### INPUTS

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

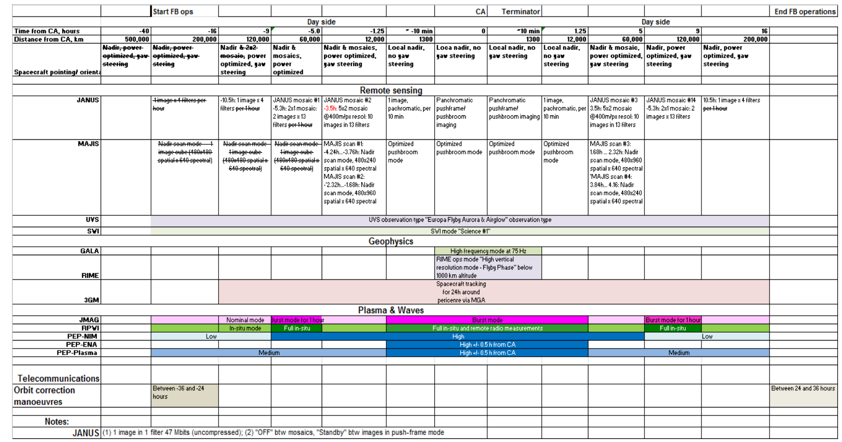
### DEVELOPMENT AT ESAC:

- Basic "informal" SciOps team for JUICE
- Basic "recycled" system setup for JUICE
- Preliminary modeling for spacecraft and payload

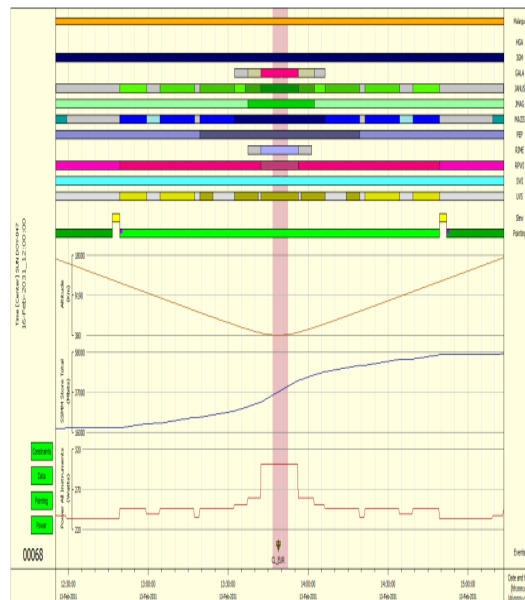
- Just "a few weeks" to do the analysis…

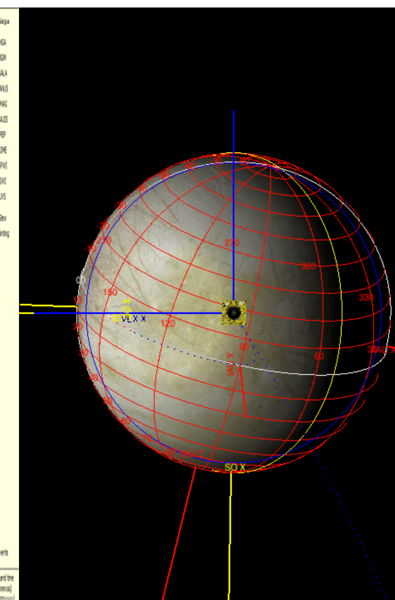
### OUTPUT:

- Operational feasibility analysis of science scenarios (MAPPS)
- Dedicated pointing geometry analysis (SOLab)



| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Start FB ops | | | | | CA | Terminator | | | | | End FB operations |
| | Day side | | | | | | | | | Day side | | | |
| Time from CA, hours | -40 | -16 | -9 | -5.0 | -1.25 | ~ -10 min | 0 | ~10 min | 1.25 | 5 | 9 | 16 | |
| Distance from CA, km | 500,000 | 200,000 | 120,000 | 60,000 | 12,000 | 1300 | | 1300 | 12,000 | 60,000 | 120,000 | 200,000 | |
| Spacecraft pointing/ orienta | ~~Nadir, power optimized, yaw steering~~ | ~~Nadir, power optimized, yaw stering~~ | Nadir ~~& 2x2 mosaic,~~ power optimized, yaw steering | Nadir & mosaics, power optimized | Nadir & mosaics, power optimized, yaw steering | Local nadir, no yaw steering | Loca nadir, no yaw steering | Local nadir, no yaw steering | Local nadir, no yaw steering | Nadir & mosaic, power optimized, yaw steering | Nadir, power optimized, yaw steering | Nadir, power optimized, yaw steering | |
| Remote sensing | | | | | | | | | | | | | |
| JANUS | | ~~1 image x 4 filters per hour~~ | -10.5h: 1 image x 4 filters ~~per 1 hour~~ | JANUS mosaic #1 -5.3h: 2x1 mosaic: 2 images x 13 filters ~~per 1 hour~~ | JANUS mosaic #2 -3.5h: 5x2 mosaic @400m/px resol: 10 images in 13 filters | 1 image, pachromatic, per 10 min | Panchromatic pushframe/ pushbroom imaging | Panchromatic pushframe/ pushbroom imaging | 1 image, pachromatic, per 10 min | JANUS mosaic #3 3.5h: 5x2 mosaic @400m/px resol: 10 images in 13 filters | JANUS mosaic #14 -5.3h: 2x1 mosaic: 2 images x 13 filters | 10.5h: 1 image x 4 filters ~~per 1 hour~~ | |
| MAJIS | | ~~Nadir scan mode – 1 image cube (480x480 spatial x 640 spectral)~~ | ~~Nadir scan mode 1 image cube (480x480 spatial x 640 spectral)~~ | ~~Nadir scan mode 1 image cube (480x480 spatial x 640 spectral)~~ | MAJIS scan #1: -4.24h...-3.76h: Nadir scan mode, 480x240 spatial x 640 spectral MAJIS scan #2: -'2.32h...-1.68h: Nadir scan mode, 480x960 spatial x 640 spectral | Optimized pushbroom mode | Optimized pushbroom mode | Optimized pushbroom mode | Optimized pushbroom mode | MAJIS scan #3: 1.68h ... 2.32h: Nadir scan mode, 480x960 spatial x 640 spectral 'MAJIS scan #4: 3.84h... 4.16: Nadir scan mode, 480x240 spatial x 640 spectral | | | |
| UVS | | UVS observation type "Europa Flyby Aurora & Airglow" observation type | | | | | | | | | | | |
| SVI | | SWI mode "Science #1" | | | | | | | | | | | |
| Geophysics | | | | | | | | | | | | | |
| GALA | | | | | | | High frequency mode at 75 Hz | | | | | | |
| RIME | | | | | | | RIME ops mode "High vertical resolution mode - Flyby Phase" below 1000 km altitude | | | | | | |
| 3GM | | | Spacecraft tracking for 24h around pericenre via MGA | | | | | | | | | | |
| Plasma & Waves | | | | | | | | | | | | | |
| JMAG | | | Nominal mode | Burst mode for 1 hour | | Burst mode | | | | | Burst mode for 1 hour | | |
| RPWI | | | In-situ mode | Full in-situ | | Full in-situ and remote radio measurements | | | | | Full in-situ | | |
| PEP-NIM | | Low | | High | | | | | | | Low | | |
| PEP-ENA | | | | | | High +/- 0.5 h from CA | | | | | | | |
| PEP-Plasma | | Medium | | | | High +/- 0.5 h from CA | | | | Medium | | | |
| Telecommunications | | | | | | | | | | | | | |
| Orbit correction manoeuvres | | Between -36 and -24 hours | | | | | | | | | | | Between 24 and 36 hours |
| Notes: | | | | | | | | | | | | | |
| JANUS | (1) 1 image in 1 filter 47 Mbits (uncompressed); (2) "OFF" btw mosaics, "Standby" btw images in push-frame mode | | | | | | | | | | | | |





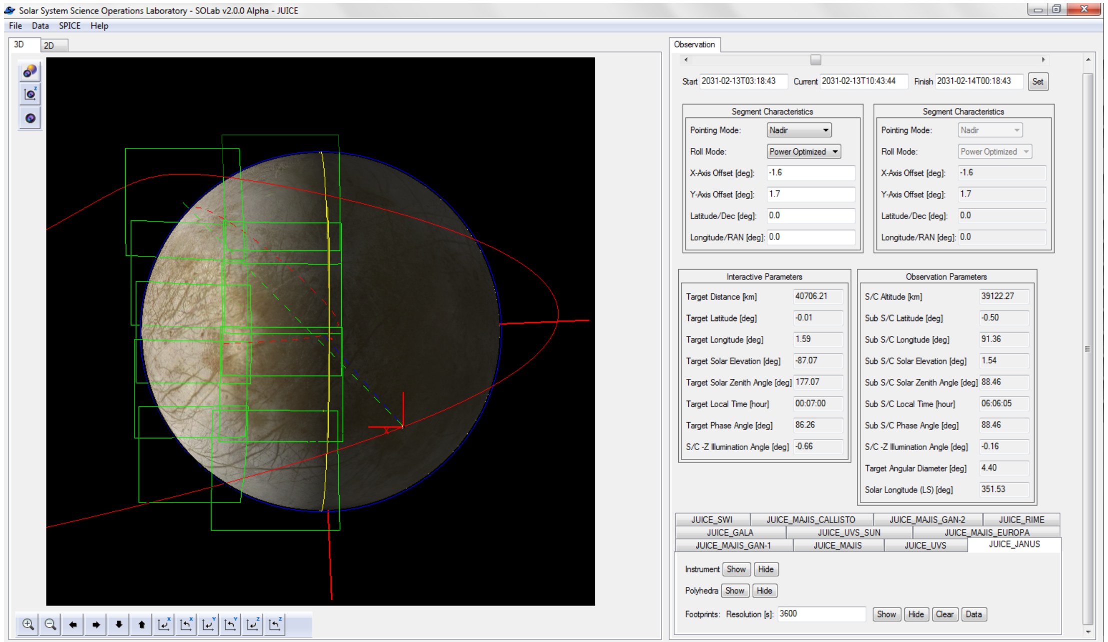
# Europa Fly-by analysis

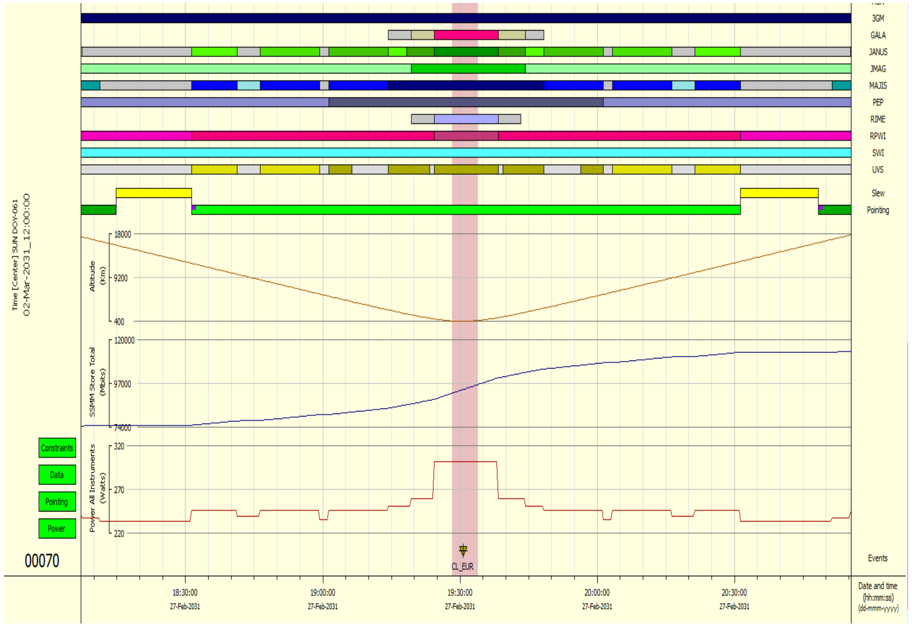
## Scientific and Operational Feasibility assessment

## Input High Level Scenario Definitions (from ESA Technical Note)

| Time before CA | -60 min to - 50 min | -45 min to -32 min | -32 min to - 30 min | -30 min | -17 min | -13 min | -7 min | +7 min to + 60 min |
|---|---|---|---|---|---|---|---|---|
| Time after CA | +50 min to +60 min | +32 min to +45 min | +30 min to +32 min | +30 min | +17min | +13 min | +7 min | |
| Altitude (km) | 12,000 to 10,000 | 9000 to 6000 | 6000 to 5700 | 5700 | 4300 | 2000 | 1000 | 1500 to 12,000 |
| SWI | Disk + limb scan Continuous operation, mode SCIENCE1, 5.23 kbit/s 48 W | Disk + limb scan Continuous operation, Mode SCIENCE1, 5.23 kbit/s 48 W | | Disk + limb scan Continuous operation, mode SCIENCE1, 5.23 kbit/s 48 W | Disk + limb scan Continuous operation, mode SCIENCE1, 5.23 kbit/s 48 W | Disk + limb scan Continuous operation, mode SCIENCE1, 5.23 kbit/s 48 W: | Disk + limb scan Continuous operation, mode SCIENCE 1, 5.23 kbit/s 48 W: | The same sequence In reverse order |

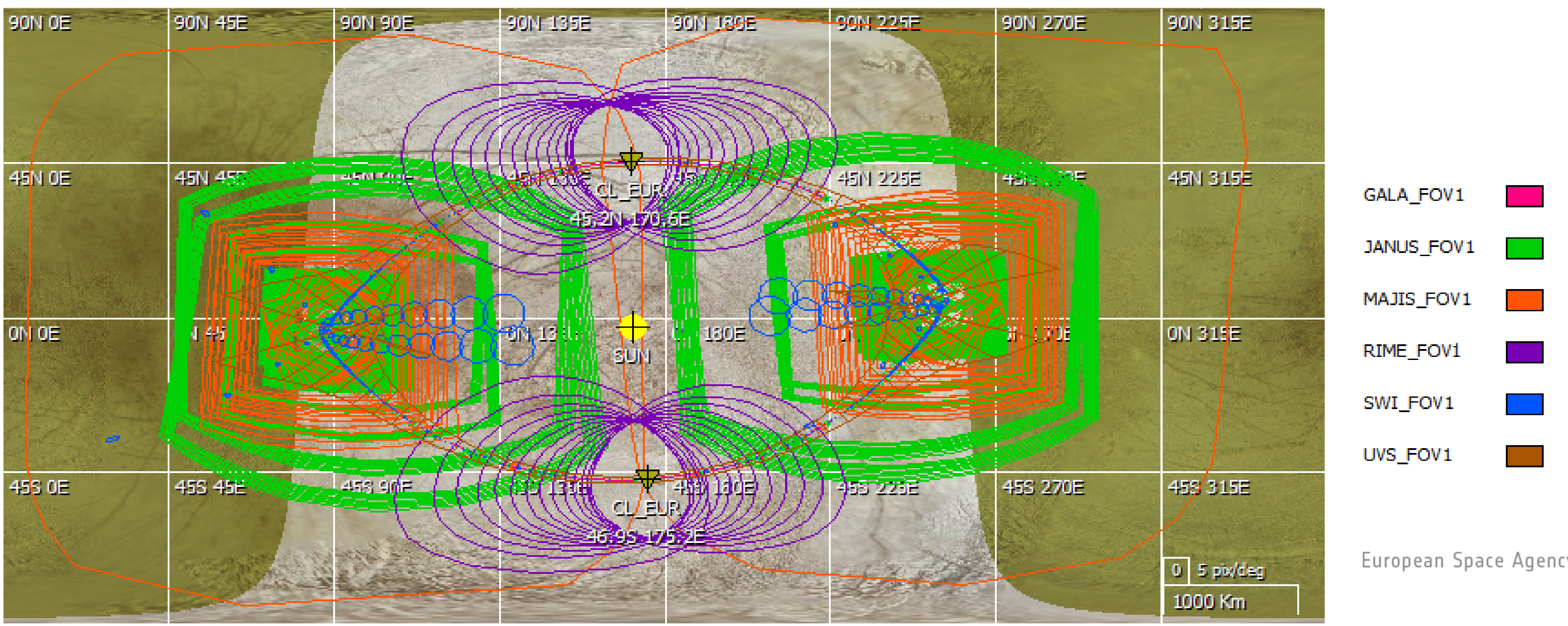
## Output Scientific and Operational feasibility analysis



# 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>75Gbit 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 230Watts</u> in average (peaks up to 300W)
  - Accumulated energy required is <u>5500Wh for each fly-by</u> (input for SC battery assessment)
  - **Surface coverage analysis demonstrates feasibility of the science objectives**



# GCO500 Sizing Case analysis
## Summary Objectives and Considerations

- **3 MAIN SCIENCE OBJECTIVES**:
  - GEOPHYSICS:
    - Characterize the global shape of Ganymede
    - Determination of the gravitational field, and the exploration of the subsurface.
    - High-resolution (both spatial and spectral) imaging of the surface over Regions Of high Interest (ROI) for geology, chemistry and eventually exobiology will also be addressed
  - REMOTE SENSING:
    - Global coverage at mid-resolution and at all wavelengths from UV to IR (achieved in previous phases)
    - High spatial and spectral resolution characterization of regions of interest
    - Exosphere composition and dynamics
  - IN-SITU:
    - Magnetosphere characterization: induced field, embedded in the intrinsic field and the Jovian field

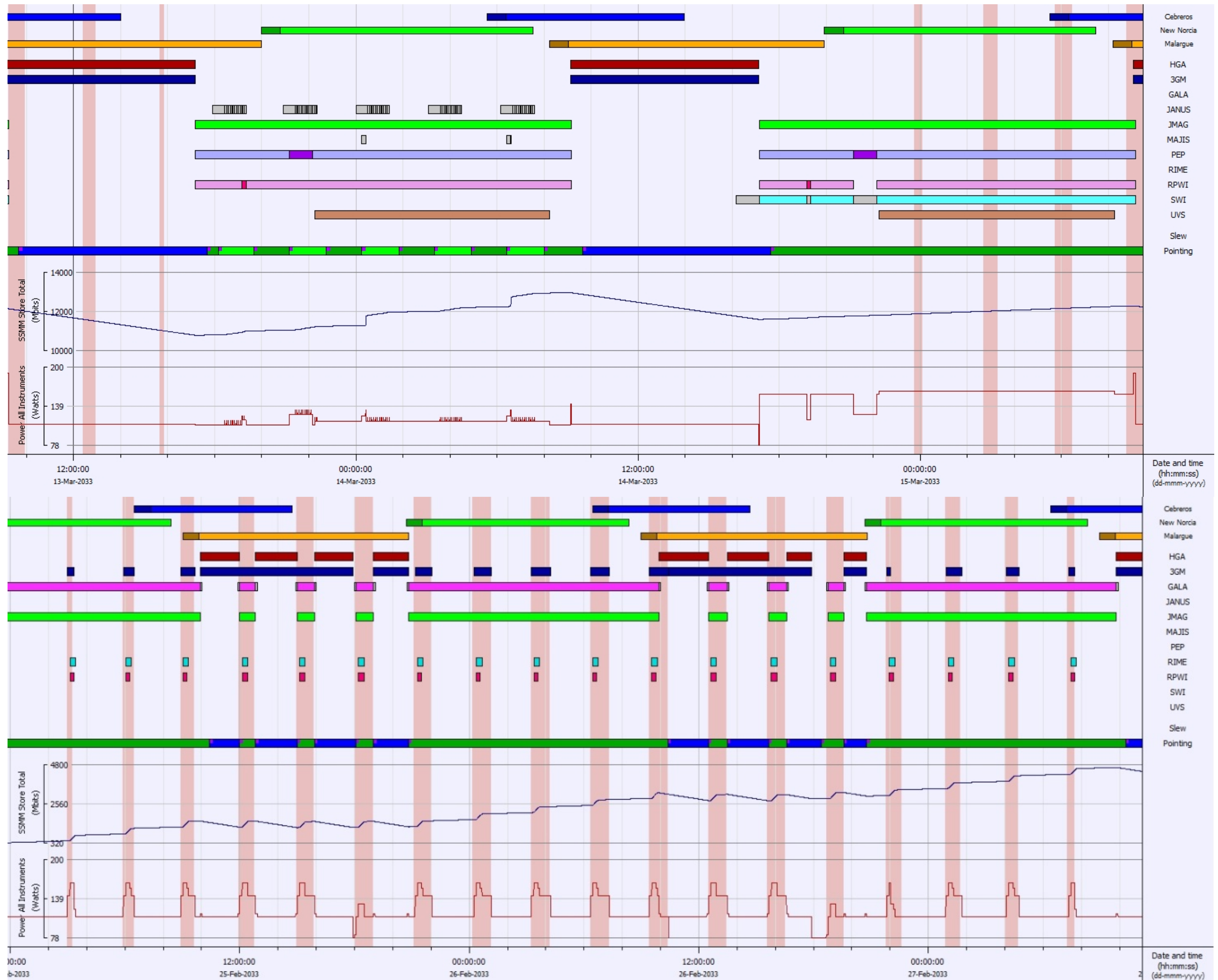
- **SCIENCE OPERATIONS CONSIDERATIONS**
  - PAYLOAD CONSTRAINTS:
    - Illumination conditions (JANUS,MAJIS), Jovian radio noise (RIME)
  - RESOURCE CONSTRAINS:
    - Data Volume (<147Gbit, 1.4Gb/day)
    - Data Downlink 8h/day on Malargue ground Station
    - Payload Power Consumption <170W

# GCO500 Sizing Case Analysis

## Long Term Planning (~100days)

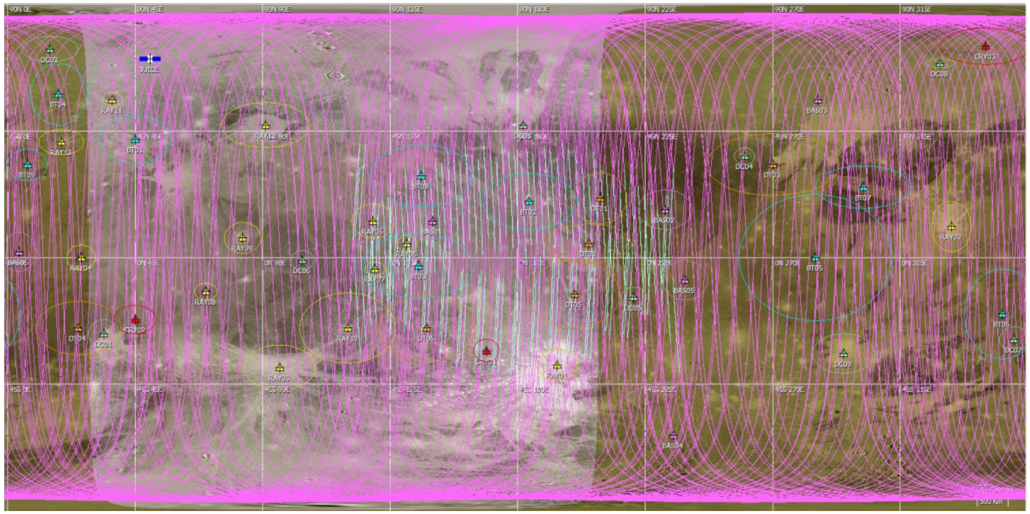
**Simulations confirm feasibility of the proposed Long Term Plan**

- **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

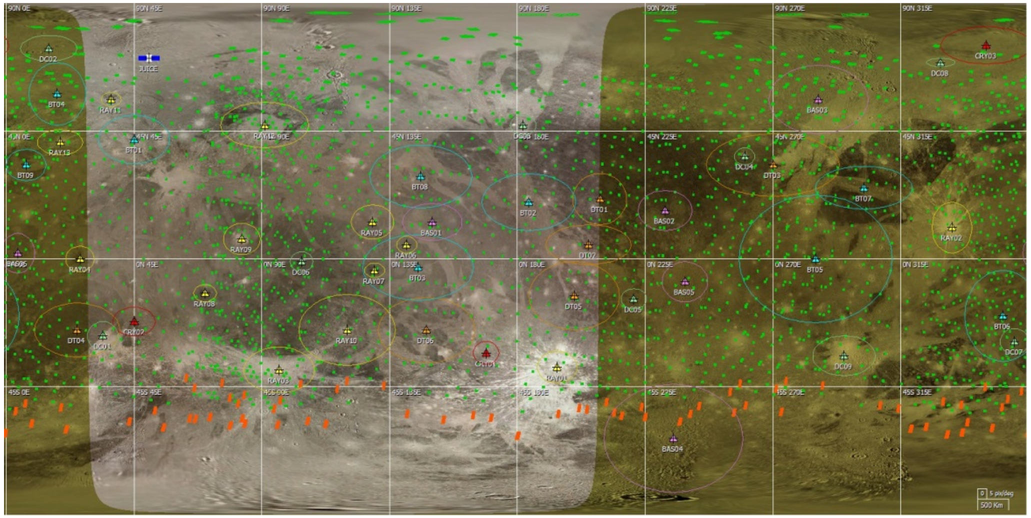


# GCO500 Sizing Case analysis
## Surface coverage analysis for GCO500

**Surface coverage analysis demonstrates feasibility of the science objectives**



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



- MAPPS simulation of remote sensing observations.
  - JANUS (green) 2.1% surface coverage
  - MAJIS (orange) 0.3 % surface coverage

# Conclusions

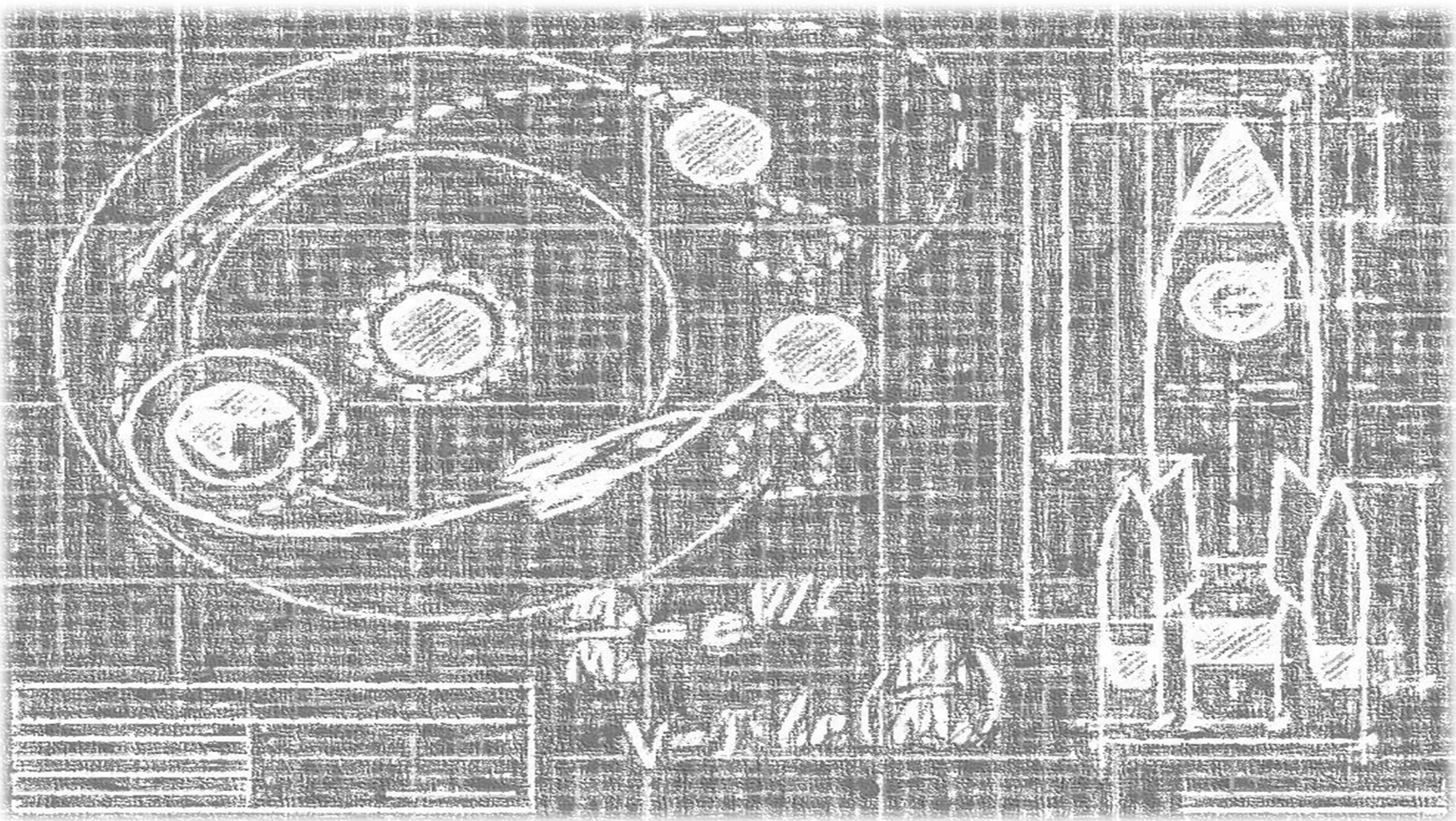
- **Science Operations Team at ESAC provided successful support to JUICE definition**

- **Early science operations analysis is needed!**
  - Demonstrate feasibility of mission science objectives
  - Estimate the adequacy of spacecraft and payload resources
  - 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…

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

# Thanks for your attention



# Early Science Operations
## Motivation

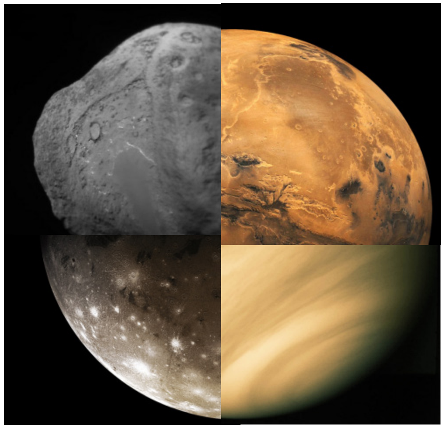
**WHY?** To (early) analyze and prove feasibility of mission objectives of (future) science operations

**WHAT?** Re-use of existing systems and expertise available in-house (@ESAC/ESA)

**SIMULATION, VISUALIZATION, and ANALYSIS of GEOMETRY and SCIENTIFIC OBSERVATION OPPORTUNITIES**

- Type of missions covered:
  - Orbiter (MEX/VEX/ExoMars/Solar Orbiter)
  - Touring (JUICE)
  - Targeting (Rosetta)
- Typical usage per mission phase:
  - Definition phase (JUICE)
  - Development Phase (BepiColombo/SolO/ExoMars)
  - Routine operations (VEX/MEX)

Multi-mission horizontal approach that builds up internal expertise



**WHO?** The current SOLab "Group"

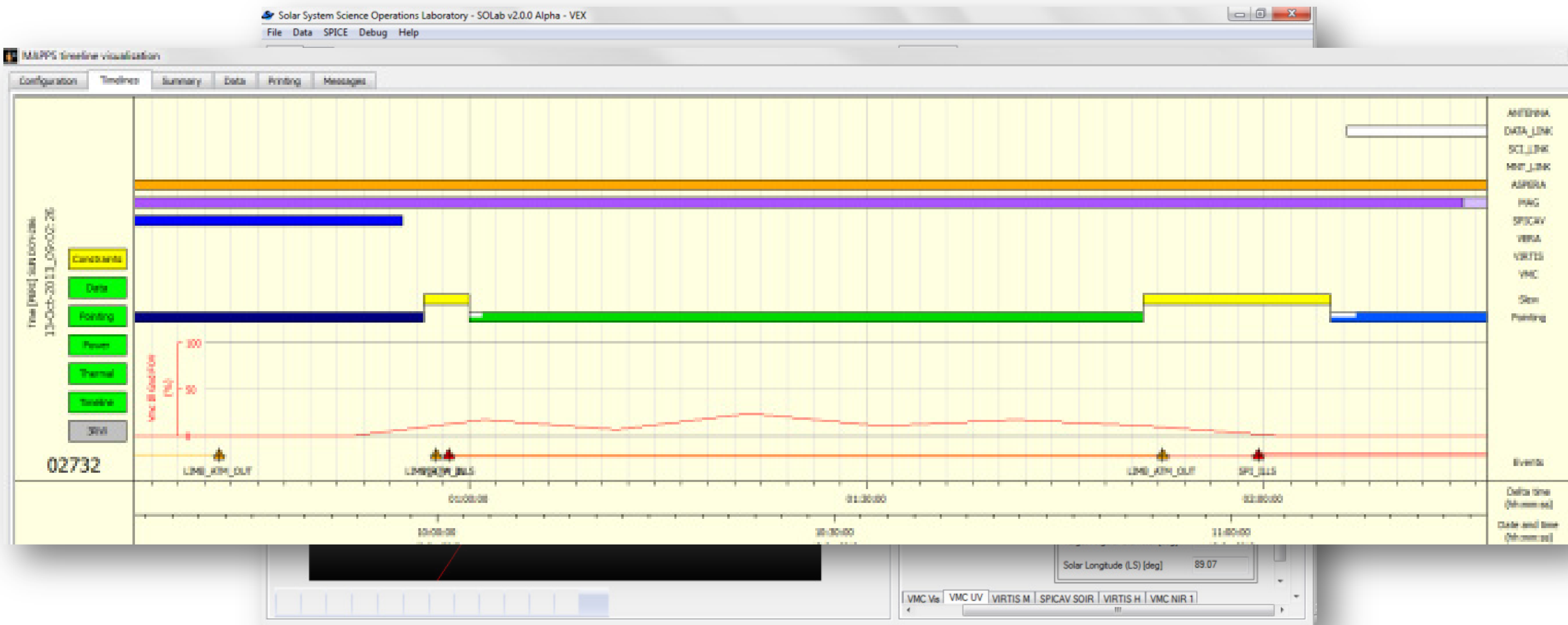
| | | |
|---|---|---|
| Alejandro Cardesín | (ISDEFE/ESA) | ExoMars, MEX, VEX, Rosetta |
| Marc Costa | (ISDEFE/ESA) | Rosetta, VEX |
| Miguel Almeida | (VEGA/ESA) | Rosetta, VEX, Smart-1 |
| Nicolas Altobelli | (ESA) | JUICE, Rosetta, Cassini-Huygens, MEX |
| David Frew | (ESA) | ExoMars, Rosetta, MEX, VEX, Smart-1 |

**WHERE?** @ ESAC - European Space and Astronomy Center, ESA site for Science Operations and Science Archives

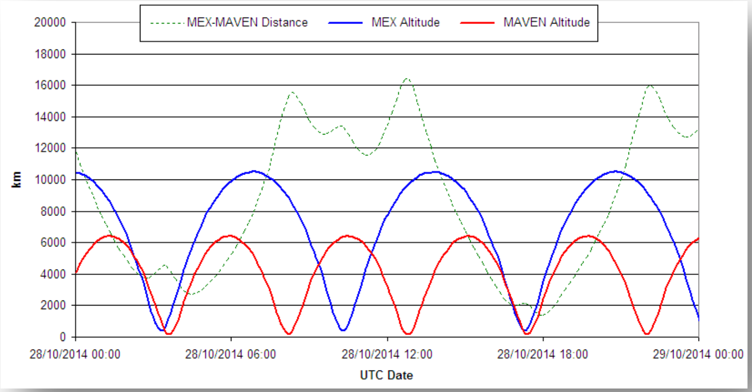
# Science Operations Activities

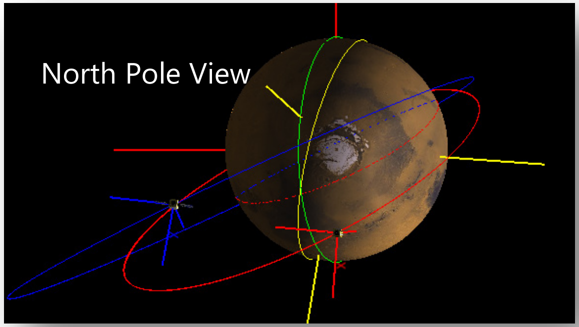
## Dedicated Timeline and pointing analysis

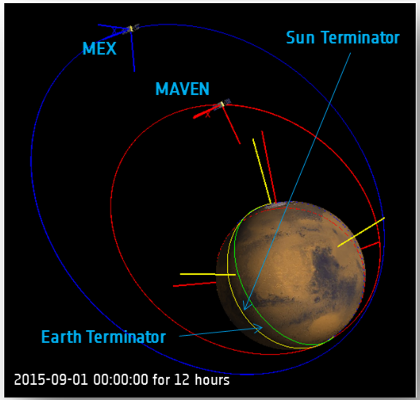
**A very simple example:** Pointing computation and optimization for VMC camera on Venus Express



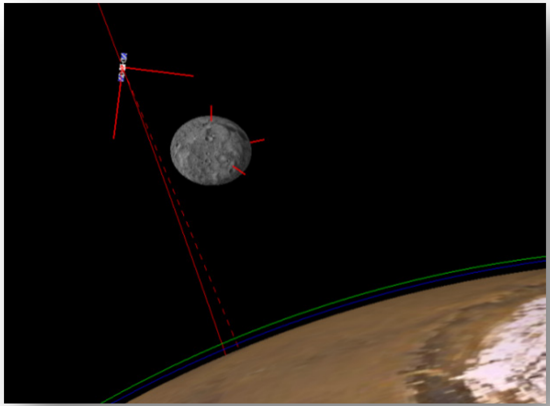
- **Computation and Analysis of Science Campaigns**
  - Joint **MEX-MAVEN** observation campaigns of the Martian magnetosphere

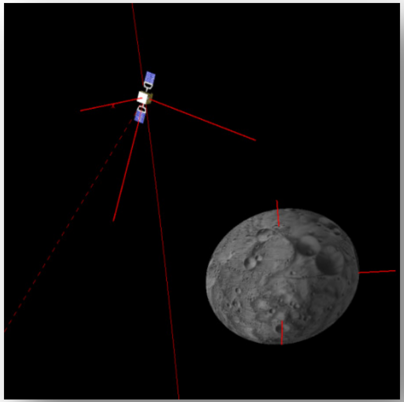



  - **MEX Phobos flyby** geometry analysis



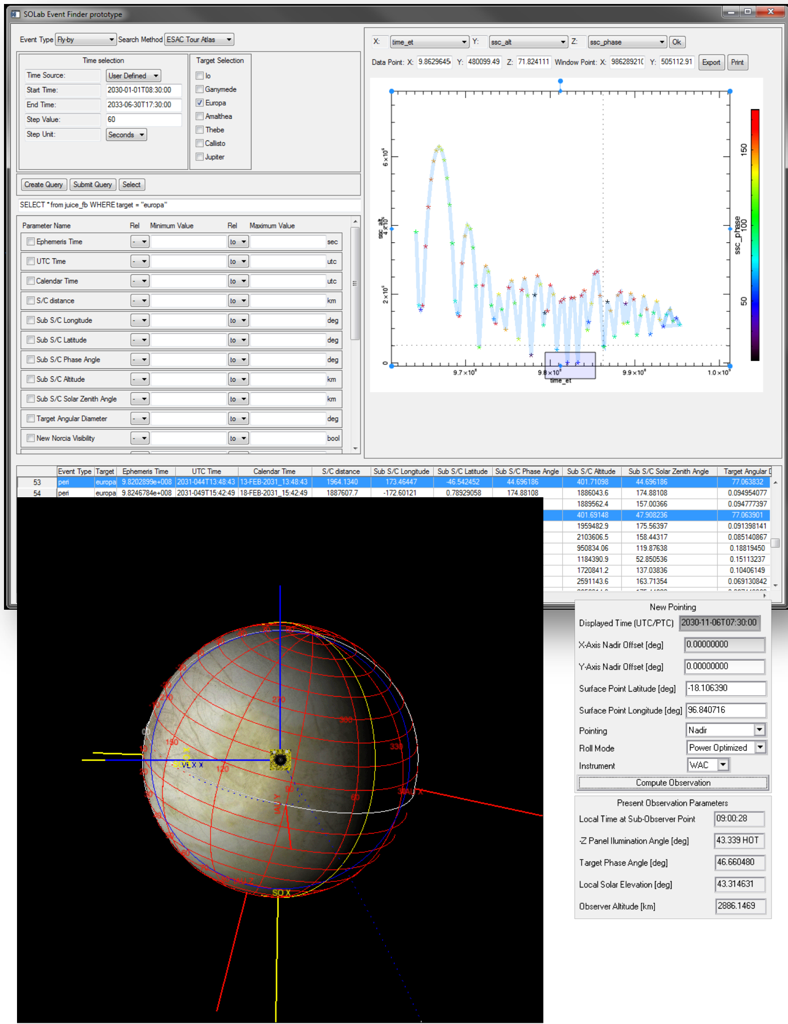


# Science Operations Activities

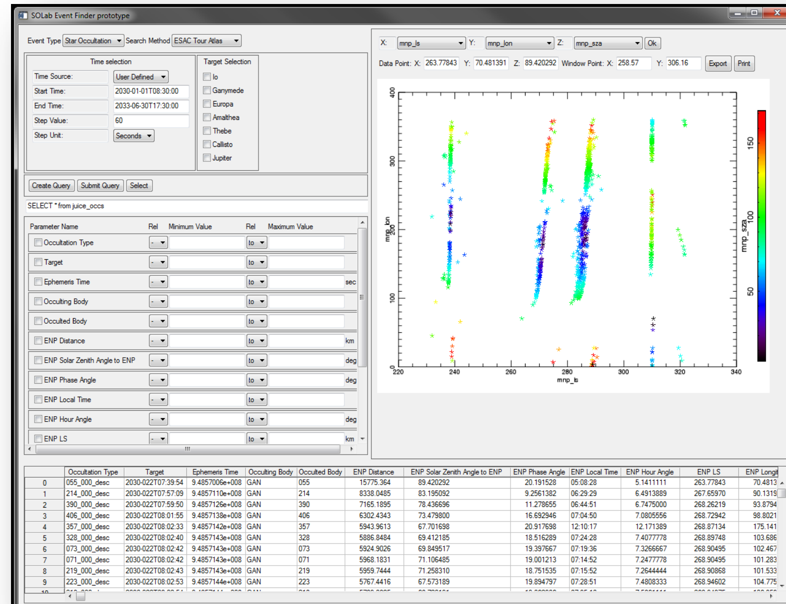
## Long Term Science Opportunity Analysis

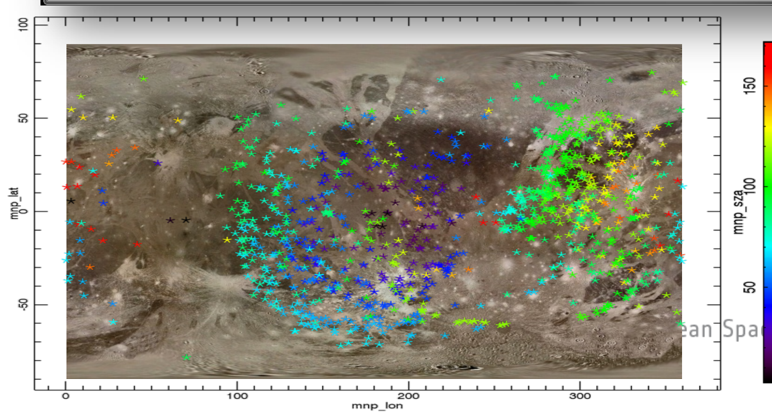
### Computation of observation opportunity events and analysis of contextual geometry

Europa fly-by opportunity analysis



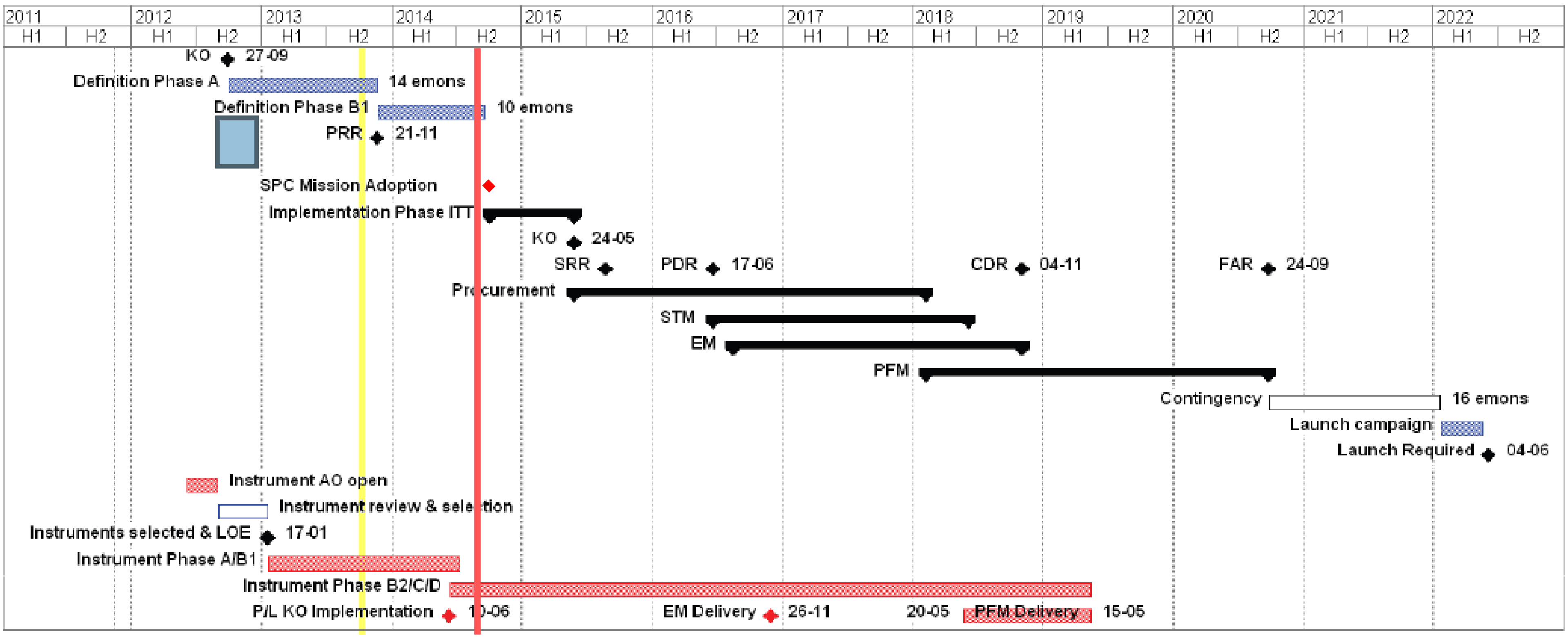

Ganymede Earth Occultation analysis



# The JUICE mission

## Development Timeline



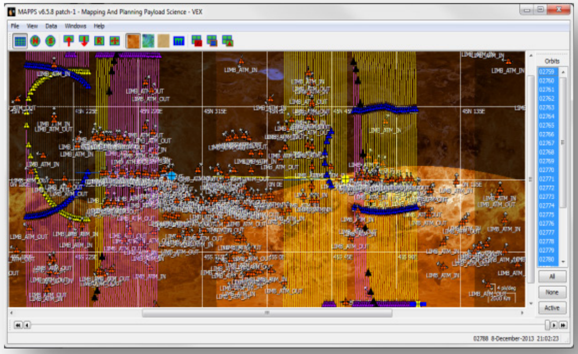

FONT: JUICE assessment study report (Yellow Book): http://sci.esa.int/juice/49837-juice-assessment-study-report-yellow-book/#

# Science Operations Tools
## MAPPS/EPS and SOLab

- Two main planning tools object of the current study:
  - MAPPS/EPS (simulation of science operations)
  - SOLab (advanced geometry computations)

### 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

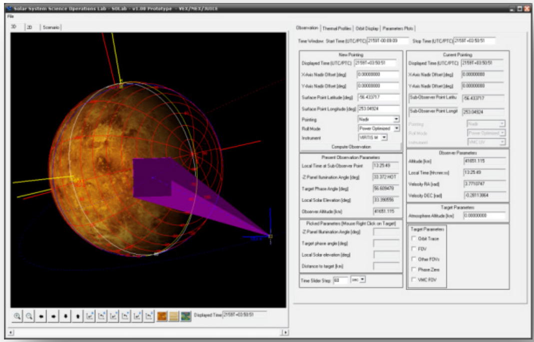


- Experiment Planning System: payload commanding modelling.
  - Payload and spacecraft resources, sequences and transitions.
  - Generation of command level sequences
  - Payload planning files

- Operationally used by:
  - SMART-1, VEX, MEX, Rosetta, BepiColombo, Solar Orbiter, Exomars TGO.

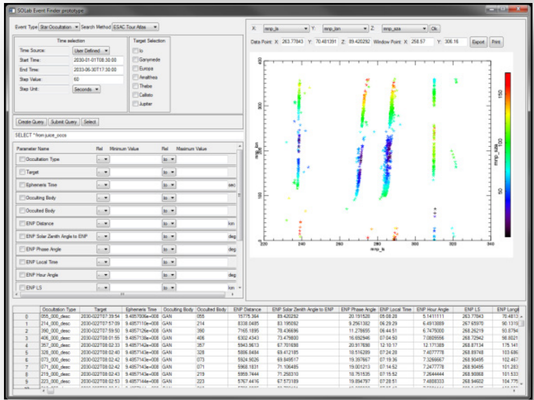
# Science Operations Tools
## MAPPS/EPS and SOLab

- Two main planning tools object of the current study:
  - MAPPS/EPS (simulation of science operations)
  - SOLab (advanced geometry computations)



### SOLab

- Solar System Science Operations Laboratory (SOLab):
  - Research project for geometry computation and 3D visualization
  - Quick analysis and visualization of observation scenarios
  - Support to Medium and Long Term science operations planning
  - Interactive pointing and attitude simulation
  - Science opportunity analysis



Prototype Software tested on :

VEX, MEX, Rosetta, Bepi Colombo, Marco Polo-R, Solar Orbiter, …

# Conclusions

**For the SOLab group:**

- Developing in-house core competitive expertise with multi-mission involvement:

  GEOMETRY-SCIENTIFIC OBSERVATION OPPORTUNITIES analysis and VISUALIZATION for planetary missions

- Demonstration that current operational and in-development tools for Solar System Science Operations can be used during the study phase of JUICE

**For the JUICE SWT:**

- Exercise with the JUICE Science Working Team the workflow with a skeleton Science Ground Segment
- Estimation of the adequacy of the available spacecraft resources for the Europa flybys
- Obtained an estimate for the spacecraft sizing for the Ganymede case
- Demostration of the feasibility of the science objectives with the preliminary sizing numbers provided by industry

# GCO500 Sizing Case analysis

## Inputs from Science Working Team

### INPUTS FOR SCIENCE OPERATIONS

- Iterations with the Science Working Team and with selected individuals in coordination with the instrument teams
- Each instrument has been assigned a specific amount of time for observation using dedicated modes (see column on the right). The total amount of data (compressed data volume) per instrument has been estimated with this strategy of observation. They are consistent with the instruments data volume allocation. It corresponds roughly to about 50 % of data for remote sensing, 25 % for in situ, and 25 % for geophysics.

| | | Survival | Standby | Op. Mode | Op. Mode | Total data volume MAPPS output Gb compressed (in red-OG | Strategy of observations (in red-OG suggestions/questions based on Pis inputs) |
|---|---|---|---|---|---|---|---|
| 3GM | Mode Name | Survival | Standby | Carrier acq. | | N/A | 1. **Carrier acquisition** mode simultaneously with Earth Communications.<br>Remark: Depending on PRR, MGA should be considered in future steps (up to two hours /day), and especially when RIME is on. |
| | Datarate (Mbps) | | | 0 | | | |
| | Power (W) | 6 | 6 | 38,87 | | | |
| GALA | Mode Name | Survival | Standby | Reduced | | 13,7 | 1. **Reduced shot-rate and shot frequency**, continuous acquisition 16 hours every three days. The operations should be planned regardless of day and night time or any other illumination conditions.<br>2. **Reduced shot-rate and shot frequency** simultaneous to RIME.<br>switch-on/switch-off: 5 minutes. Stand-by mode in this 5 Minutes phases, i.e. 14.5 W<br>Remark: "reduced" mode as proposed by PI. It will be documented in the next |
| | Datarate (Mbps) | | | 0,007 | | | |
| | Power (W) | 14,5 | 14,5 | 37,8 | | | |
| JANUS | Mode Name | Off | Standby | cience 2x2 | | 29 | 1. **2x2 binning** (15 m/pxl). DR = 0.55 Mbps for 23 s in science 1x1 (12.7 Mb/image).<br>With proper illumination conditions, MAPPS should plan for imaging all ROIs when no conflict is identified. Try to avoid multiple imaging of the same area.<br>Switch-on procedure - 30 minutes<br>Remark: Observations should be focused on ROI only. Mode 2x2 is suggested by PI to get an averaged estimate. It will be documented in the next version of EID-B.<br>Other modes should be considered after PRR in agreement with modes as listed in EID-B. |
| | Datarate (Mbps) | | | 0,55 | | | |
| | Power (W) | ??? | 22 | 28,3 | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| JMAG | Mode Name | Off | Grad | | | 14 | 1. **Grad mode** only- close to continuous - 16 hours / day (when no D/L).<br>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.<br>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).<br>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)<br>2. **High mode** randomly when no D/L (1 hour/day).<br>Remark: Strategy to be balanced within WG#3 in future steps. |
| | Datarate (Mbps) | | | 0,0016 | 0,0081 | | |
| | Power (W) | 8 | 8 | 34,5 | 51 | | |
| RIME | Mode Name | Survival | Standby | Orbital | | 28 | 1. **Orbital mode** over ROI only when jupiter shielding effective. Cross-tracking whenever possible.<br>Remark: Observations should be simultaneous to (i) GALA, (ii) RPWI "High", and (iii) 3GM MGA in future steps if feasible-not considered in this simulation. |
| | Datarate (Mbps) | | | 0,25 | | | |
| | Power (W) | 13,3 | 13,3 | 25,1 | | | |
| RPWI | Mode Name | Off | Standby | Survey | Full | 11,7 | 1. **Survey Mode** close to continuous when no D/L (15,66 hours/day).<br>2. **Full mode** 20 mn/day randomly when no D/L, especially simultaneous to RIME.<br>Remark: Strategy to be balanced within WG#3 in future steps. |
| | Datarate (Mbps) | | | 0,00096 | 0,05568 | | |
| | Power (W) | 4,716 | 4,716 | 5,5 | 13,3 | | |
| SWI | Mode Name | Survival | Standby | Science1 | | 7,7 | **Science 1 mode**: continuous acquisition 4 hours / day.<br>Switch on duration: 60 minutes<br>Remark: mitigation between different modes and startegy of observation to be discussed within WG#2 in future steps. |
| | Datarate (Mbps) | | | 0,00523 | | | |
| | Power (W) | 1,1362 | 1,1362 | 48,5645 | | | |
| UVS | Mode Name | Survival | Standby | Histogram | | 8,3 | 1. **Histogram mode**: continuous acquisition with 8 hours / day.<br>Switch on/off duration: close to instantaneous, but if the instrument is "on" all the time.<br>Remark: mitigation between different modes and strategy of observation to be discussed within WG#2 in future steps. Histogram mode as proposed by PI. It will be documented in the next version of EID-B. |
| | Datarate (Mbps) | | | 0,00283 | | | |
| | Power (W) | 4,5 | 4,5 | 9,7 | | | |
| | | | | | | 157 | |

# GCO500 Sizing Case analysis

## Science Operations Strategy for a MAPPS lead study

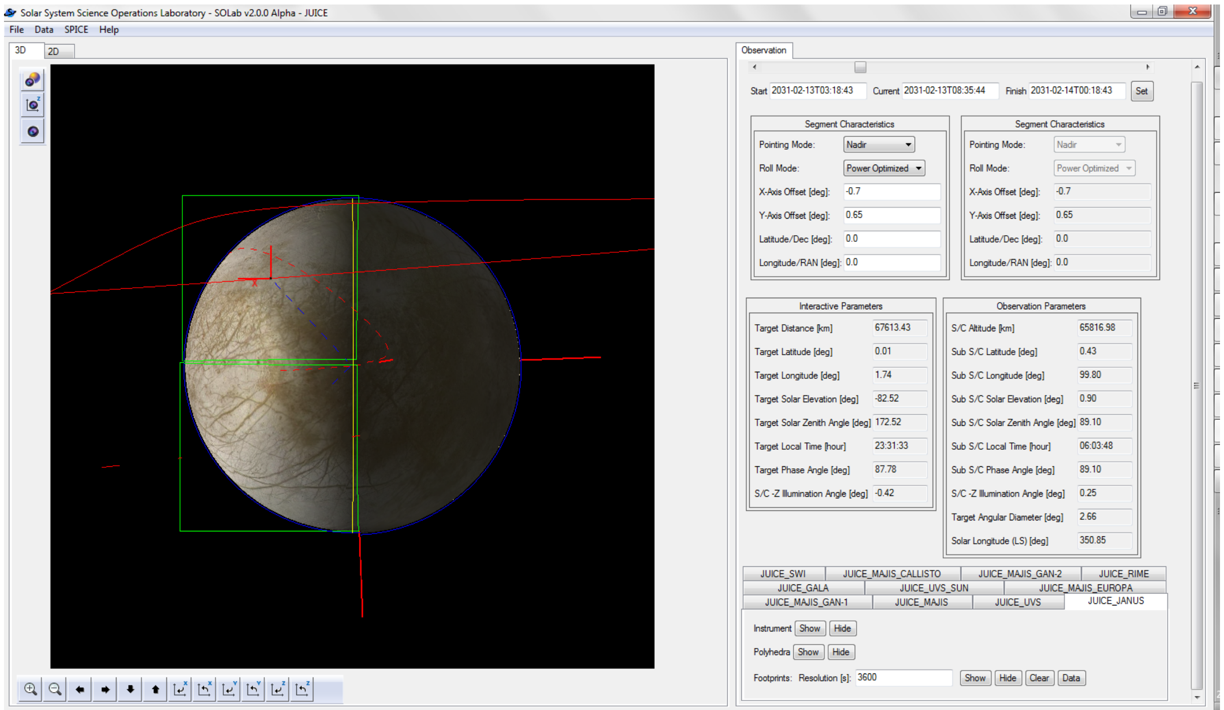
- First operational strategy was to divide the whole phase in the three science cases: Remote Sensing, Geophysics and In Situ.
- Each of that phase was given a whole day of operations and therefore an even distribution along the whole phase. This lead in roughly 33 repetitions for each case.
- This approach is compliant with the initial studies that were provided to industry but both were found to be not ideal for science observation scheduling.
- On top of that first iteration, given the priority that RIME has during this phase. RIME operates when there is an anti-Jovian opportunity window (**SOLab**!). 6 sets of 3 days Geophysics observations were of higher priority (lack of other instruments being operated was compensated in the rest of the phase).
- This was followed by a study of observation opportunities for JANUS and MAJIS of ROIs (**SOLab**!), the analysis provided by the MAPPS team revealed that there are a total amount of 2463 ROI observation opportunities with favourable geometry
- The last step to enhance the operational strategy was to complement observations with other instruments, such as for example during the RIME campaigns to also have GALA, RPWI, 3GM and JMAG.

**Data Volume and Power conflicts were identified during the planning process and were also used as drivers for the evolution of the operational strategy. In terms of Data, this analysis has shown that some observations had to be reduced in order to meet the Data Volume objectives. Additionally the analysis shows that there is a Data Volume carry-over to the next phase GCO200 with the current strategy (around~20Gbites).**

# Hands-on JUICE

## SOLab led feasibility assessment: Europa Flyby

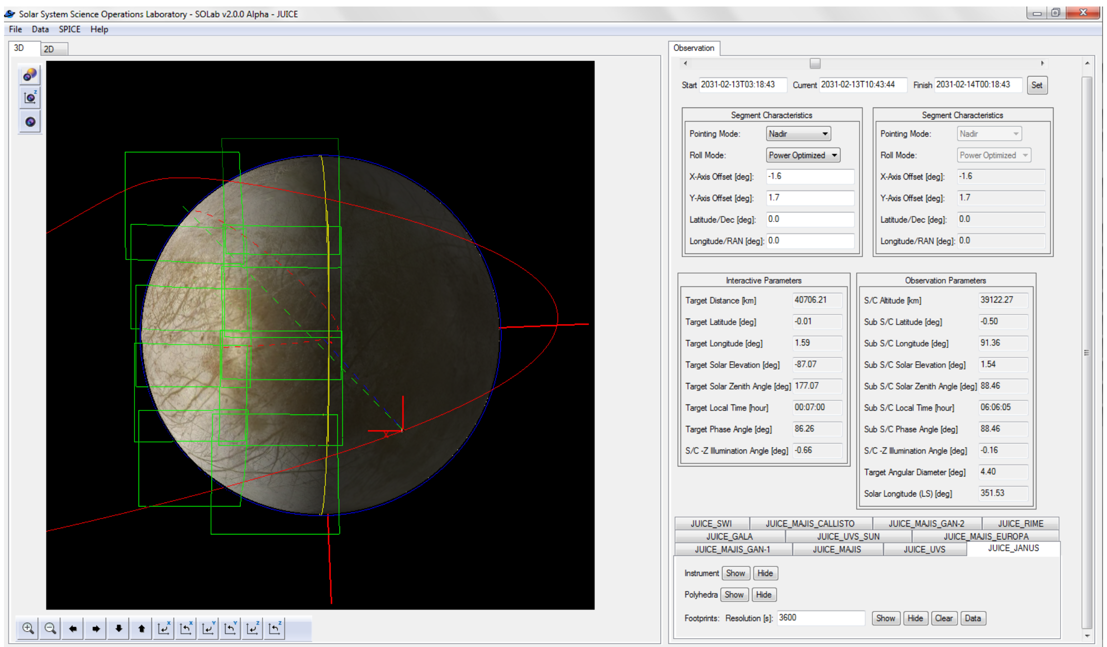
| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Start FB ops | | | | | CA | Terminator | | | | | End FB operations |
| | | | | Day side | | | | | | | Day side | | |
| **Time from CA, hours** | **-40** | **-16** | **-9** | **-5.0** | **-1.25** | **~ -10 min** | **0** | **~10 min** | **1.25** | **5** | **9** | **16** | |
| **Distance from CA, km** | **500,000** | **200,000** | **120,000** | **60,000** | **12,000** | **1300** | | **1300** | **12,000** | **60,000** | **120,000** | **200,000** | |
| **Spacecraft pointing/ orienta** | ~~**Nadir, power optimized, yaw steering**~~ | ~~**Nadir, power optimized, yaw stering**~~ | **Nadir ~~& 2x2 mosaic,~~ power optimized, yaw steering** | **Nadir & mosaics, power optimized** | **Nadir & mosaics, power optimized, yaw steering** | **Local nadir, no yaw steering** | **Loca nadir, no yaw steering** | **Local nadir, no yaw steering** | **Local nadir, no yaw steering** | **Nadir & mosaic, power optimized, yaw steering** | **Nadir, power optimized, yaw steering** | **Nadir, power optimized, yaw steering** | |
| | | | | | | | | | | | | | |
| | | | | | Remote sensing | | | | | | | | |
| **JANUS** | | ~~1 image x 4 filters per hour~~ | -10.5h: 1 image x 4 filters ~~per 1 hour~~ | JANUS mosaic #1 -5.3h: 2x1 mosaic: 2 images x 13 filters ~~per 1 hour~~ | JANUS mosaic #2 -3.5h: 5x2 mosaic @400m/px resol: 10 images in 13 filters | 1 image, pachromatic, per 10 min | Panchromatic pushframe/ pushbroom imaging | Panchromatic pushframe/ pushbroom imaging | 1 image, pachromatic, per 10 min | JANUS mosaic #3 3.5h: 5x2 mosaic @400m/px resol: 10 images in 13 filters | JANUS mosaic #14 -5.3h: 2x1 mosaic: 2 images x 13 filters | 10.5h: 1 image x 4 filters ~~per 1 hour~~ | |



# Hands-on JUICE

## SOLab led feasibility assessment: Europa Flyby

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Start FB ops | | | | | CA | Terminator | | | | | End FB operations |
| | | | | Day side | | | | | | Day side | | | |
| **Time from CA, hours** | **-40** | **-16** | **-9** | **-5.0** | **-1.25** | **~ -10 min** | **0** | **~10 min** | **1.25** | **5** | **9** | **16** | |
| **Distance from CA, km** | **500,000** | **200,000** | **120,000** | **60,000** | **12,000** | **1300** | | **1300** | **12,000** | **60,000** | **120,000** | **200,000** | |
| **Spacecraft pointing/ orienta** | ~~**Nadir, power optimized, yaw steering**~~ | ~~**Nadir, power optimized, yaw stering**~~ | **Nadir ~~& 2x2 mosaic,~~ power optimized, yaw steering** | **Nadir & mosaics, power optimized** | **Nadir & mosaics, power optimized, yaw steering** | **Local nadir, no yaw steering** | **Loca nadir, no yaw steering** | **Local nadir, no yaw steering** | **Local nadir, no yaw steering** | **Nadir & mosaic, power optimized, yaw steering** | **Nadir, power optimized, yaw steering** | **Nadir, power optimized, yaw steering** | |
| | | | | | | | | | | | | | |
| | | | | | Remote sensing | | | | | | | | |
| **JANUS** | | ~~1 image x 4 filters per hour~~ | -10.5h: 1 image x 4 filters ~~per 1 hour~~ | JANUS mosaic #1 -5.3h: 2x1 mosaic: 2 images x 13 filters ~~per 1 hour~~ | JANUS mosaic #2 -3.5h: 5x2 mosaic @400m/px resol: 10 images in 13 filters | 1 image, pachromatic, per 10 min | Panchromatic pushframe/ pushbroom imaging | Panchromatic pushframe/ pushbroom imaging | 1 image, pachromatic, per 10 min | JANUS mosaic #3 3.5h: 5x2 mosaic @400m/px resol: 10 images in 13 filters | JANUS mosaic #14 -5.3h: 2x1 mosaic: 2 images x 13 filters | 10.5h: 1 image x 4 filters ~~per 1 hour~~ | |

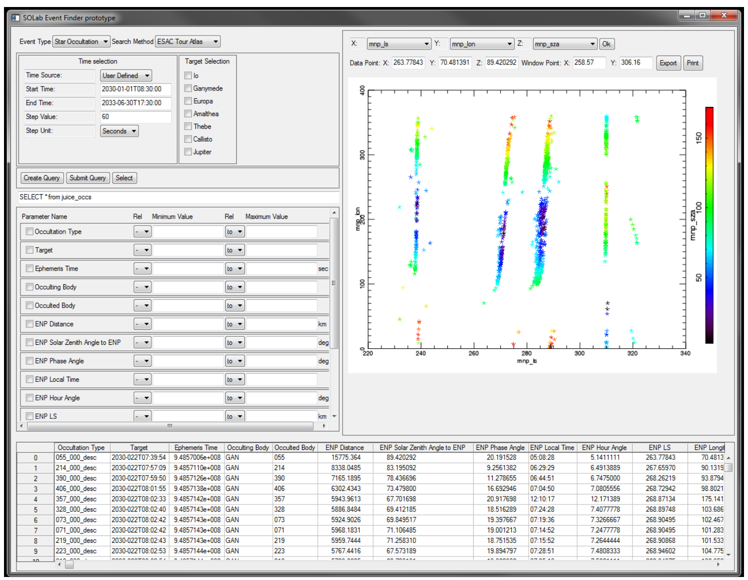



```
CLS_APP_EUR (COUNT = 1) -05:18:00   JSGS  INCLUDE "JN_EUR_CLS_APP_MOSAIC#1_PTR_v01.ptr"
CLS_APP_EUR (COUNT = 1) -05:18:00   JSGS  INCLUDE "JN_EUR_CLS_APP_MOSAIC_ON_ITL_v01.itl"
CLS_APP_EUR (COUNT = 1) -05:08:00   JSGS  INCLUDE "JN_EUR_CLS_APP_MOSAIC_OFF_ITL_v01.itl"

00:00:00  JSGS  NADIR_START ( \
               ROLL_MODE = POWER_OPTIMISED \
               PITCH = 0.65 [degrees] \
               YAW = 0.65 [degrees] \
               SLEW_POLICY = BEFORE_NEXT)

00:05:00  JSGS  NADIR_START ( \
               ROLL_MODE = POWER_OPTIMISED \
               PITCH = 0.65 [degrees] \
               YAW = -0.7 [degrees] \
               SLEW_POLICY = IMMEDIATE)

00:10:00 JSGS  NADIR_END

000_00:00:00  JANUS  *  SWITCH_MODE (CURRENT_MODE = SCIENCE [ENG])
```

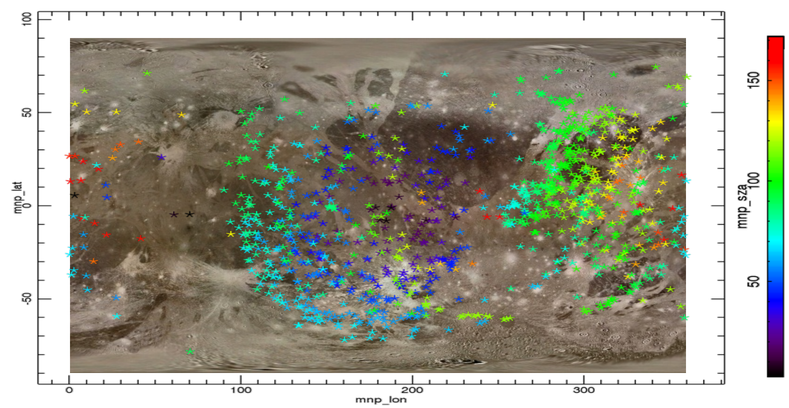
# Science Opportunity Analysis

## Right time and right conditions for science

- Computation of observation opportunities to find best observation condition (e.g. Occultation's, fly-bys, illumination).
  - An **event** is a user defined geometrical condition which is true for a given time period or instant.
  - Events can be combined on order to define **observation opportunities**. Earth and star occultations, separation angles, flyby's, latitude coverage…
- **Event Finder & Handler**
  - Uses APIs from SPICE geometry finder or queries precomupted database
  - Displays the events and allows to refine the search by sorting the events
  - Interfaces with the Visualization and plotting Module.
- Example: JUICE Tour Atlas Stellar/Sun/Earth occultations database



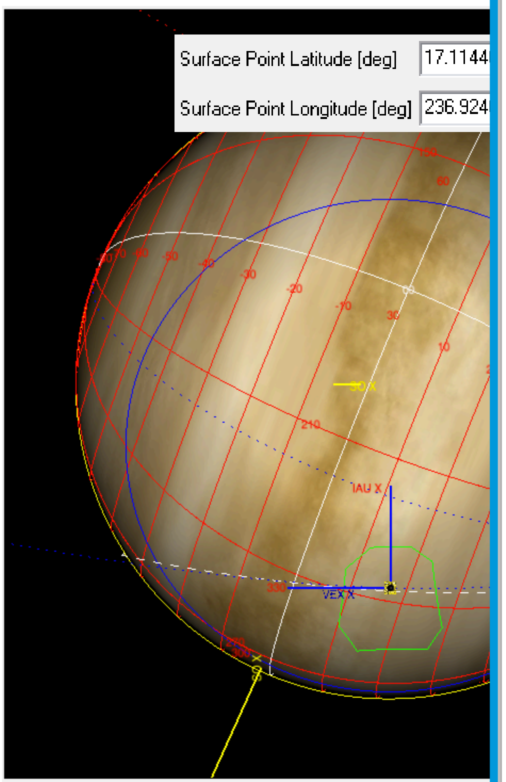

- The user requests an event with an interface.
- Events are displayed in a table and in a multidimensional plot



# Pla… …ing

## 3.Ena… …observations

- Zero phase Angle Obs…
- Hard to analyze witho…

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NATURE | NEWS: EXPLAINER

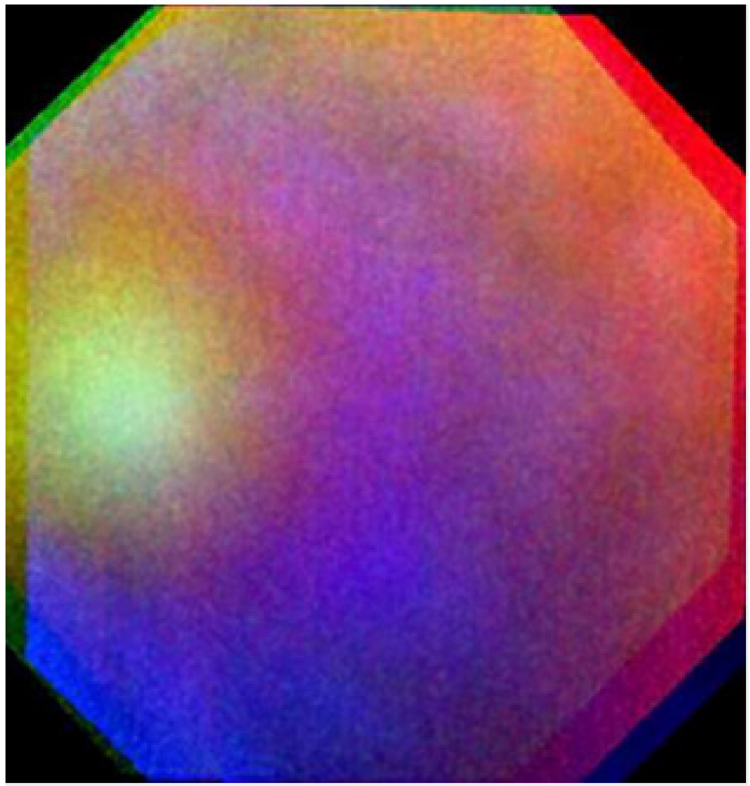
### Why the 'Venus rainbow' is actually a glory

**The first sighting of the light spectacle on another planet reveals properties of the mysterious Venusian clouds.**

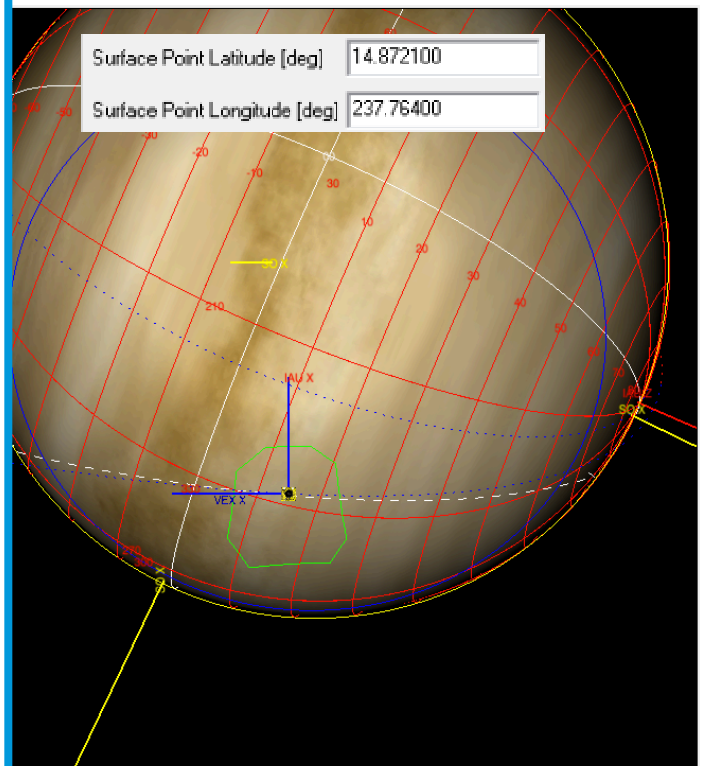
George Musser

14 March 2014 Corrected: 03 April 2014

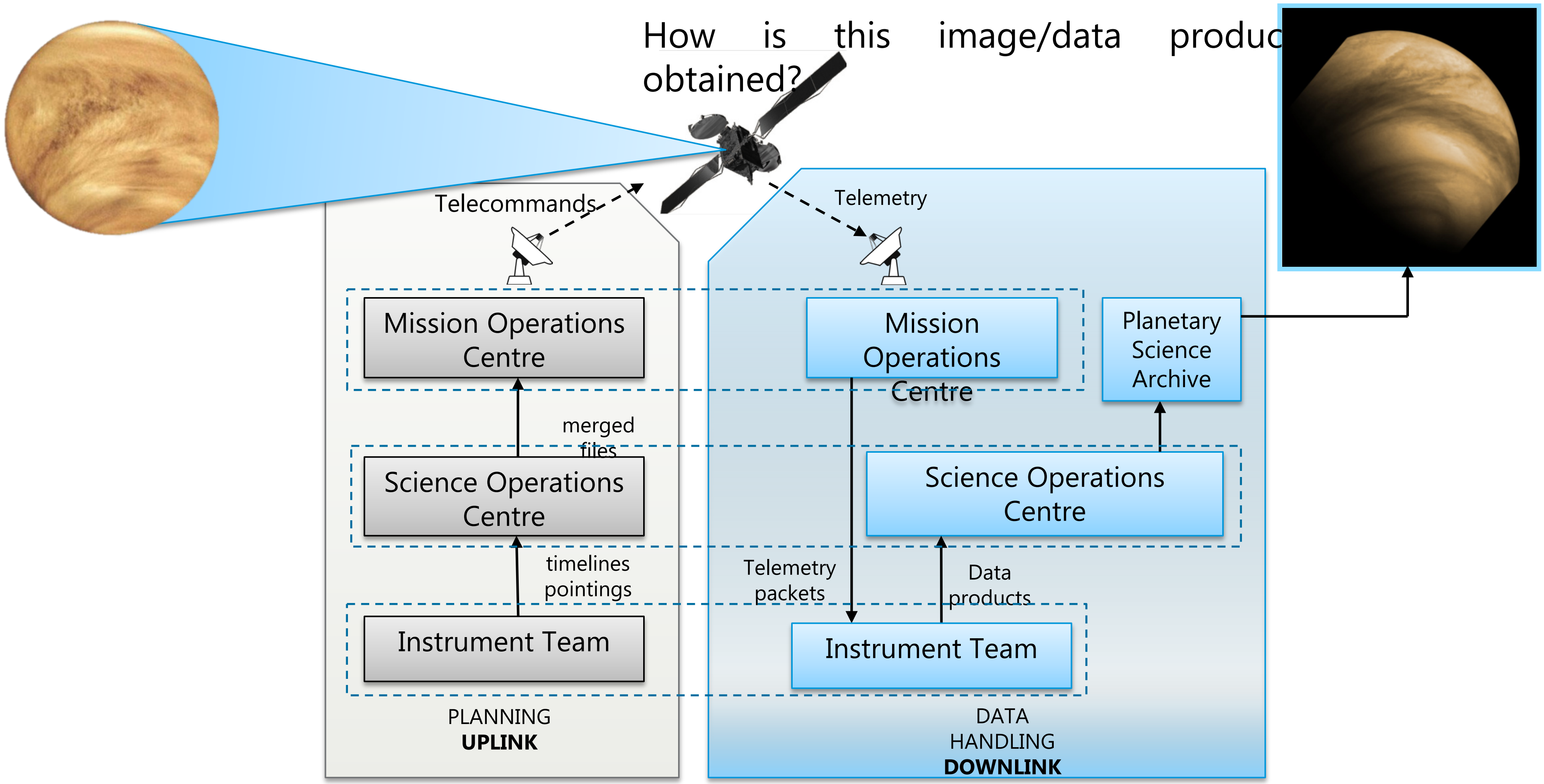
Rights & Permissions



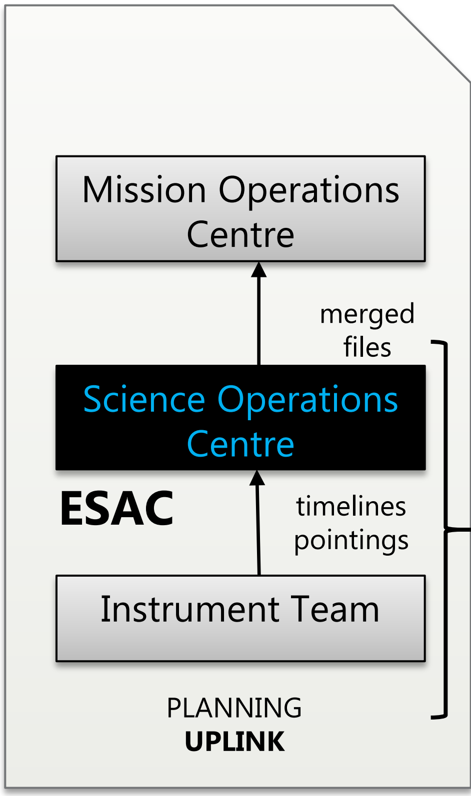
An optical effect called a glory seen by the Venus Express probe from an altitude of 6,000 kilometres. The false-colour image is composed of images at ultraviolet, visible, and near-infrared wavelengths taken ten seconds apart, so that they do not overlap perfectly.



# Extra Slide
## Science Concept



# Extra Slide
## ESA Science Operations background




**Long Term Planning LTP**

- Pre-allocation of science case priorities (orbit basis) for each mission phase
- This is used as a baseline for discussion taking into account the most relevant geometrical & operational parameters

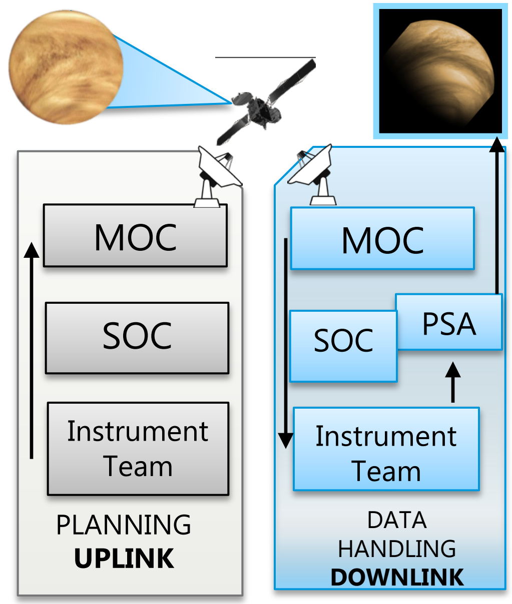
**Medium Term Planning MTP**

- Definition of activities for each orbit in one cycle of 28 days/orbit
- Pointing and Timeline are defined for each orbit

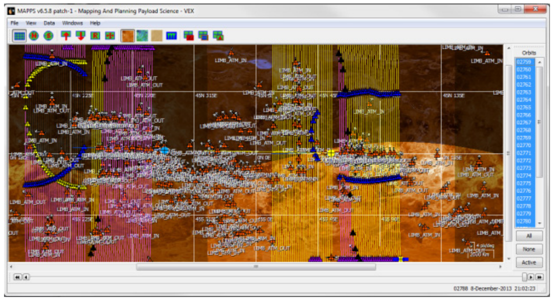
**Short Term Planning STP**

- Timeline is expanded to command sequence level
- Operations can be fine-tuned with minor modifications, respecting resource envelopes

# Extra Slide
## Concept



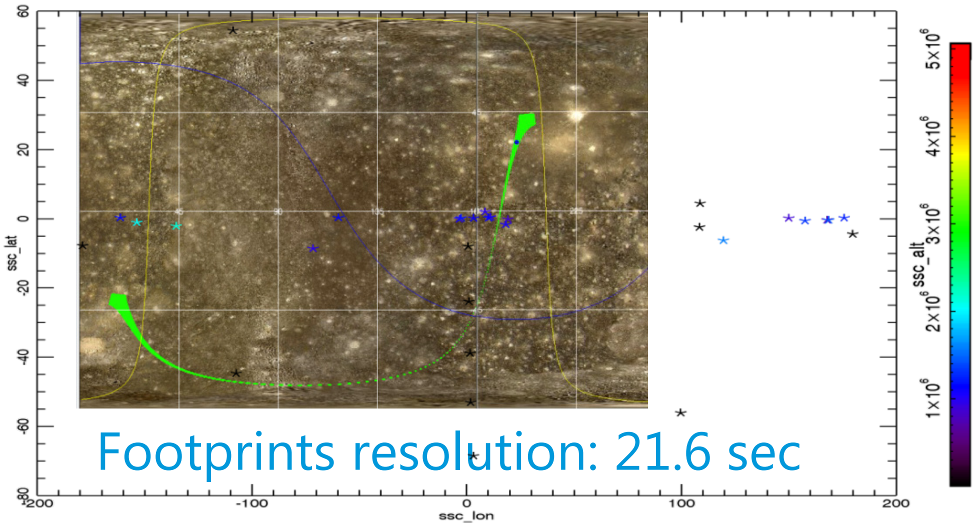

- Planetary Sciences planning activities are often driven by spacecraft technical constraints, such as thermal limitations, link budgets or pointing limitations.
- Science Operations Centers when deriving requirements usually put emphasis in giving the user the tools to deal with such constraints.
- To improve the science planning for planetary missions a prototype of a Science Observation



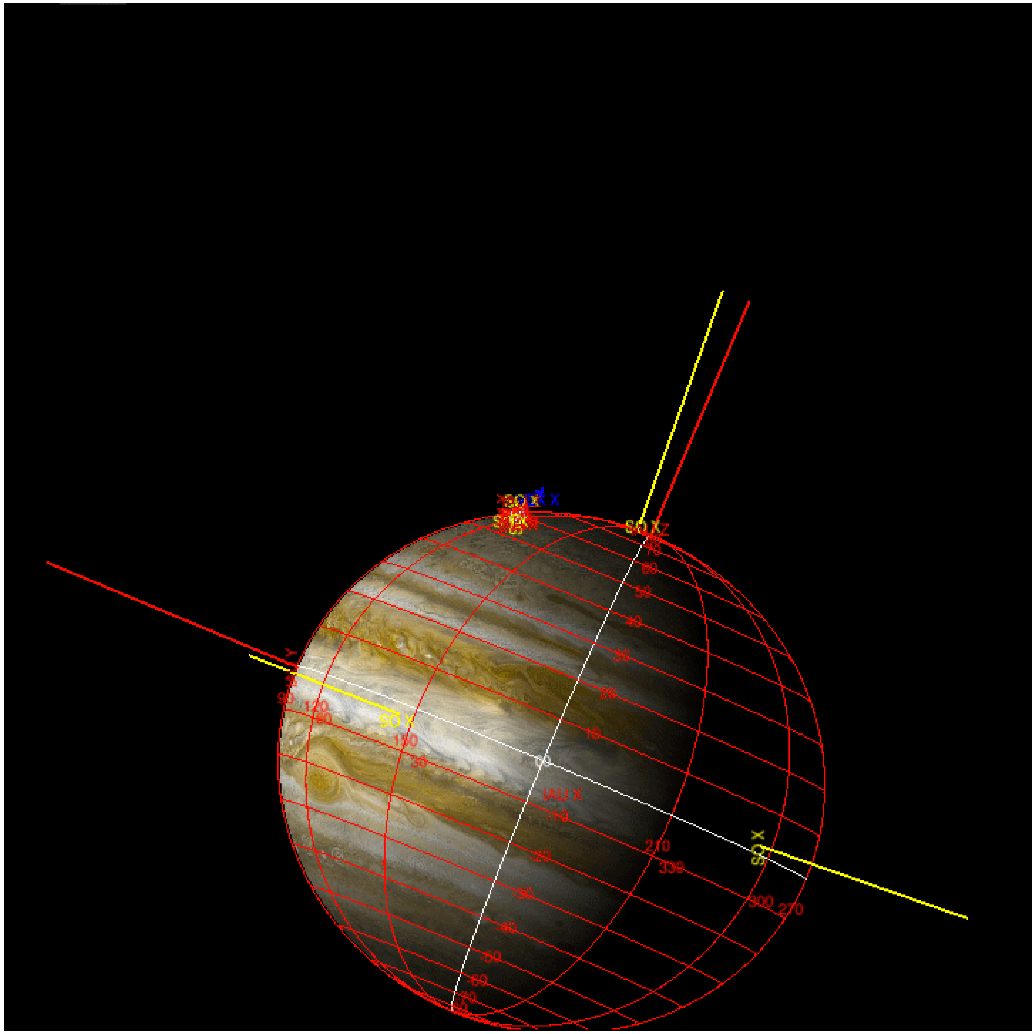
The aim of this project is to investigate new software techniques for computation, visualization and analysis of scientific observation opportunities for interplanetary missions, focusing on the geometrical requirements to cover the scientific mission objectives.

# Extra Slide
## Callisto flybys

- Callisto flybys during Jupiter High Latitude Phase.




Footprints resolution: 21.6 sec



# Extra Slide
## Ganymede surface coverage

- Ganymede 200km orbit phase. Orbit trace for 48 hours.