SPICE for ESA Missions

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SPICE and Auxiliary Data Engineer

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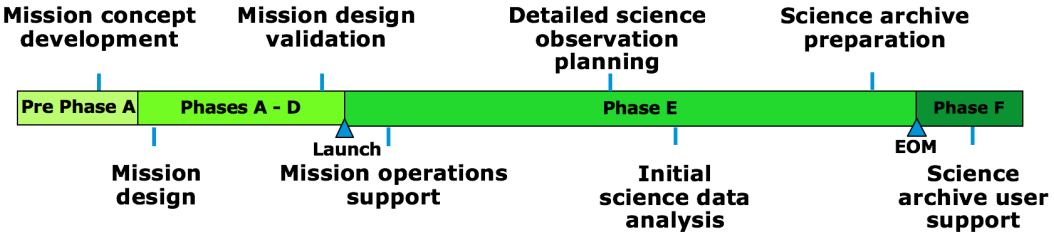
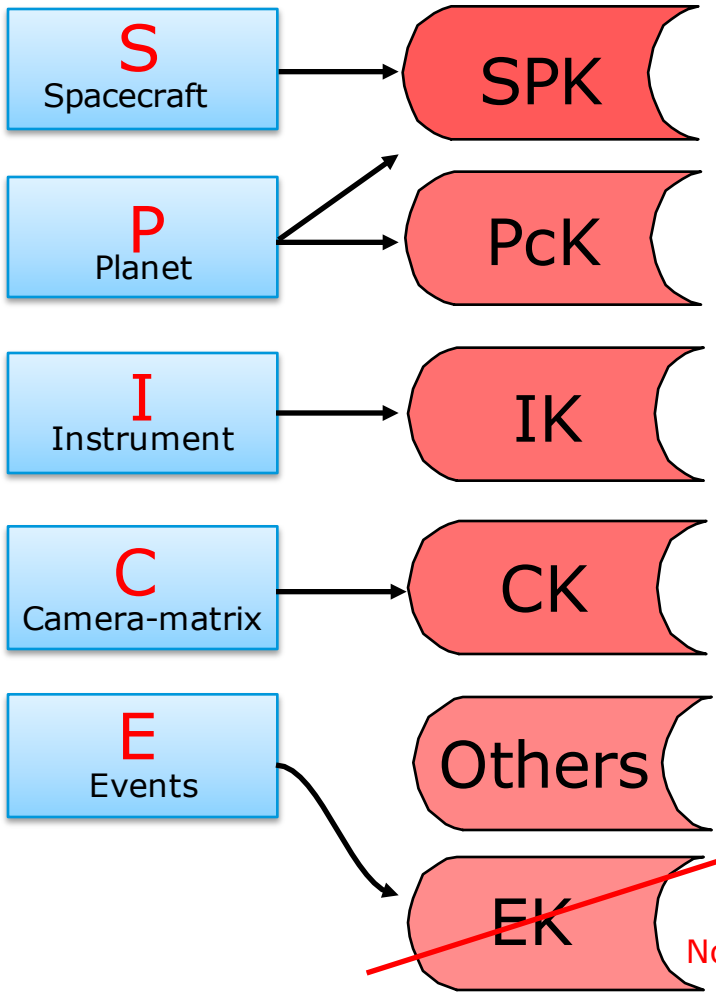
SPICE in a nutshell

- SPICE is an information system that uses *ancillary data* to provide Solar System geometry information to scientists and engineers for planetary missions in order to plan and analyze scientific observations from space-born instruments. SPICE was originally developed and maintained by the Navigation and Ancillary Information Facility (NAIF) team of the Jet Propulsion Laboratory (NASA).
- "Ancillary data" are those that help scientists and engineers determine:
  - where the spacecraft was located
  - how the spacecraft and its instruments were oriented (pointed)
  - what was the location, size, shape and orientation of the target being observed
  - what events were occurring on the spacecraft or ground that might affect interpretation of science observations
- SPICE provides users a large suite of SW used to read SPICE ancillary data files to compute observation geometry.
- SPICE is open, very well tested, extensively used and provides tons of resources to learn it and implement it.
- SPICE is the recommended means of archiving ancillary data by NASA's PDS and by the IPDA
- The ancillary data (kernels) comes from: The S/C, MOC/SGS, S/C manufacturer and Instrument teams, Science Organizations.

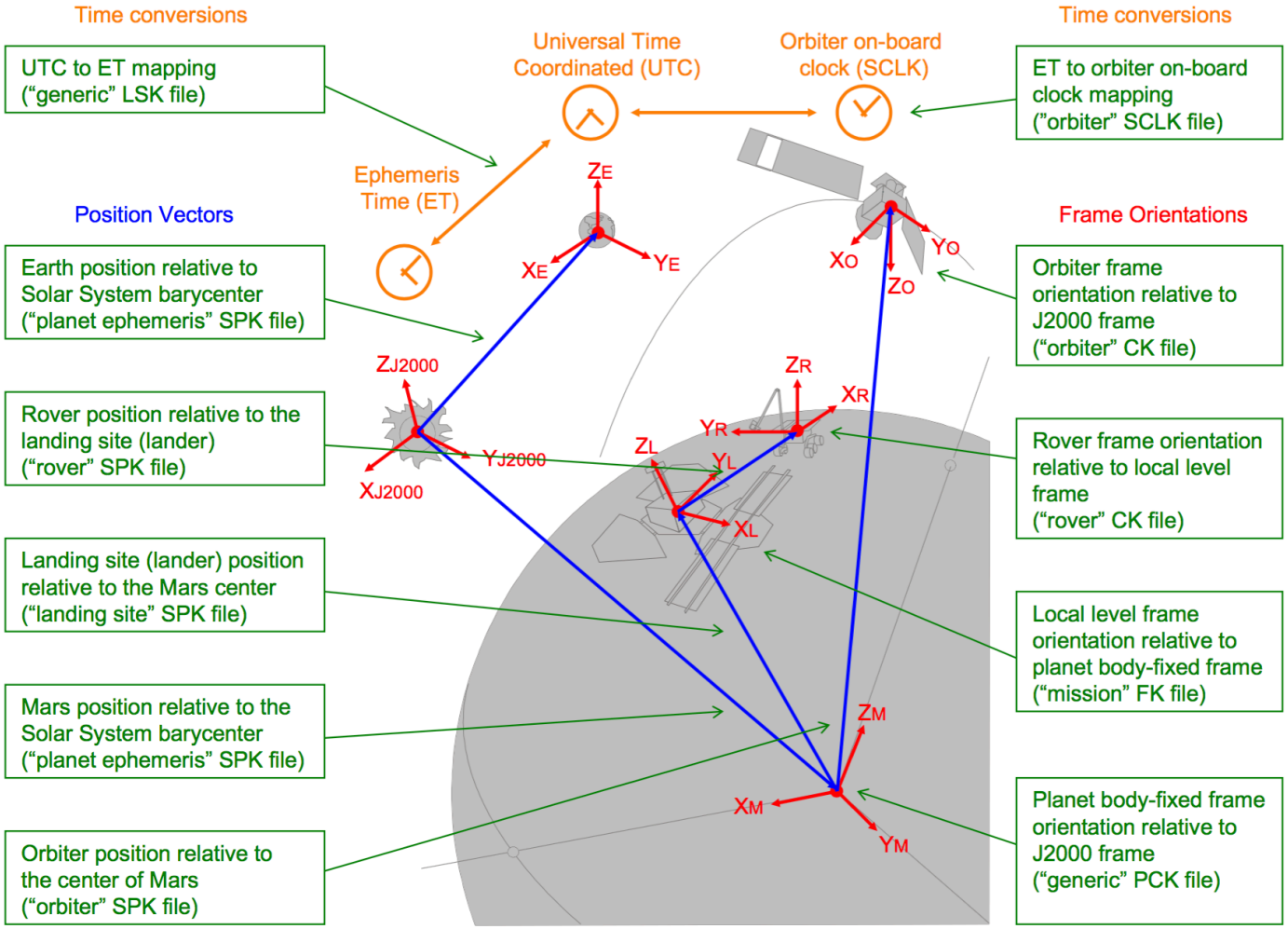


SPICE in a nutshell



For binary data. Text files are manually produced.

SPICE in a nutshell



The ESA SPICE Service

- The ESA SPICE Service (ESS) leads the SPICE operations for ESA's planetary missions (and Solar Orbiter). Its main activities are:
  - The group is responsible at ESAC for the generation, development, maintenance and archive of the SPICE Kernel Datasets for the ESA Planetary Missions (and Solar Orbiter).
  - It develops and operates software to convert orbit, attitude, telemetry and spacecraft clock correlation data into the corresponding SPICE formats.
  - Provides consultancy and support to the Science Ground Segments and the Science Community of the planetary missions for SPICE and ancillary data management.

Available, SPICE Kernels Datasets:

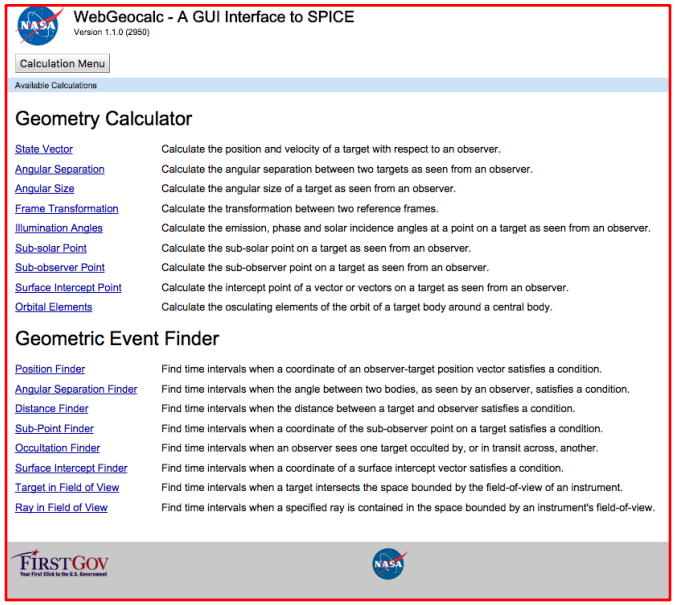
Releases and support to the community is provided

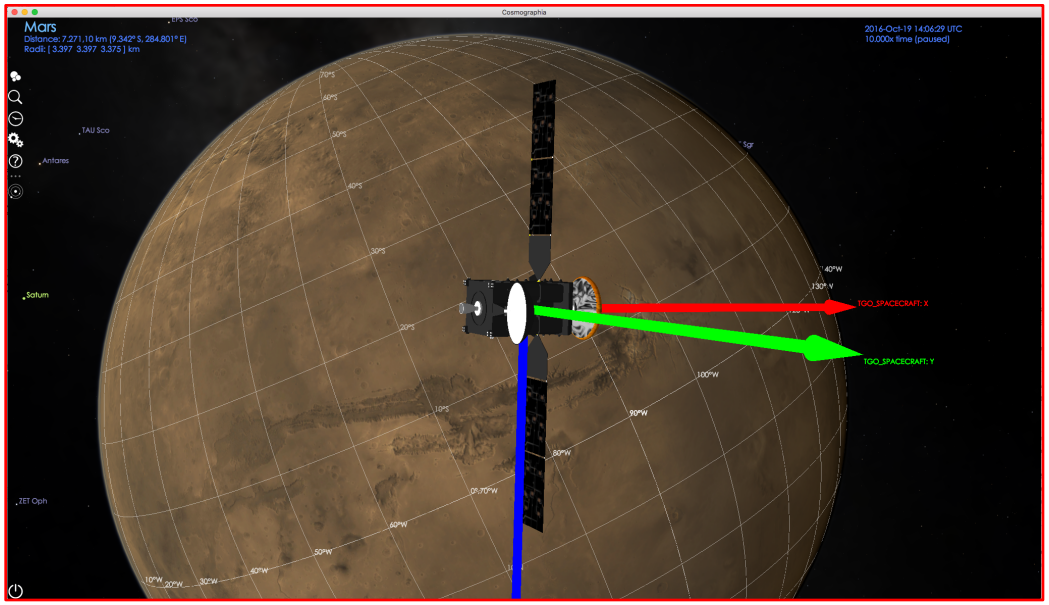
- ESS also provides an instance of WebGeocalc and Cosmographia:
  - **WebGeocalc** is a web-based interface to some SPICE Functions, extremely powerful for quick-look data analysis
  - **Cosmographia** is a 3D-Visualization Tool for a full SPICE Scenario.

- Everything is accessible from: **spice.esac.esa.int** .

The ESA SPICE Service

- WebGeocalc (WGC) is a web-based graphical user interface to SPICE. It offers many observation geometry computations available in SPICE through a standard web browser. The ESS provides WebGeocalc to support mission planning, mission operations and science data analysis.
- SPICE-enhanced Cosmographia is an interactive tool providing 3D visualization of S/C trajectory and orientation, instrument filed-of-view and footprints, and many additional elements of space mission geometry..
- Both tools have been proven to have an incredible added value for quick-look analysis, pointing design and contextualization of science data.



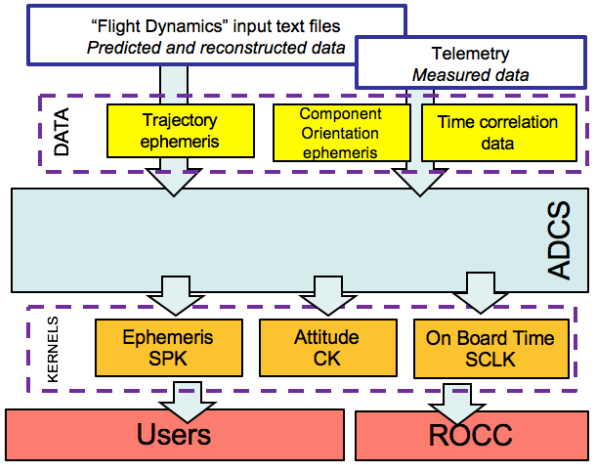


SPICE for ESA Missions

- The main purpose of the ESS is to provide a complete, consistent, high-quality, validated and up-to-date SPICE Kernel Dataset (SKD) for the mission it supports in order to be able to use SPICE in an operations environment and for data analysis.
- A SKD consists on a complete set of SPICE Kernels that cover the whole mission lifespan including long term predicted trajectory and orientation. Kernels in a SKD can be classified in two main types:
  - **Setup kernels (STK)** [FK, IK, PCK, LSK] are developed by ESS and are reviewed and iterated with the SGS and with the Instrument Teams when need be during the whole duration of the mission.
  - **Time-varying kernels (TVK)** [SPK, CK, SCLK, MK] are generated with an operational pipeline and the source data is provided by the Flight Dynamics/ROCC in terms of OEMs, AEMs and Housekeeping TM data.
- SKDs are released on a regular basis when STKs are updated. For missions in operational phase updates will include the periodic release of TVKs.
- It is also important to distinguish in between SKDs published in the ESA FTP (Study and Operational) or by another means and the peer-reviewed and PSA-PDS compliant Archived SKDs (following the PDS3 and PDS4 standards from the Planetary Data System and IPDA).
- Please note that everything stated here is implemented for ExoMars2016 and SPICE Kernels have been successfully been implemented and have been operational for SMART-1, Venus-Express, ROSETTA and Mars-Express –which is still in operations-. We are also working on reconstructing the Giotto and the Huygens Kernels and we the SKDs for Solar Orbiter, JUICE and BepiColombo are in very good shape.

SPICE for ESA Missions

- Operational kernels contain the following information:
  1. Set of Reference Frames of interest for geometry computations (FK)
  2. FoV and boresight modeling for remote and in situ sensors -at least- (IK)
  3. Predicted trajectory and as-planned or default orientation for the rover (SPK, CK)
  4. Reconstructed trajectory and orientation and on-board measured orientation for S/C
  5. OBT to UTC/CAL time conversion (SCLK)
  6. Orientation of S/C parts (CK from HK Telemetry)
  7. Position of scans or turn-tables or articulations of payload (CK from HK Telemetry)
- The Auxiliary Data Conversion System next-generation (ADCSng) generates the time-varying kernels when the mission is in operations and provides up-to-date trajectory, attitude and orientation information to science operations engineers and scientists.
- The distribution of SKDs is done via:
  - An operational FTP with all the kernels that were ever produced,
  - A permanent link to a zip file that contains the latest operational kernels and
  - A Bitbucket Git repository with the latest operational subset of the SPICE Kernels.
- SKD STK releases occur in a regular basis and the latest kernels are listed in the so-called meta-kernel file.

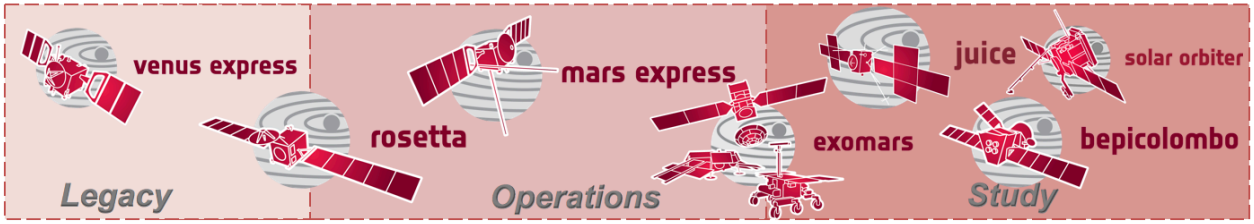


SKD Status – June 2017

Mission	Ref Frames FOV LOS	Predicted Orbit Attitude	Measured Attitude	Reconstructed Attitude	OBT conversion	S/C Element Orientation	Payload Orientation	Archived?
Mars Express								
ExoMars TGO								
Rosetta								
Venus Express								
BepiColombo								
Solar Orbiter								
JUICE								
SMART-1								
Chandrayaan-1								
(Cassini-)Huygens								
Giotto								

Available, SPICE Kernels Datasets:

Releases and support to the community is provided



SKD Status – April 2018

Mission	Ref Frames FOV LOS	Predicted Orbit Attitude	Measured Attitude	Reconstructed Attitude	OBT conversion	S/C Element Orientation	Payload Orientation	Archived?
Mars Express								
ExoMars TGO								
Rosetta								
Venus Express								
BepiColombo								
Solar Orbiter								
JUICE								
SMART-1								
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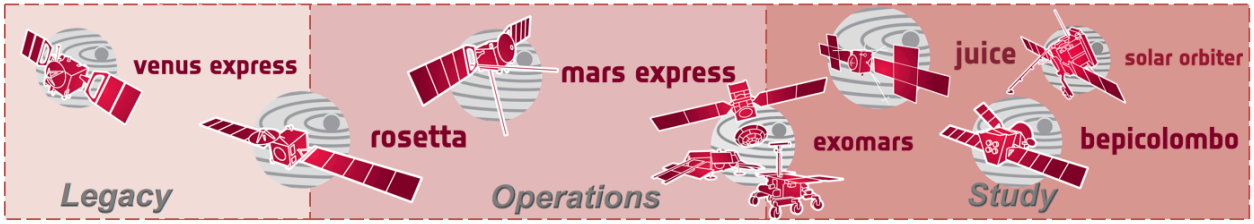


Using SPICE

- We want to analyze Phobos images from the HRSC instrument in MEX, more concretely images that with good resolution taken less than 1.000 km from Phobos **-> WebGeoCalc or GF System**
- Then we could constrain our search in the PSA UI.

Input Values

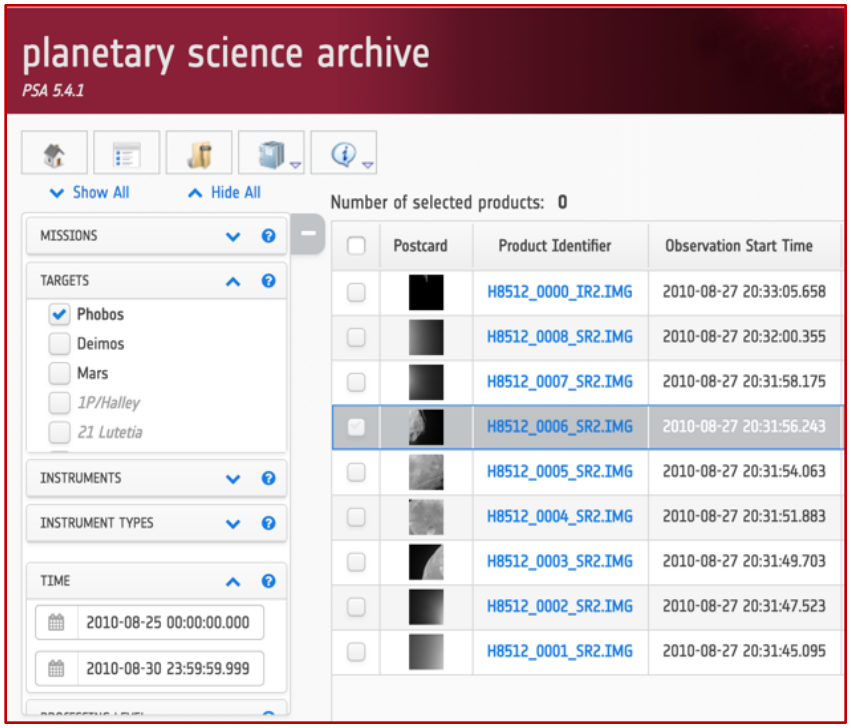
Calculation type	Distance Event Finder
Target	PHOBOS
Observer	MARS EXPRESS
Light propagation	No correction
Time system	UTC
Time format	Calendar date and time
Time range	2010-01-01 to 2010-12-01, step 6 hours
Event condition	is less than 1000
Output time unit	seconds
Complement result window	no
Result interval adjustment	No adjustment
Result interval filtering	No filtering

Tabular Results

Click a value to save it for a subsequent calculation.

Save All Intervals

	Start Time	Stop Time	Duration (secs)
1	2010-02-28 16:18:07.102645 UTC	2010-02-28 16:29:03.406319 UTC	656.30367434
2	2010-08-24 08:22:05.025171 UTC	2010-08-24 08:32:29.283596 UTC	624.25842512
3	2010-08-27 20:28:51.926715 UTC	2010-08-27 20:34:53.806208 UTC	361.87949306



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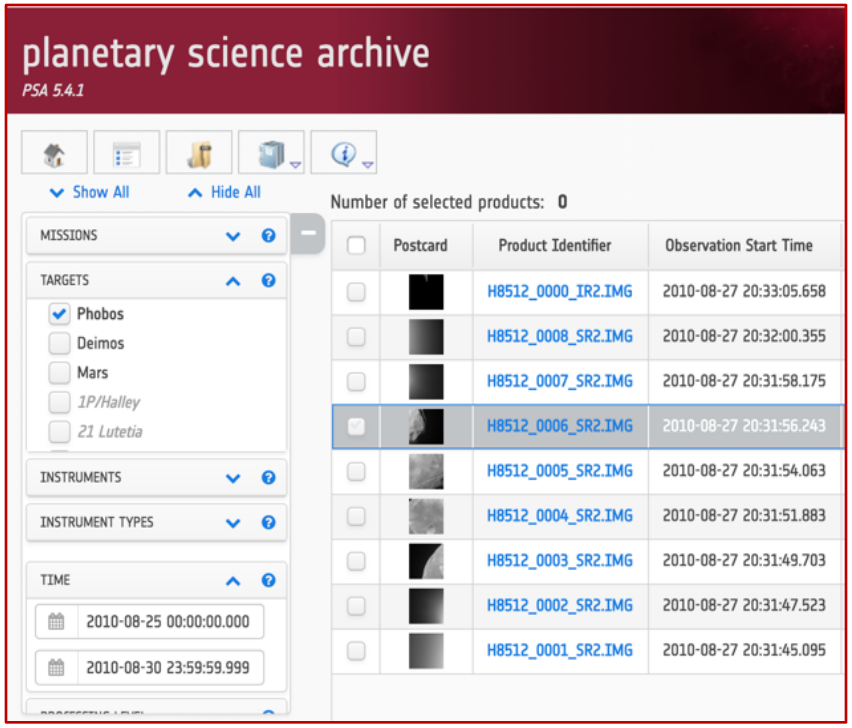
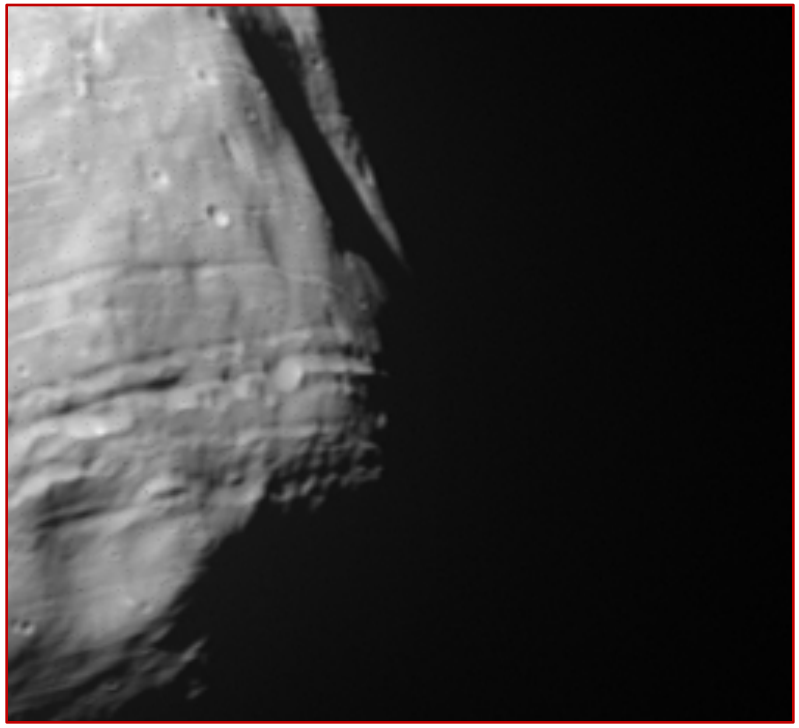
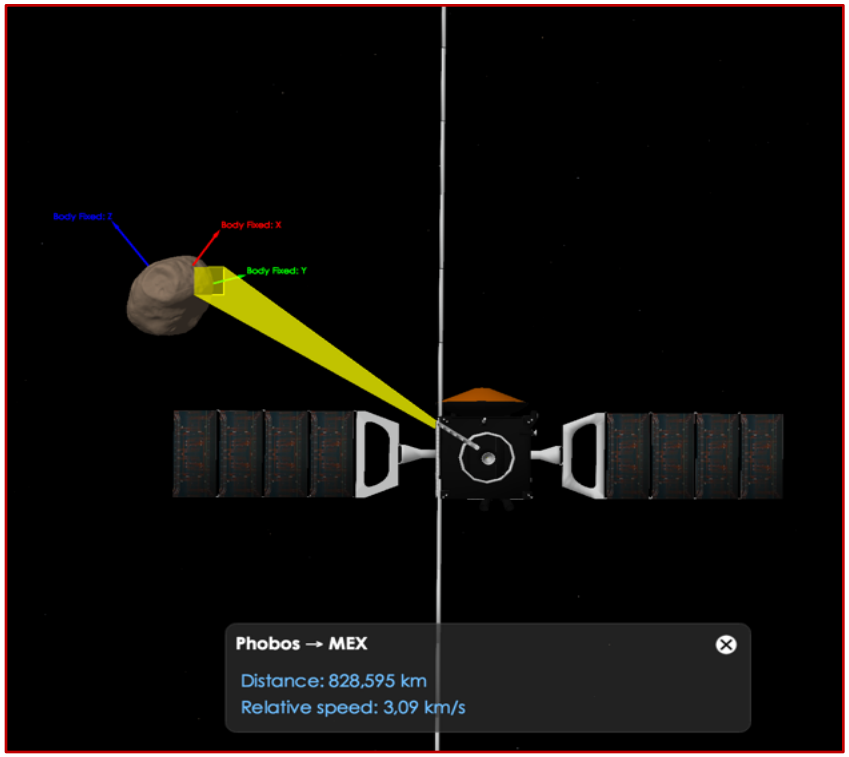
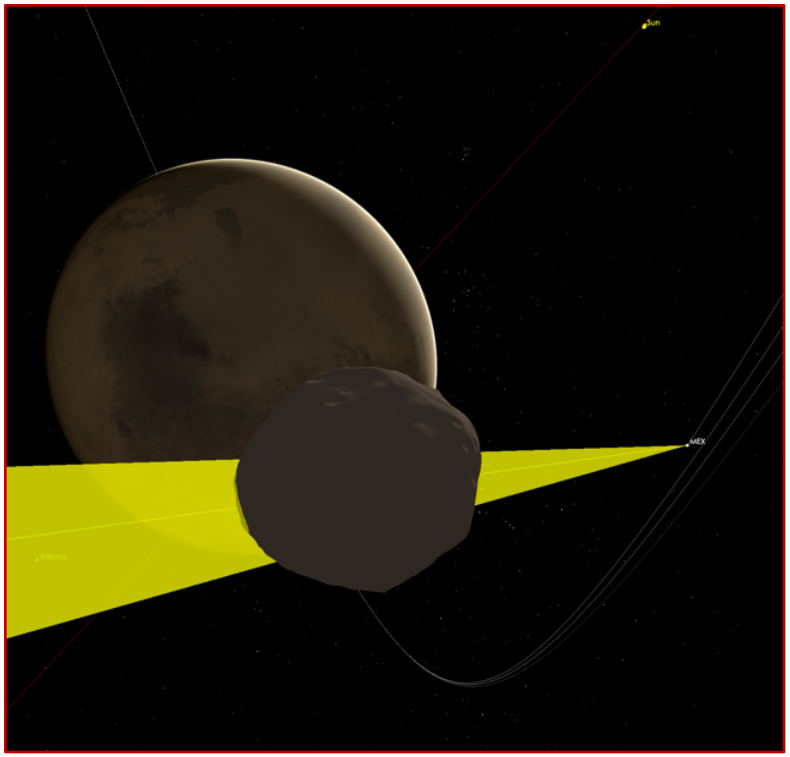




Using SPICE

- We can use Cosmographia to asses the geometry of the observation and to double-check that the kernels are correct





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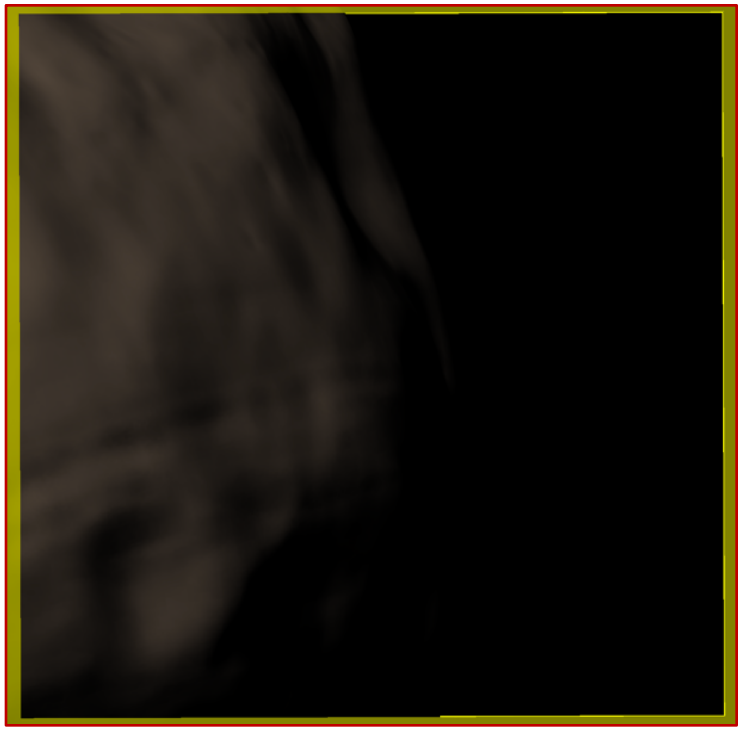
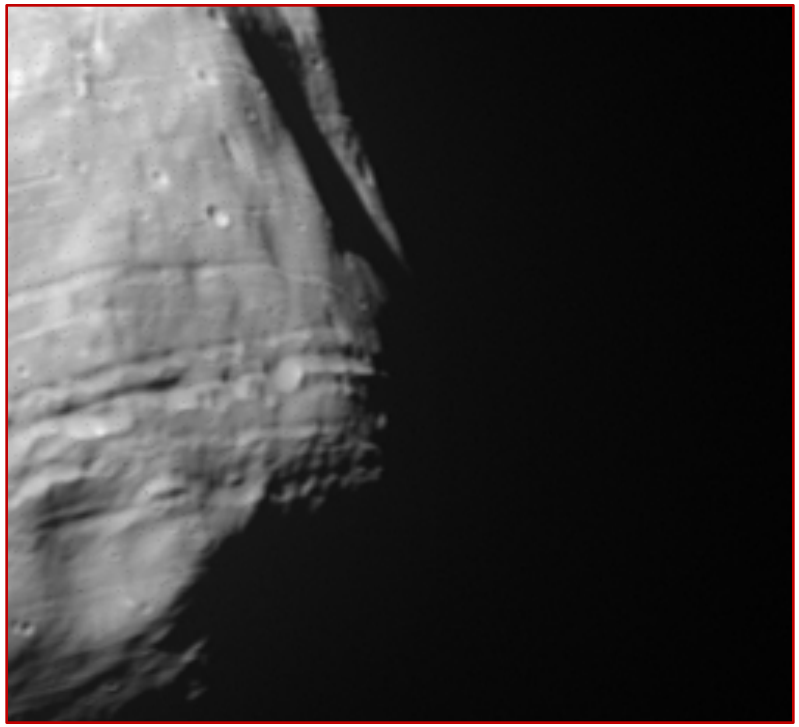




Using SPICE

```
import spiceypy as spiceypy
import math

#
# We load the MEX operational MK
#
spiceypy.furnsh('MEX_OPS_LOCAL.TM')

#
# We convert from UTC to Ephemeris Time (ET)
#
et = spiceypy.utc2et('2010-08-27T20:31:56')

#
# We obtain the HRSC boresight and boresight reference frame
#
id = spiceypy.bodn2c('MEX_HRSC_SRC')
(shape, frame, bsight, vectors, bounds) = spiceypy.getfov(id, 100)

#
# We obtain the intersection between the boresight and Phobos
#
(spoint, trgepc, srfvec ) = spiceypy.sincpt('ELLIPSOID', 'PHOBOS', et, 'IAU_PHOBOS', 'NONE', 'MEX', frame, bsight)

#
# Finally we compute the illumination angles
#
(trgepc, srfvec, phase, solar, emissn) = spiceypy.ilumin('ELLIPSOID', 'PHOBOS', et, 'IAU_PHOBOS', 'NONE', 'MEX', spoint)

print('Phase Angle: {}, Solar Incidence: {} in DEG'.format(math.degrees(phase), math.degrees(solar)))
```

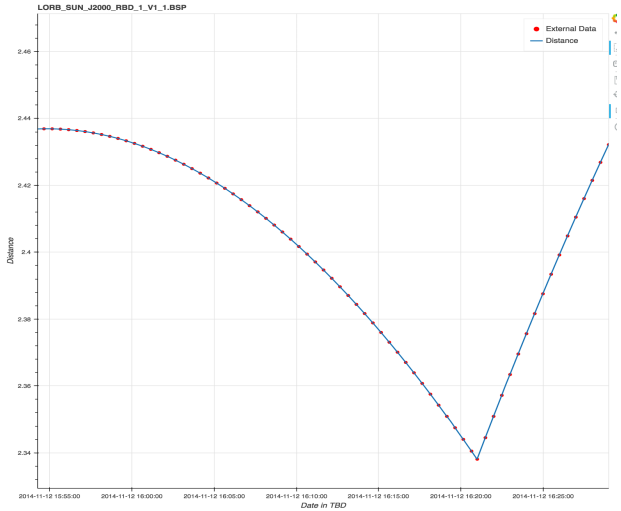
```
Phase Angle: 36.16827291588401, Solar Incidence: 81.9668118763624 in DEG
```

Introducing spiops a collaborative Python package

- spiops is **a Python Package** that uses SpiceyPy to use SPICE Toolkit APIS to provide higher-level functions than the ones available with SPICE. This functions have been identified in my day-to-day work from having to implement multiple times a series of SPICE APIs to obtain a given derived functionality. spiops is aimed to assists the users to extend the usage of SPICE.
- **Functionalities** vary from the computation of the illumination of a given Field-of-View to obtaining the coverage of a given S/C for a particular meta-kernel, plotting Euler Angles or comparing different kernels.
- The underlying idea of spiops is to be used as a **multi-user and multi-disciplinary pool of re-usable SPICE based functions** and to provide an easier interface to certain SPICE functionalities with objects to provide cross mission and discipline support of SPICE for ESA Planetary and Heliophyisics missions.
- Available for Python in PyPi
- ReadTheDocs documentation: `pip install spiops`

  ftp://spiftp.esac.esa.int/spiops/html/index.html

```
start_time = '2014-11-12T15:00:03'
stop_time  = '2014-11-12T17:34:03'

resolution = 1

interval = TimeWindow(start_time, stop_time, resolution=1)

comet = Target('67P/C-G', time=interval, frame='67P/C-G_CK')
lander = Observer('ROS_LANDER', time=interval, target=comet)

external_data = utils.convert_ESOCorbit2data('LORB_EME2000_RBD_1_V1_0.ROS')

lander.Plot('distance', external_data=external_data)
```



Other packages that will use spiops are coming soon with benefits for SPICE users (see poster)

Conclusion

REMARKS

- We are moving towards providing the best SPICE Kernels for ESA Planetary Missions possible.
- In the coming months the Rosetta, MEX and VEX Archived Datasets will be consolidated.
- Using Cosmographia and WebGeocalc might be an asset that you had not considered.
- Kernels Dataset releases are announced in the mailing lists and release notes are available.

COMMUNICATE

- Stay tuned. You can join one of the mailing list. There's one for each planetary mission: spice_mex@sciops.esa.int, spice_vex@sciops.esa.int, spice_ros@sciops.esa.int, spice_em16@sciops.esa.int, spice_bc@sciops.esa.int, spice_juice@sciops.esa.int
- You can also join the OpenPlanetary **slack** channel.

COLLABORATE

- Are you producing SPICE kernels that can enhance or complement our dataset? Provide it to us!
- Do you have a certain SPICE-derived function or have the need for one? consider **spiops**!

LEARN

- We provide **SPICE Training Classes** in Europe (typically Madrid) in a biannual basis. Next training is at **ESAC, Madrid from 19-21 June**. Register now!
- We also provide half-day workshops at ESAC that can be joined remotely.