The Solar System Science Operations Laboratory

SCIOPS 2013
11th September 2013, ESAC/ESA

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Alejandro Cardesín (ISDEFE/ESA)

Introduction
Motivation

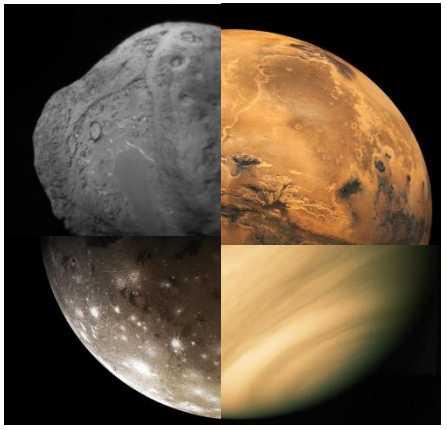
WHY? Bringing science to science operations

WHAT? Developing in-house (@ESAC) core competitive expertise:

GEOMETRY-SCIENTIFIC OBSERVATION OPPORTUNITIES analysis and VISUALIZATION for planetary missions

- Type of missions covered:
  - Orbiter (MEX/VEX/Solar Orbiter)
  - Touring (JUICE)
  - Targeting (Marco-Polo/Rosetta)
- Typical usage per mission phase:
  - Definition phase (JUICE/MP-R)
  - Long-term planning (BepiColombo/SolO/Ros)
  - Routine phase (VEX/MEX)

Multi-mission horizontal approach that builds up internal expertise

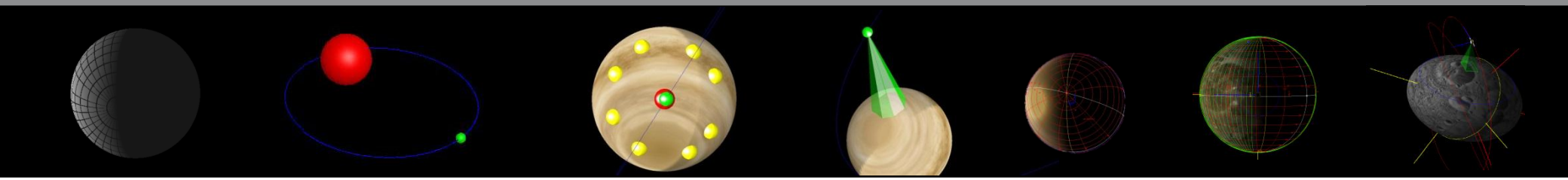


WHO? The current SOLab Multi-mission "Group"

Marc Costa	(ISDEFE/ESA)	Venus Express
Miguel Almeida	(VEGA/ESA)	Rosetta
Nicolas Altobelli	(ESA)	JUpiter ICy moons Explorer
Alejandro Cardesín	(ISDEFE/ESA)	Mars Express

PROVE IT!

Introduction
Project Development



ESAC Trainee Project
(M. Almeida)
Oct 2010 – Apr 2011

SRE-OD contract with INSA
(N.Altobelli/A. Cardesín)
Oct 2011 – Sep 2012

SRE-OD/ISDEFE with MEX/VEX/SolO/Bepi
(N. Altobelli/A. Cardesín)
Nov 2012 – Apr 2013

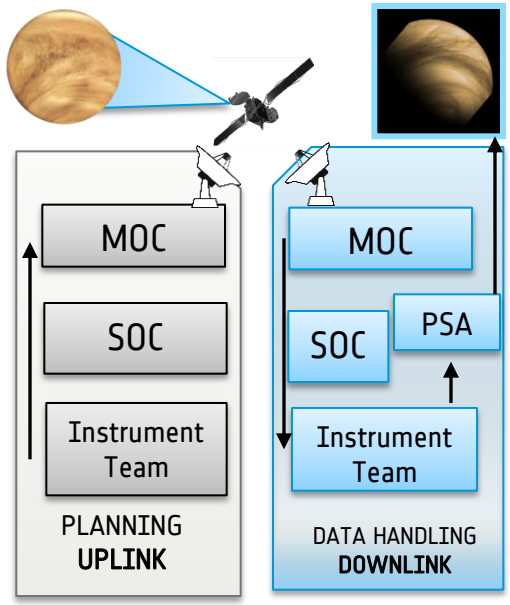
VEX Planner
SOLab group
May 2013 -

VEX
MEX
JUICE
SolO
Bepi
Rosetta
MarcoPolo-R

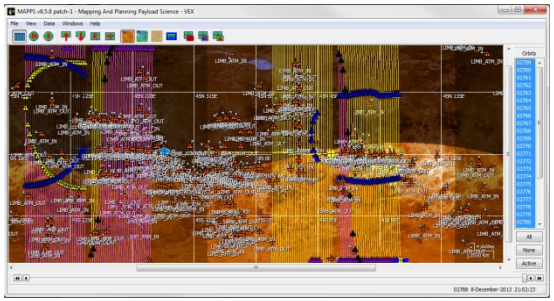
Learning process
Visualization module 3D/2D
Plot & Data Export
Science Opportunity Analysis
Object Oriented Design
Integration with other systems

FTE (M. Costa)
Trainee (M. Costa)
Trainee (P. Arriazu)
Master Students
P. Hebrero
D. Sors

Enhancing Science Planning
Concept



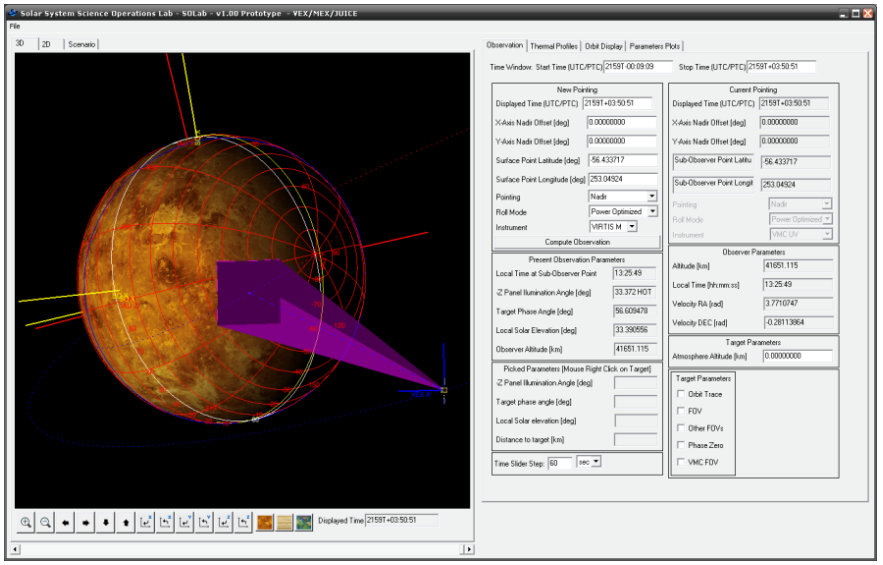
- Planetary Sciences planning activities are often driven by spacecraft technical constraints, such as thermal limitations, link budgets or pointing limitations.
- Science Operations Centers when deriving requirements usually put emphasis in giving the user the tools to deal with such constraints.
-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

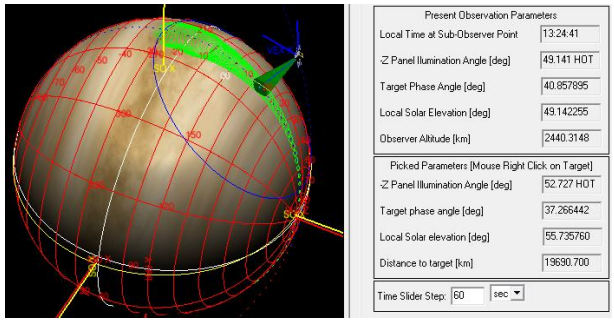


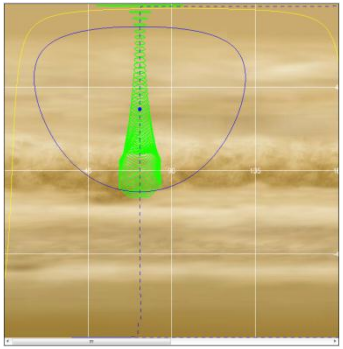
The aim of this project is to investigate new software techniques for computation, visualization and analysis of scientific observation opportunities for interplanetary missions, focusing on the geometrical requirements to cover the scientific mission objectives.

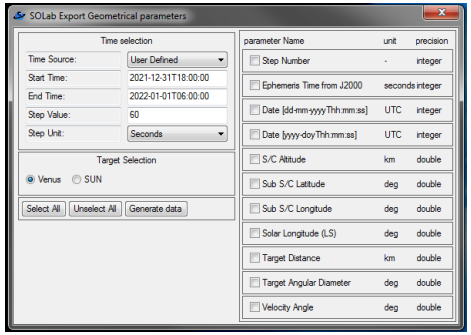
Enhancing Science Planning
Prototype description

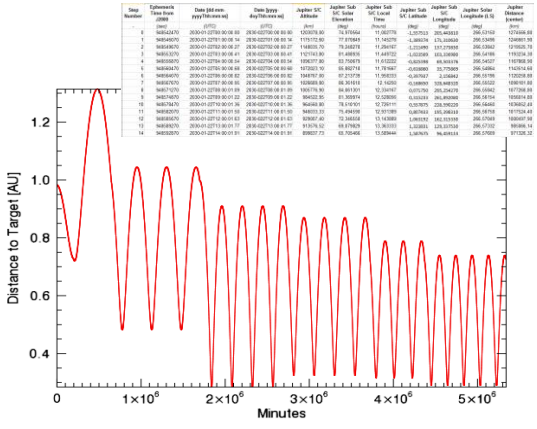
- Modular and highly configurable tool. Most of the options are modified via configuration file.
- Interactive definition of attitude for supporting the creation of pointing requests.
- Plotting capability, taylorable geometrical quantities to be analized.
- Production of large amounts of datasets covering all the time given by the kernels with the desired resolution.











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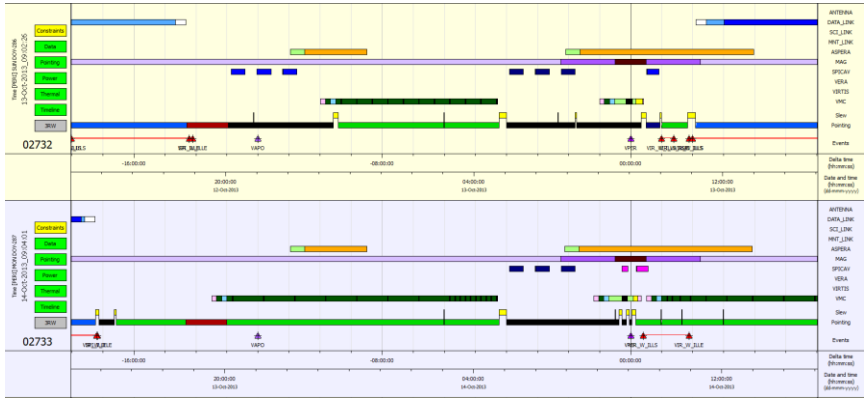
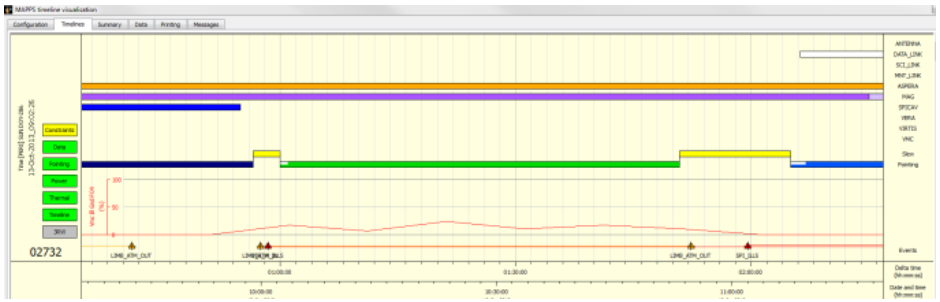
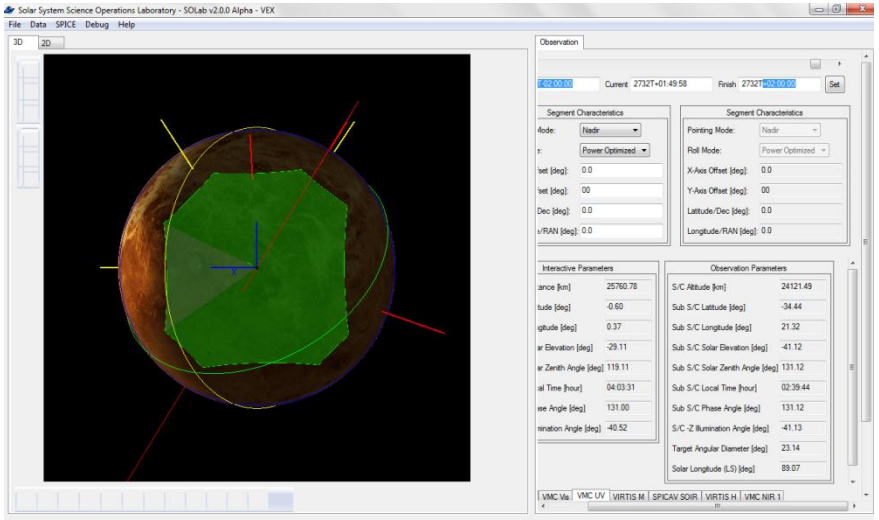
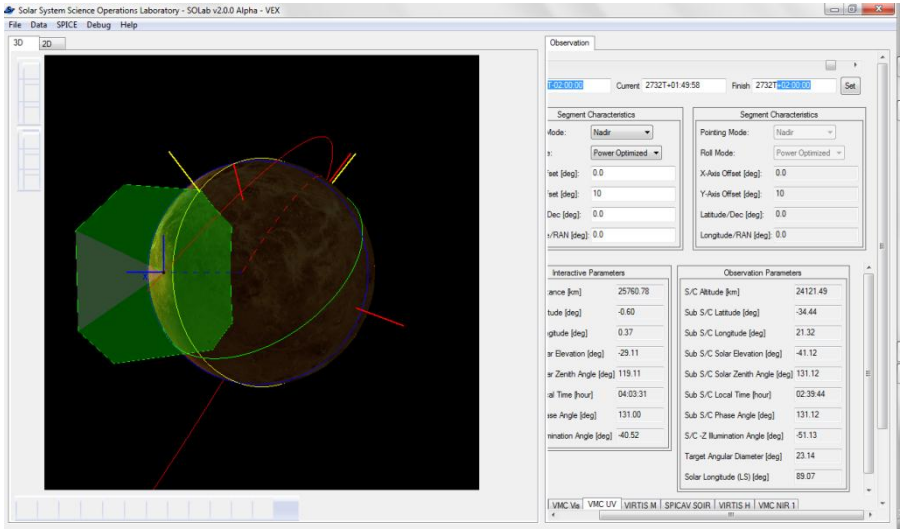
Enhancing Science Planning
Medium Term Planning applications

Pointing optimization for VMC camera on VEX in MTP098









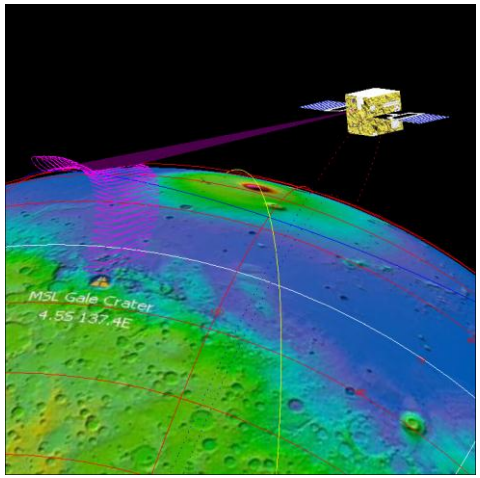
MAPPS-SOLab integration

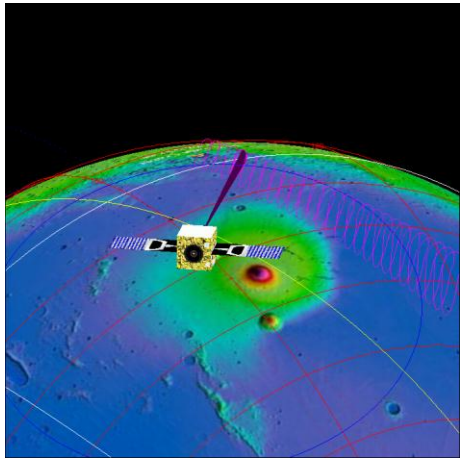
MEX Limb & Spot Tracking, Phobos Fly-by

- **Integration with other operational systems** and generate operational products for science operations engineers (pointing request, attitude files…).

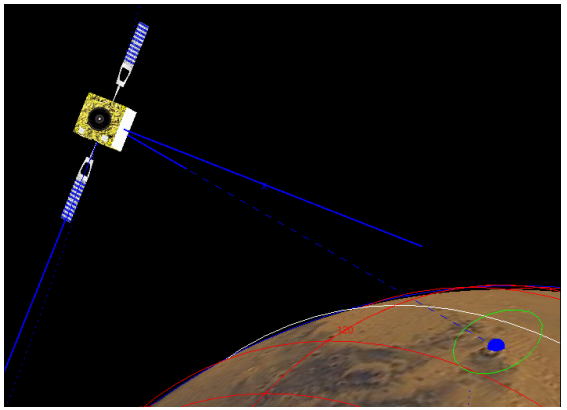
- MAPPS quaternions can be converted into SPICE kernels and loaded by SOLab

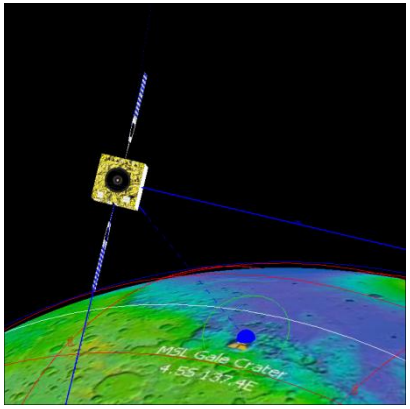
- **Example 1**:
  - Limb Tracking over MSL Gale Crater
  - Vertical profile of the atmosphere at different latitudes, passing over Gale Crater





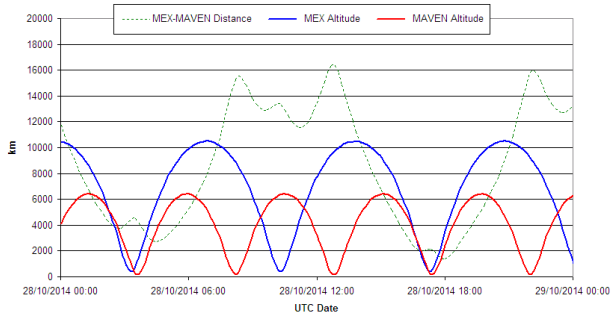
- **Example 2**:
  - Tracking MSL Gale Crater
  - Study of the same target at different emission angles

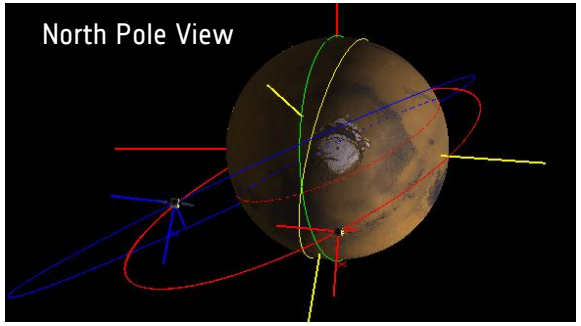


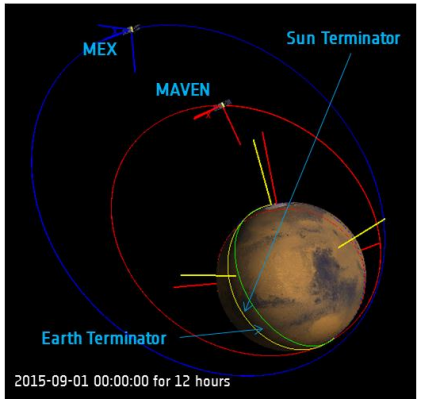


MAPPS-SOLab integration
Multiple object Scenario complementation

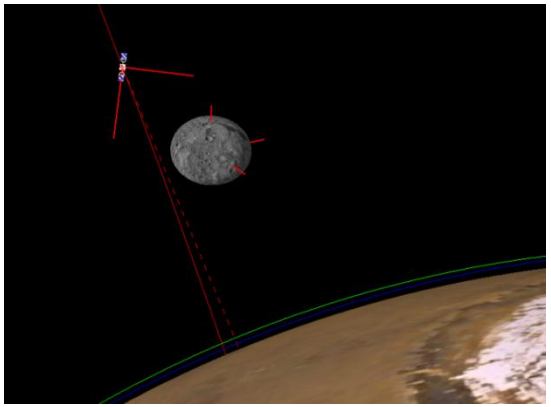
- **Complement other operational systems:** Provide quick answers from non immediately available resources
- **Example 1**:
  - Joint **MEX-MAVEN** observation campaigns of the Martian magnetosphere
  - Long Term analysis of science campaigns with Olivier Witasse, presented at AGU

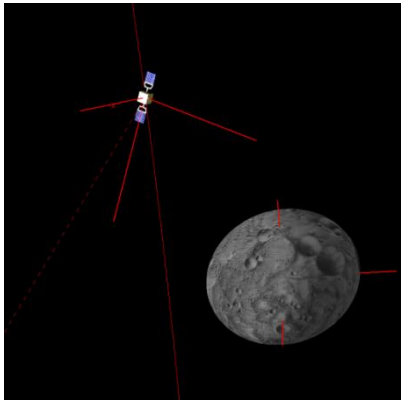




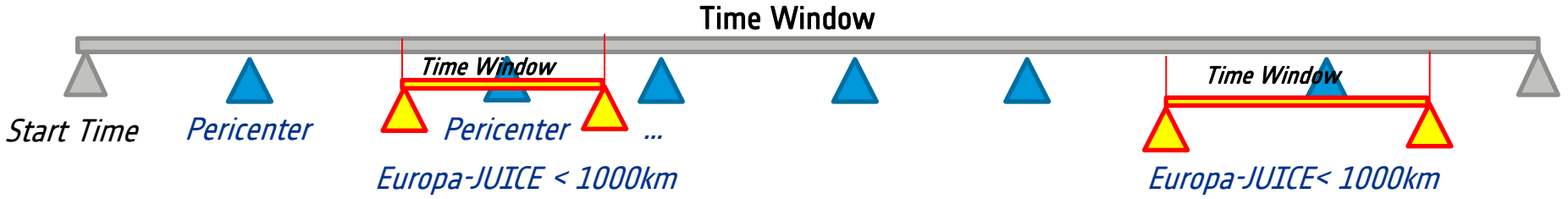


- **Example 2:**
  - **Phobos flyby** campaign.
  - Provide contextual geometry of planned pointing for instrument teams.





- Science Opportunity Analysis.
  - Computation of observation opportunities to find best observation condition (e.g. Occultation's, fly-bys, illumination).
  - Computation of events and science constraints to be visualized and stored in databases.
  - Events start and stop times define Time Windows
- 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…
  - Time Windows resulting from science opportunity analysis (Event finding) are combined to build high level science campaigns or observations.



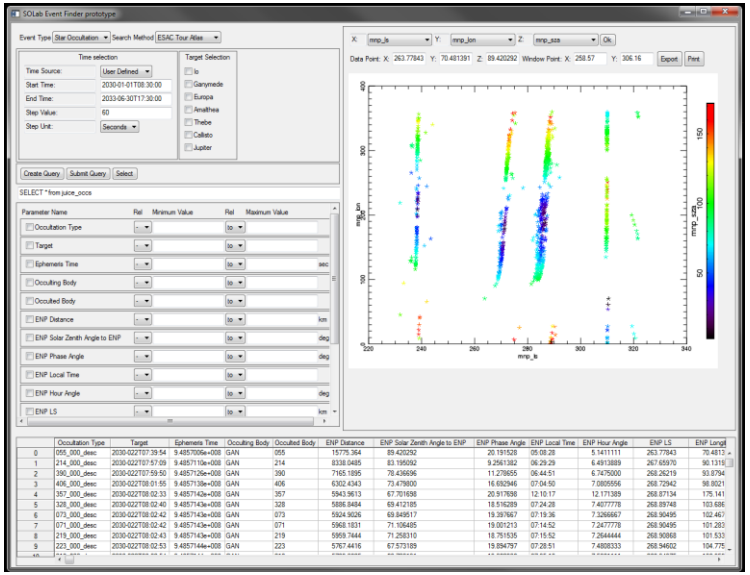
Science Opportunity Analysis
Implemented modules

- **Event Finder**

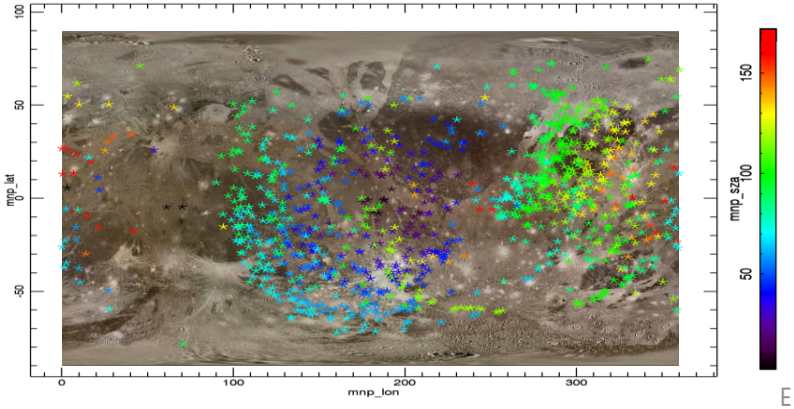
  Defines the syntax of events and retrieves them using:
  1. ESAC Science Opportunity Repository: Precomputed events for the whole mission stored in databases.
  2. SOLab internal event finder using SPICE geometry Finder.

- **Event Handler**
  - Displays the events and allows to refine the search by sorting the events
  - List of events can be exported in any format (EPS…)
  - 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



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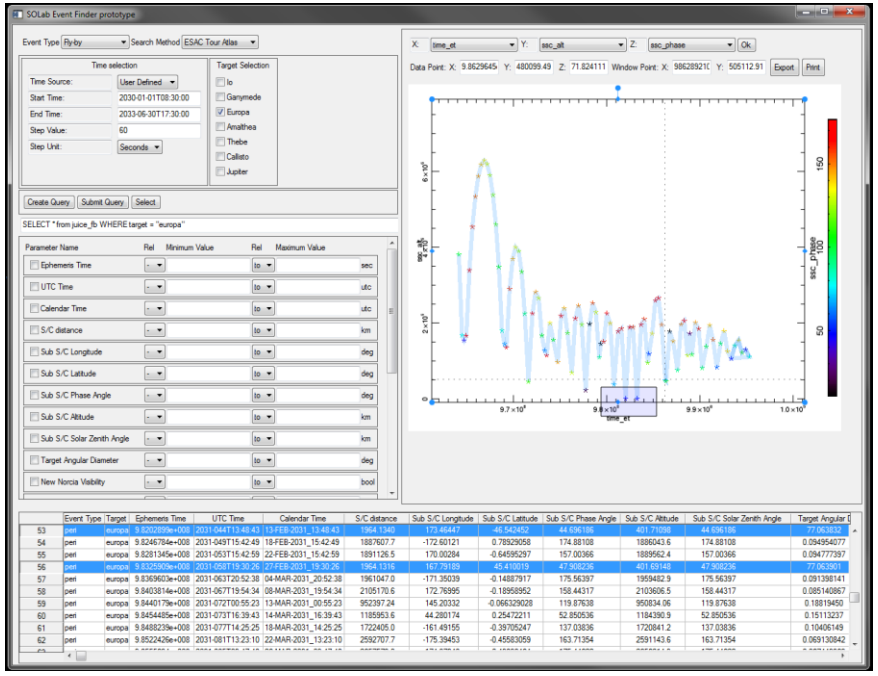
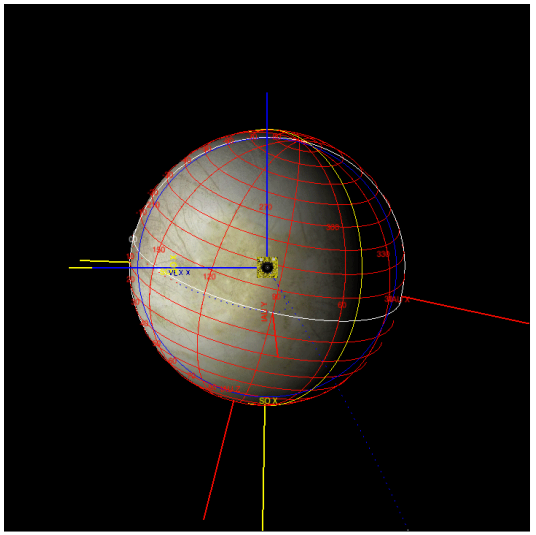
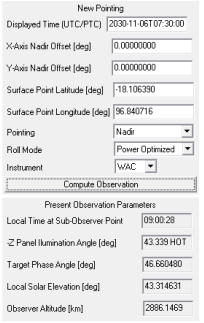
Science Opportunity Analysis
When events and geometry come together

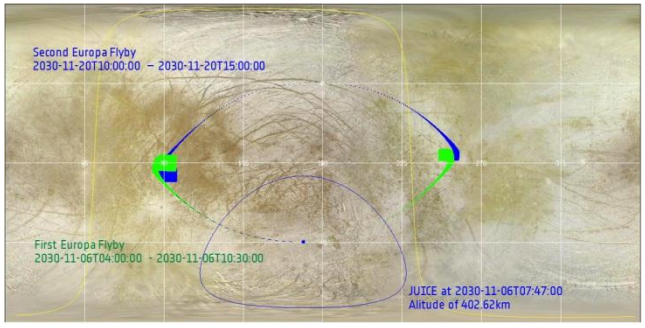
Selection of events and 'contextual geometry' analysis

- User selects Europa as a Target *SELECT * from juice_fb WHERE target = "europa"*
- Using the Event Handler the search can be refined
- In the following the closest flybys are chosen and one is analyzed









- First Europa fly-by animation displaying JANUS camera

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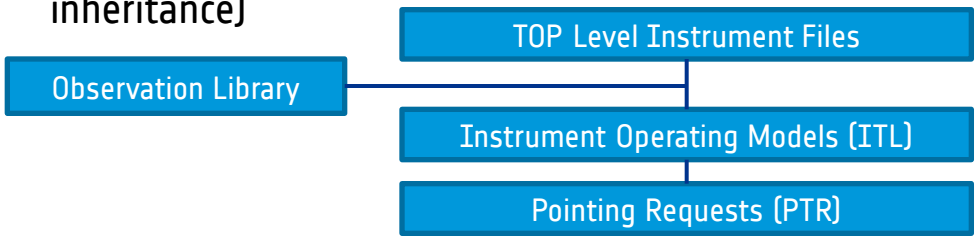
SciOps Feasibility assessment for JUICE
System setup

Support the Science Implementation Plan of JUICE's Science Working Team

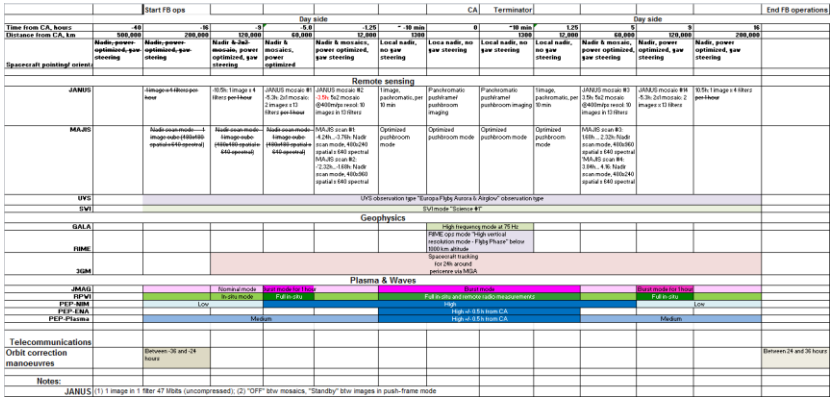
INPUTS
- Experiment Interface Document – B
- Schematic set of Operational Scenarios
- High Level Science Operations Concept

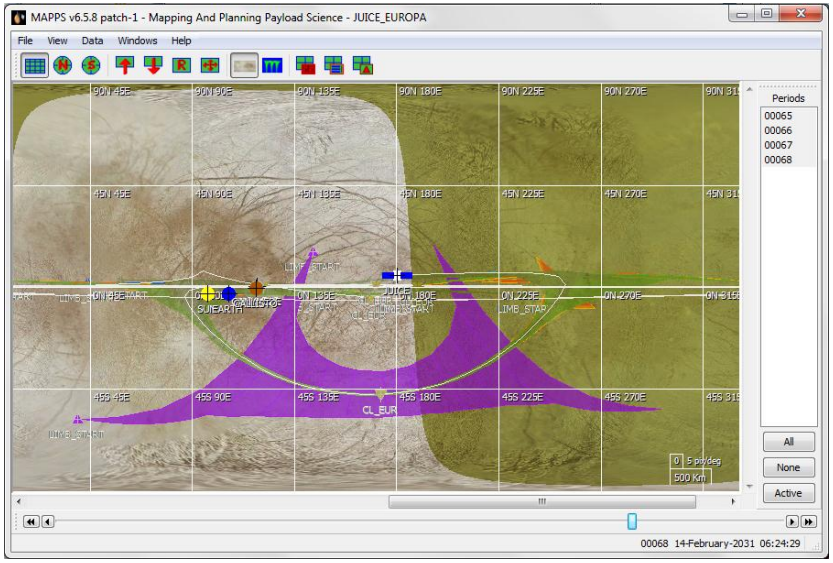
CONTRIBUTION BY THE GROUP:
- MAPPS setup for JUICE.
- Preliminary Instrument and spacecraft resources modeling (EDFs and SPICE Kernels).
- Creation of generic operational products (Rosetta, VEX and MEX inheritance)



- Interface definition between SOLab and MAPPS.
- Creation of scenario specific operational products from science requirements

OUTPUT:
- Realistic Science Operations feasibility study,
- Sizing of science cases for industry (SSMM)





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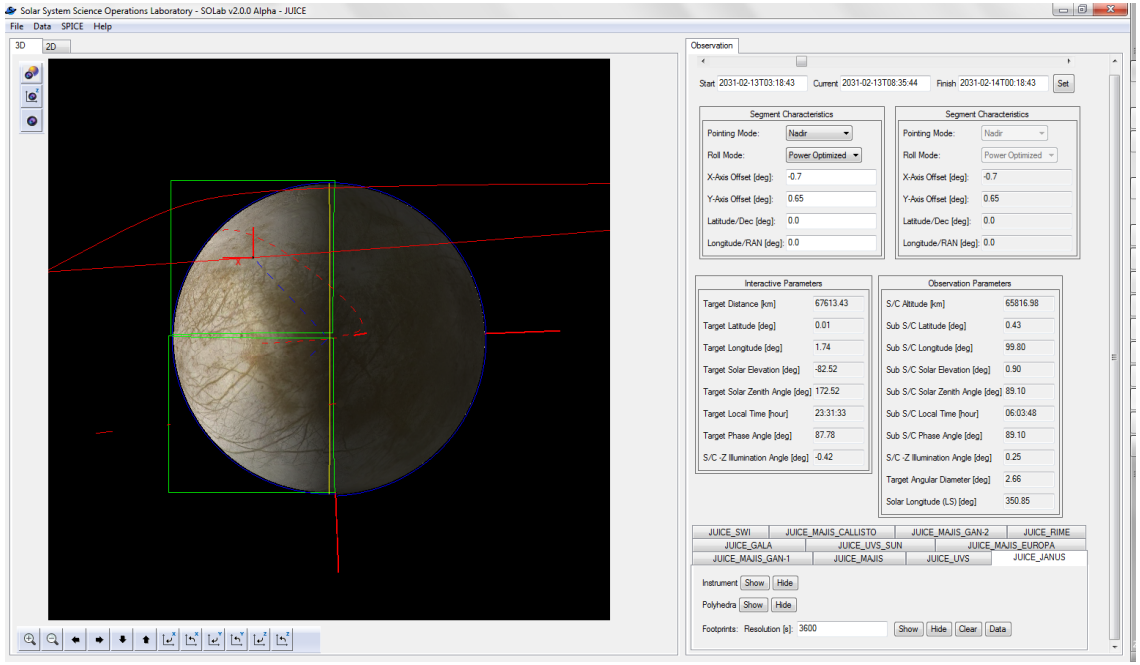
SciOps Feasibility assessment for JUICE

Operational Scenario: Europa Flyby (I)

		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, gaw steering~~	~~Nadir, power optimized, gaw steering~~	Nadir ~~& 2x2 mosaic~~, power optimized, gaw steering	Nadir & mosaics, power optimized	Nadir & mosaics, power optimized, gaw steering	Local nadir, no gaw steering	Loca nadir, no gaw steering	Local nadir, no gaw steering	Local nadir, no gaw steering	Nadir & mosaic, power optimized, gaw steering	Nadir, power optimized, gaw steering	Nadir, power optimized, gaw 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~~	

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CLS_APP_EUR (COUNT = 1) -05:08:00   JSGS  INCLUDE "JN_EUR_CLS_APP_MOSAIC_Off_ITL_v01.itl"

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                  PITCH = 0.65 [degrees] \
                  YAW = 0.65 [degrees] \
                  SLEW_POLICY = BEFORE_NEXT)

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                  ROLL_MODE = POWER_OPTIMISED \
                  PITCH = 0.65 [degrees] \
                  YAW = -0.7 [degrees] \
                  SLEW_POLICY = IMMEDIATE)

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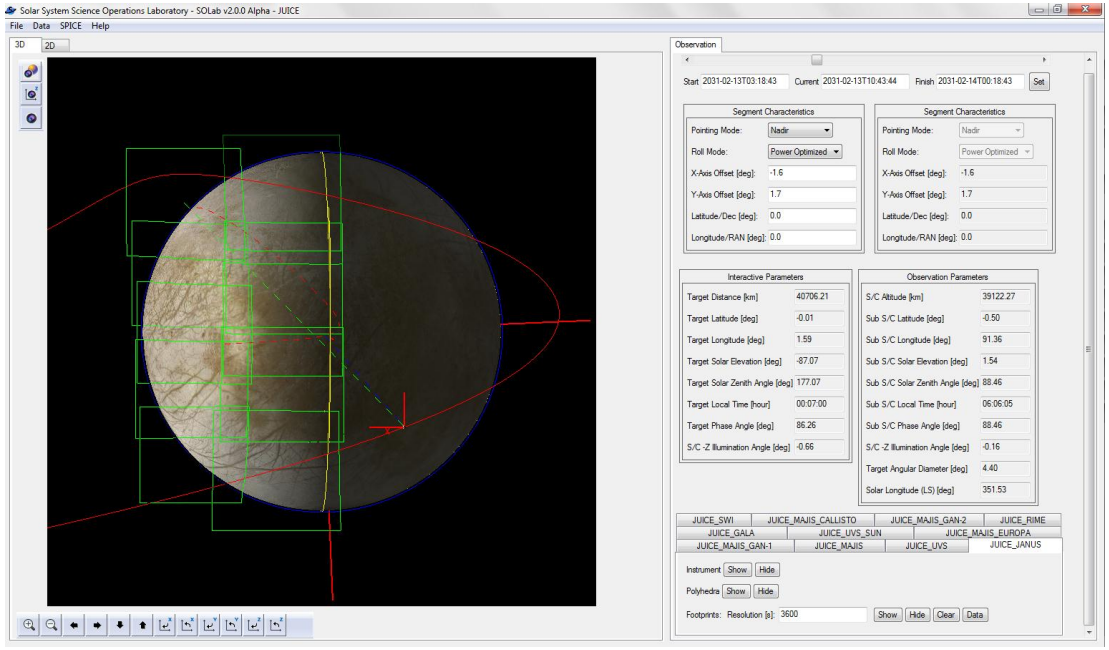
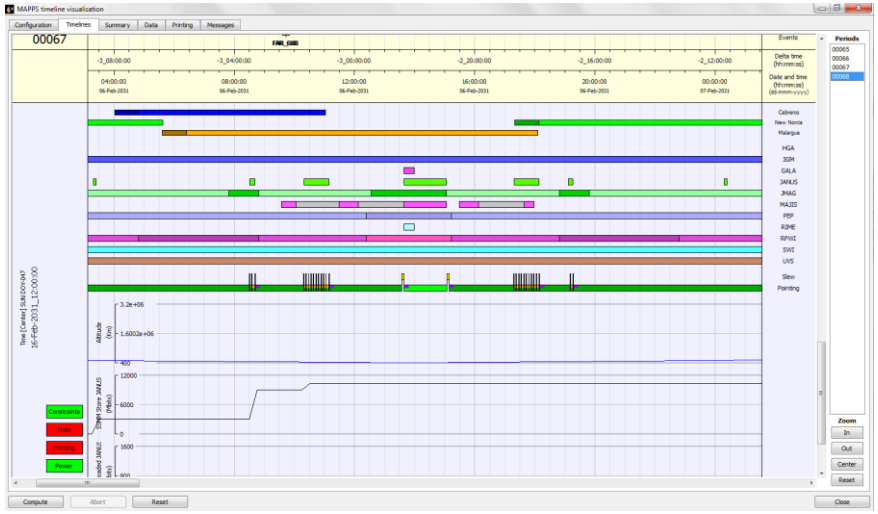
000_00:00:00  JANUS  *  SWITCH_MODE (CURRENT_MODE = SCIENCE [ENG])
```

SciOps Feasibility assessment for JUICE

Operational Scenario: Europa Flyby (II)

		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	0	1300	12,000	60,000	120,000	200,000	
Spacecraft pointing/ orienta	~~Nadir, power optimized, gaw steering~~	~~Nadir, power optimized, gaw steering~~	~~Nadir & 2x2 mosaic~~, power optimized, gaw steering	Nadir & mosaics, power optimized	Nadir & mosaics, power optimized, gaw steering	Local nadir, no gaw steering	Loca nadir, no gaw steering	Local nadir, no gaw steering	Local nadir, no gaw steering	Nadir & mosaic, power optimized, gaw steering	Nadir, power optimized, gaw steering	Nadir, power optimized, gaw 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~~	

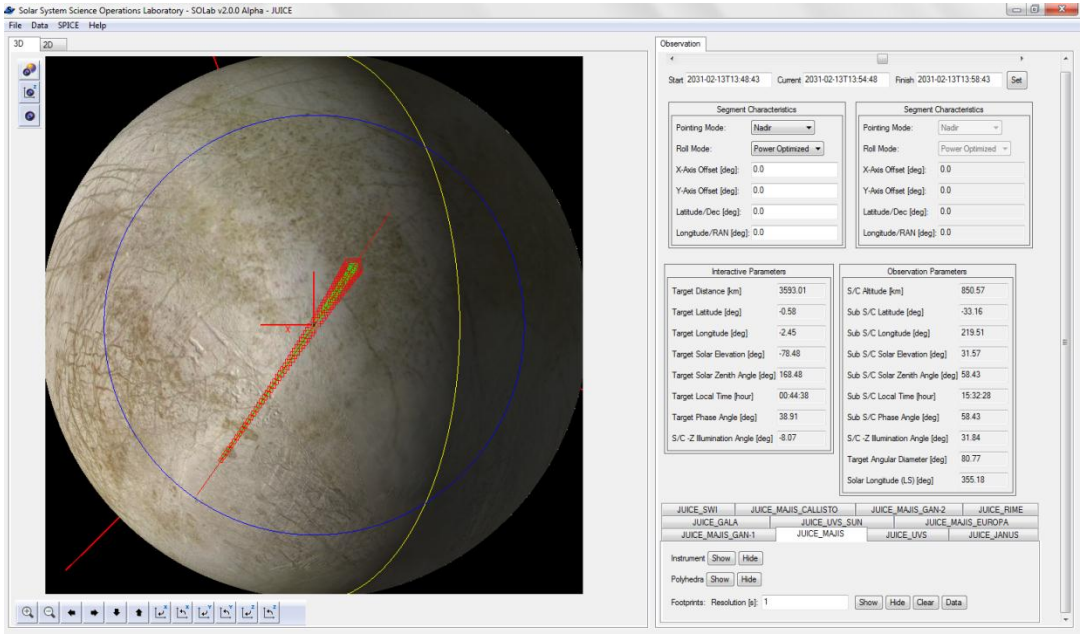


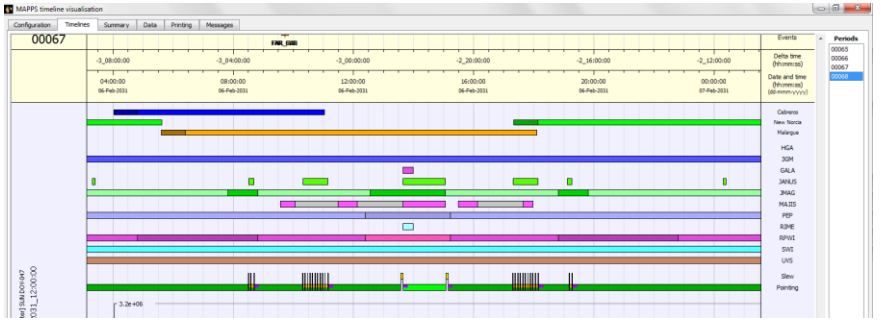


SciOps Feasibility assessment for JUICE

Operational Scenario: Europa Flyby (III)

		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, gaw steering~~	~~Nadir, power optimized, gaw steering~~	Nadir ~~& 2x2 mosaic~~, power optimized, gaw steering	Nadir & mosaics, power optimized	Nadir & mosaics, power optimized, gaw steering	Local nadir, no gaw steering	Loca nadir, no gaw steering	Local nadir, no gaw steering	Local nadir, no gaw steering	Nadir & mosaic, power optimized, gaw steering	Nadir, power optimized, gaw steering	Nadir, power optimized, gaw 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~~	





DATA SUMMARY REPORT

INSTRUMENT DATA VOLUME STATISTICS

	Data Volume (Mbits)	Data Share
GALA Total Data Volume	1.395	0.00%
JANUS Total Data Volume	129000.000	31.45%
JMAG Total Data Volume	571.309	0.14%
MAJIS Total Data Volume	276672.000	67.45%
PEP Total Data Volume	0.000	0.00%
RIME Total Data Volume	2880.000	0.70%
RPWI Total Data Volume	1087.340	0.27%
SWI Total Data Volume	481.538	0.12%
UVS Total Data Volume	24552.635	5.99%
TOTAL Data Volume:	410212.044	100.00%

DATA DOWNLINK STATISTICS

	Data Downlink (Mbits)	Percentage
Available Downlink:	43335.700	100.00%
Data Downloaded:	11248.300	25.96%
Unused Downlink:	32087.500	74.04%

Summary
Conclusions

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

  GEOMETRY-SCIENTIFIC OBSERVATION OPPORTUNITIES analysis and VISUALIZATION for planetary missions

- **Science Opportunity Analysis**
  - Computation of observation opportunities to find best observation condition (e.g. Occultation's, fly-bys…)
- **Prototype for context geometry analysis of pointings and observations/campaigns**
  - Quick visualization and interactive refinements of pointings
  - Generation of derived geometry datasets

- **Integration with other operational systems** and generate operational products for science operations engineers (pointing request, attitude files…)

- **Proof of concept for multi-mission group** re-using expertise and technology from other projects


Thanks for your attention
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