

SPICE @ ESA

Status and Future Work

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Christophe Arviset



ESPC-DPS
18th October 2019, Geneve

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:

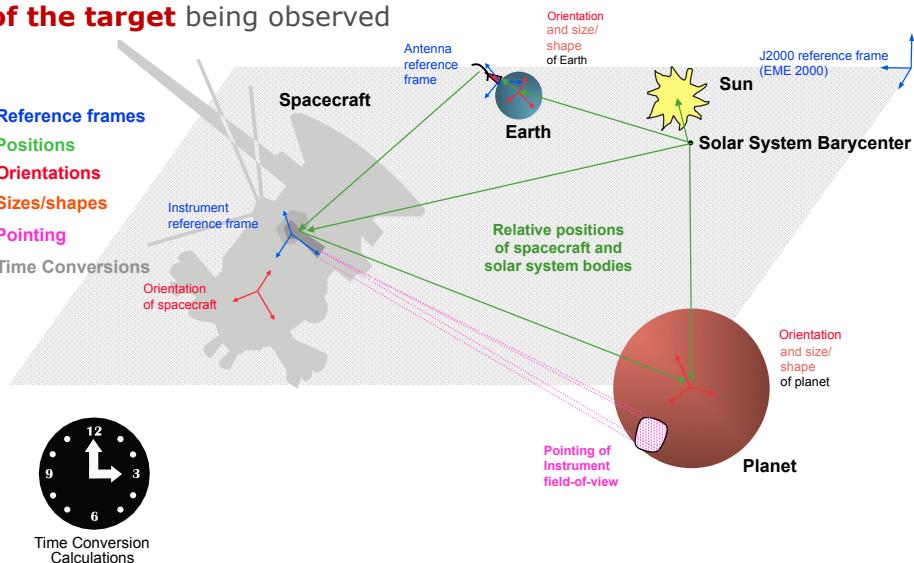
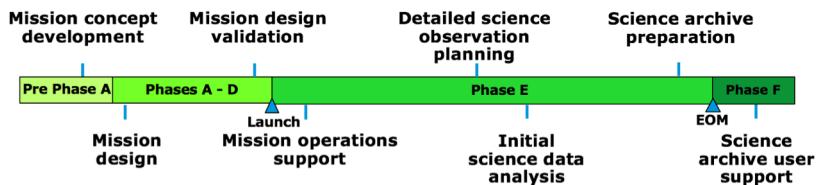
where the **spacecraft** was **located**

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

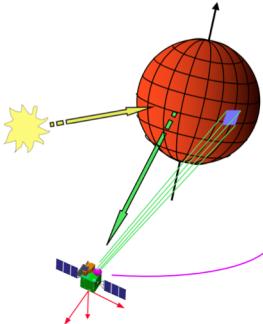
- SPICE provides users a large suite of SW used to read SPICE ancillary data files to compute observation geometry.
- The ancillary data (kernels) comes from: The S/C, MOC/SGS, S/C manufacturer and Instrument teams, Science Organizations.



SPICE in a nutshell



Compute many kinds of observation geometry parameters at selected times

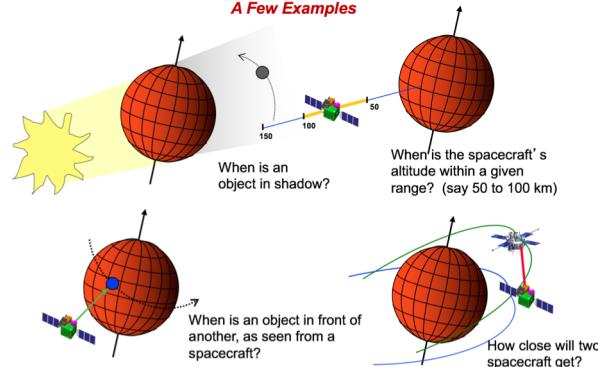


A Few Examples

- Positions and velocities of planets, satellites, comets, asteroids and spacecraft
- Size, shape and orientation of planets, satellites, comets and asteroids
- Orientation of a spacecraft and its various moving structures
- Instrument field-of-view location on a planet's surface or atmosphere

Find times when a specified “geometric event” occurs, or when a specified “geometric condition” exists

A Few Examples



Time conversions

UTC to ET mapping (“generic” LSK file)

Universal Time Coordinated (UTC)

Orbiter on-board clock (SCLK)

Time conversions

ET to orbiter on-board clock mapping (“orbiter” SCLK file)

Position Vectors

Earth position relative to Solar System barycenter (“planet ephemeris” SPK file)

Ephemeris Time (ET)

Rover position relative to the landing site (lander) (“rover” SPK file)

Landing site (lander) position relative to the Mars center (“landing site” SPK file)

Mars position relative to the Solar System barycenter (“planet ephemeris” SPK file)

Orbiter position relative to the center of Mars (“orbiter” SPK file)

Frame Orientations

Orbiter frame orientation relative to J2000 frame (“orbiter” CK file)

Rover frame orientation relative to local level frame (“rover” CK file)

Local level frame orientation relative to planet body-fixed frame (“mission” FK file)

Planet body-fixed frame orientation relative to J2000 frame (“generic” PCK file)



The **ESA SPICE Service (ESS)** based at ESAC leads the SPICE operations for ESA's planetary missions. Its main activities are:

- Generate, develop, maintain and archive the SPICE Kernel Datasets (SKD) for the ESA Planetary Missions (and Solar Orbiter);
- Develop and operates software to convert orbit, attitude, telemetry and spacecraft clock correlation data into the corresponding SPICE formats;
- Provide consultancy and support to the Science Ground Segments and the Science Community of the planetary missions for SPICE and ancillary data management.

ESA SPICE Service are: Marc Costa Sitja, Bjoern Griege and (sometimes) a trainee, the group is managed by Christophe Arviset.

ESS also provides an instance of **WebGeocalc** and the **Cosmographia** configuration for ESA missions:

- **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.

We provide **SPICE Training Classes** in Europe in a biannual basis. Next training 16th-19th June 202.

- [Workshop on Solar System geometry with SPICE](#) Wed, 18 Sep, 13:30-17:00 Pluto (Room 13)
- Recording of last SPICE Training at ESAC is available in YouTube

SPICE Kernel Dataset

- The main purpose is to provide a complete, consistent, high-quality, validated and up-to-date **SPICE Kernel Dataset (SKD)**
- 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 the ESA SPICE Service (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 by ESS with an operational pipeline and the source data is provided by the Flight Dynamics or the given SGS Downlink group in terms of OEMs, AEMs and Housekeeping TM data.
- The **SKD** will 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. Test trajectories and orientation for the S/C (**SPK, CK**)
 4. OBT to UTC/CAL time conversion (**SCLK**)
 5. Measured and Reconstructed trajectory and orientation for the S/C (**SPK, CK**)
 6. Orientation of S/C parts and/or instruments (**CK from HK Telemetry**)
 7. Digital Shape Models of extended bodies (**DSK**)

(Completed with generic kernels for target body ephemeris and models, leap-seconds, etc)
- ESS has focused efforts on systematically providing meta-kernels (**MK**) to users.



SKD Version Control and Distribution



It is also important to distinguish between SKDs published in the ESA FTP (Study and Operational) and BitBucket and the peer-reviewed **and PSA-PDS compliant Archived SKDs** (following the PDS3 and PDS4 standards from the PDS and IPDA).

Version and Configuration Control

- All SKDs are under configuration control and new releases happen constantly.
- SKDs are released on a regular basis when **STKs are updated** and when in operations are time tagged in a daily/weekly basis when **TVKs are updated**.

The distribution of SKDs is done via:



An operational FTP with all the kernels that were ever produced:
<ftp://spiftp.esac.esa.int/data/SPICE>



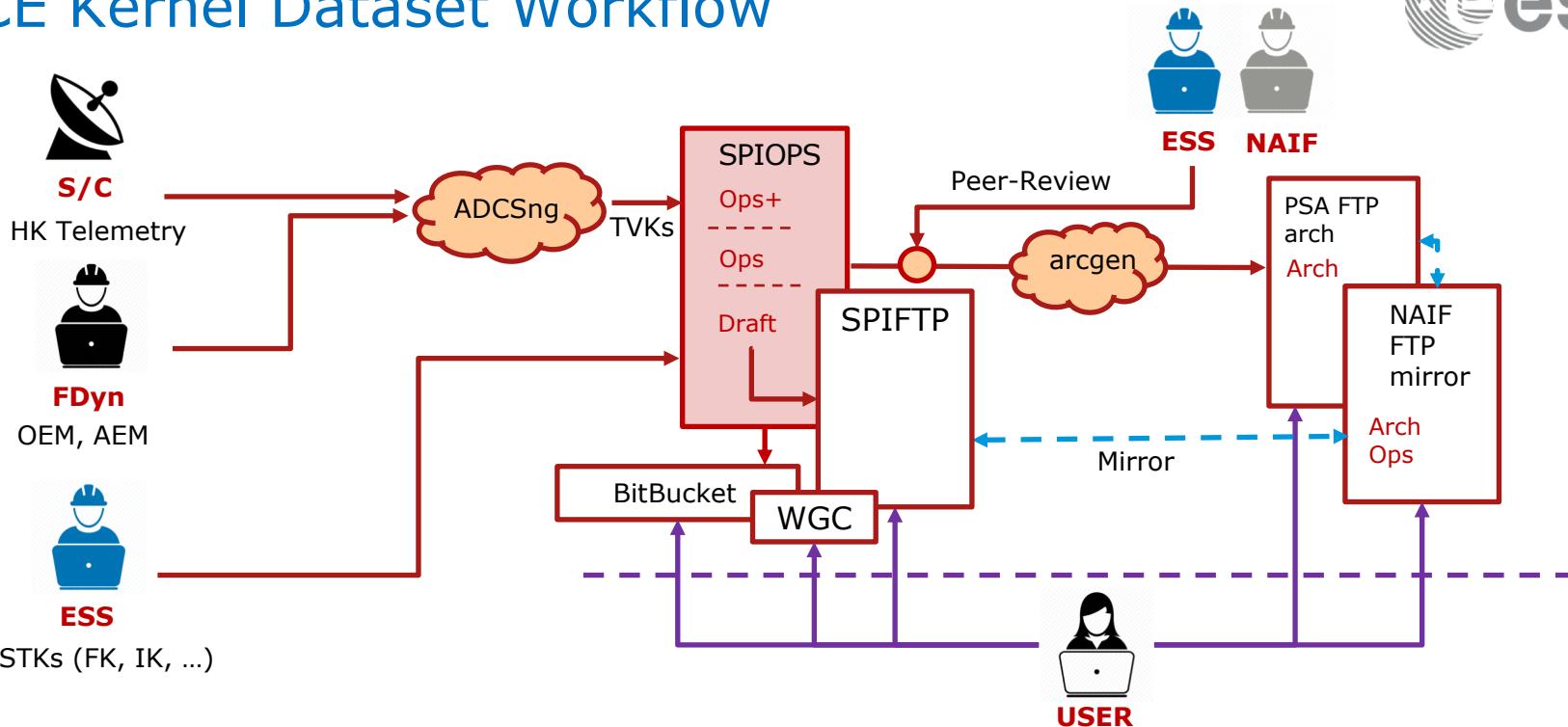
A permanent link to a ZIP file that contains the latest operational subset of the SPICE Kernels



A BitBucket Git repository with a given subset of the SPICE Kernels (operational, planning, archived etc.). [Https://repos.cosmos.esa.int/socci/projects/SPICE_KERNELS](https://repos.cosmos.esa.int/socci/projects/SPICE_KERNELS)

This ensures inter-operability in between internal and external users and with WGC

SPICE Kernel Dataset Workflow



- The Auxiliary Data Conversion System next-generation (ADCSng) generates the time-varying kernels when the mission is in operations and provides up-to-date time correlation, trajectory and orientation information to users.

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.

 **Jet Propulsion Laboratory**
California Institute of Technology

WebGeocalc
Version 2.1.0 (4386 N66 11-FEB-2019)

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.

	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

planetary science archive
PSA 5.4.1



Show All ▾ Hide All ▾

Number of selected products: 0

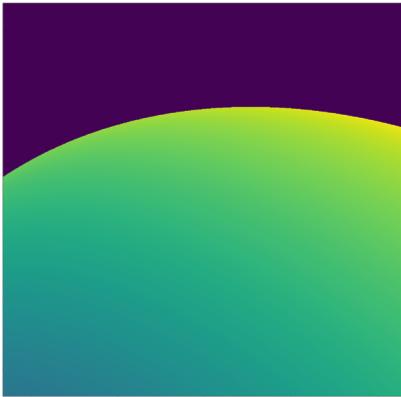
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Using SPICE

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load last meta-kernel  
loop per pixel  
spice.getfov  
spice.sincpt  
spice.illumf
```

Using SPICE

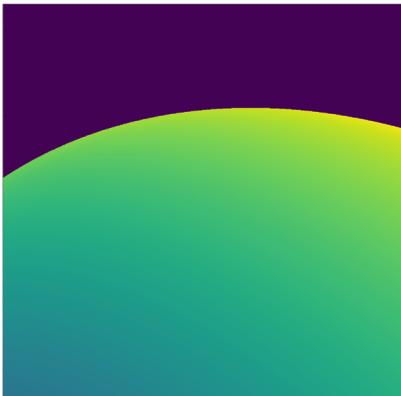
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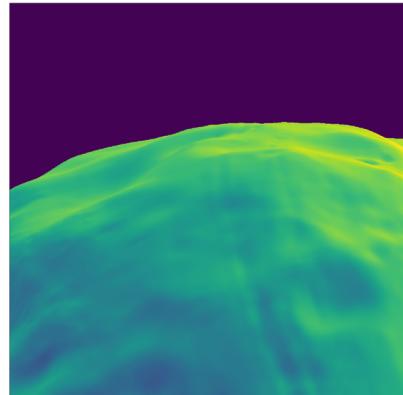
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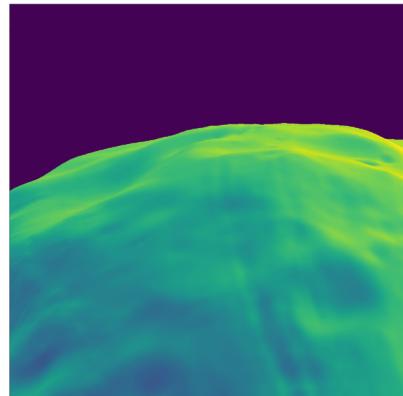
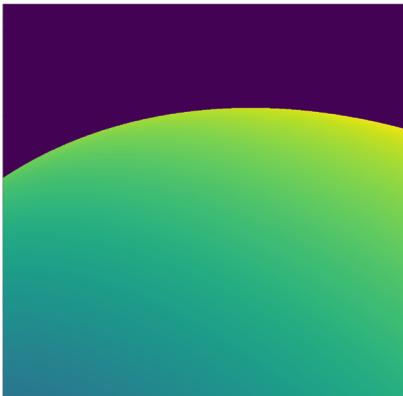


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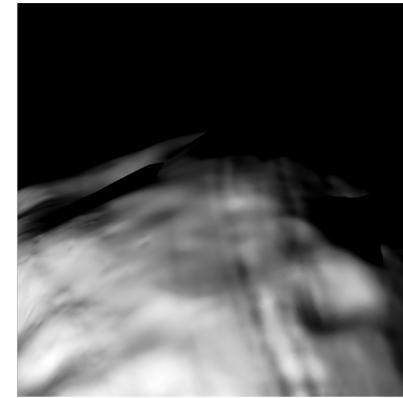
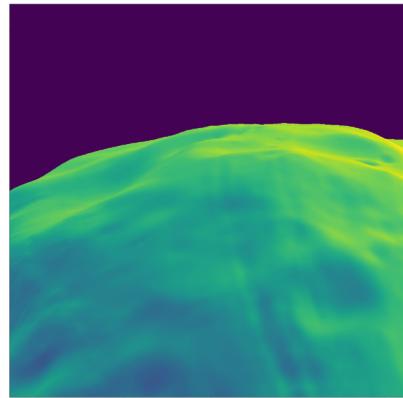
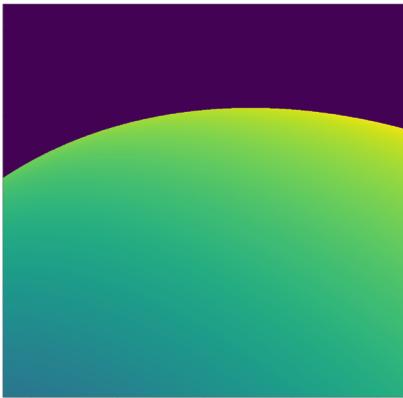


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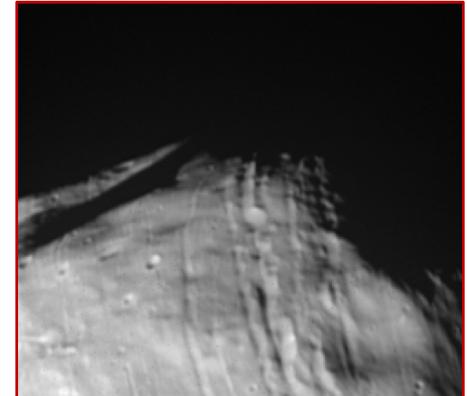
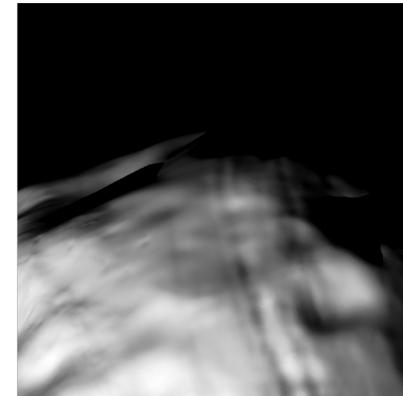
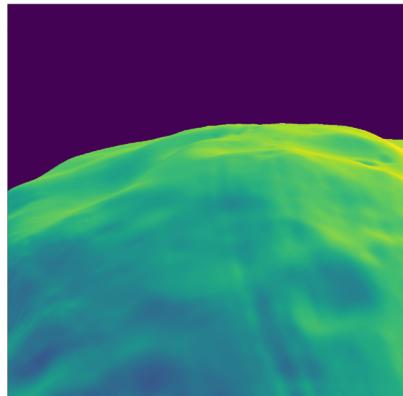
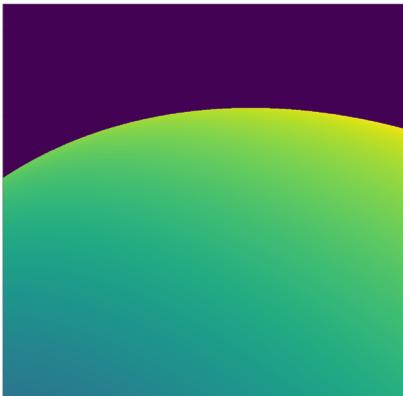


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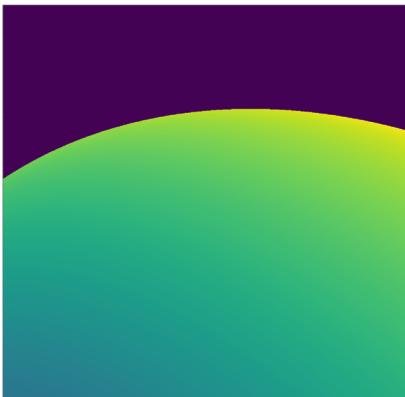
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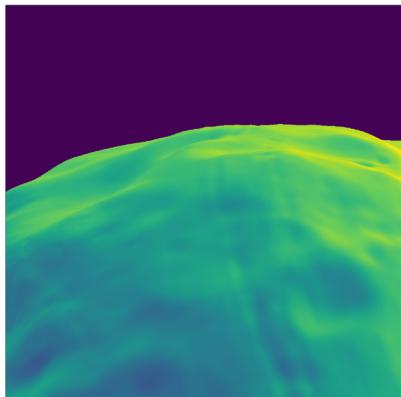
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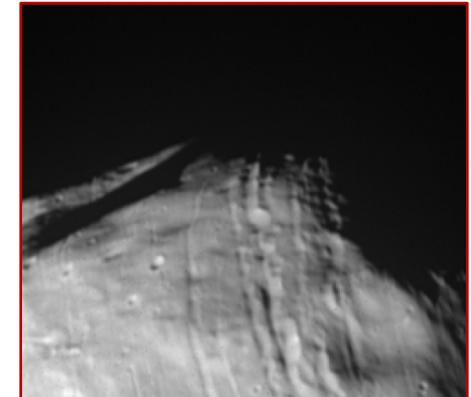
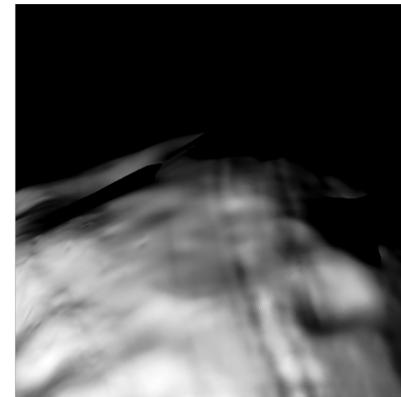
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Lines of code?



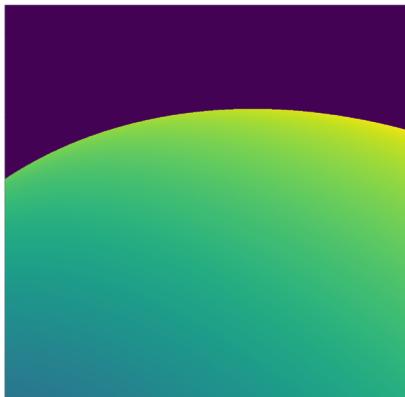
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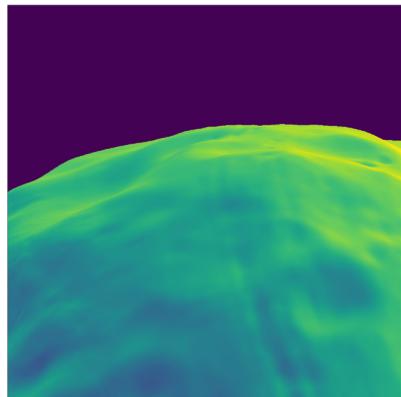
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Lines of code? **37**



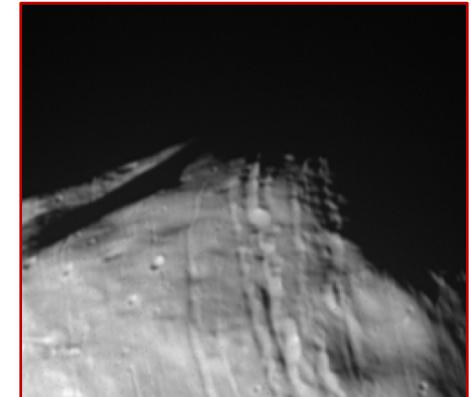
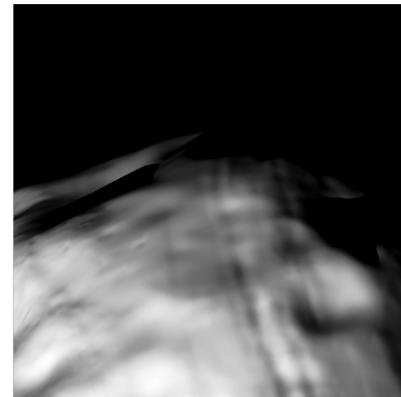
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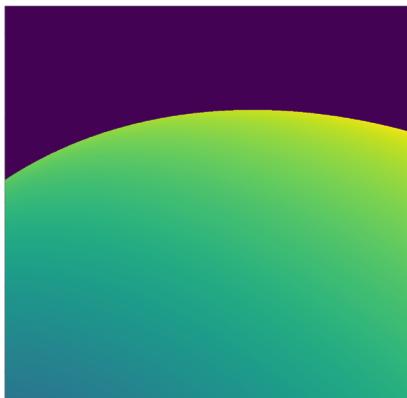
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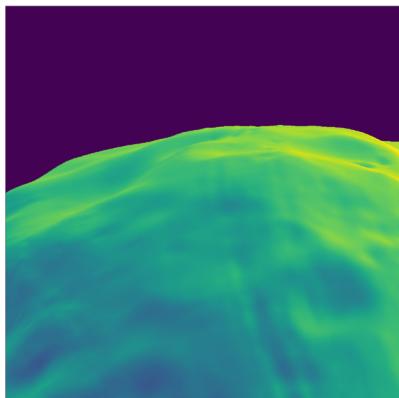
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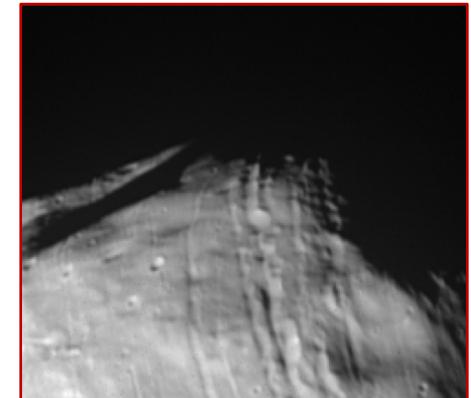
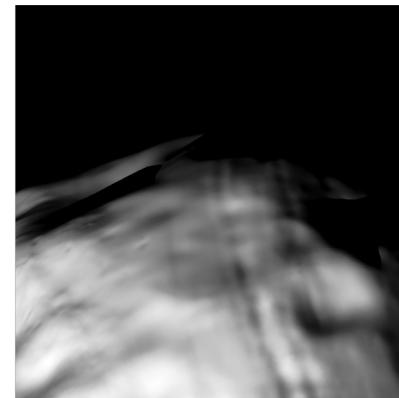
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Using SPICE

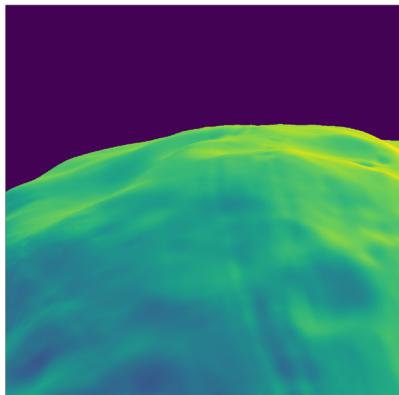
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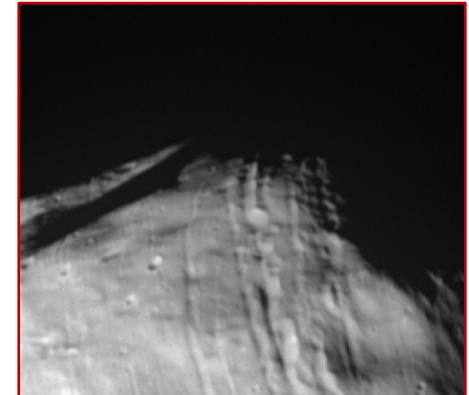
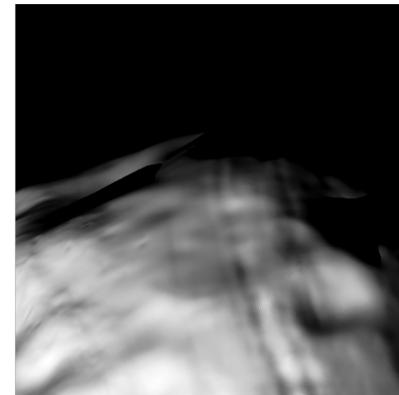
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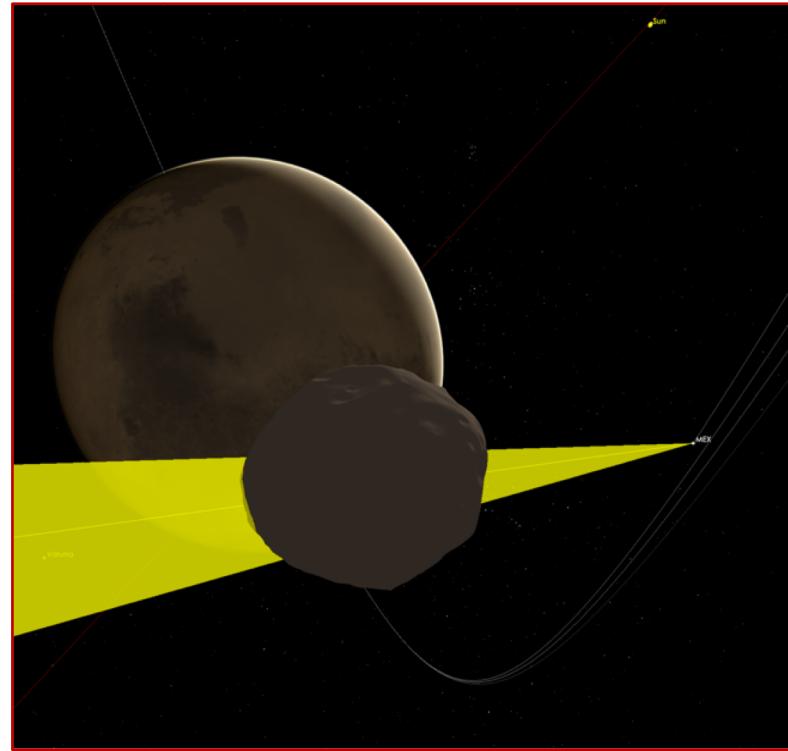
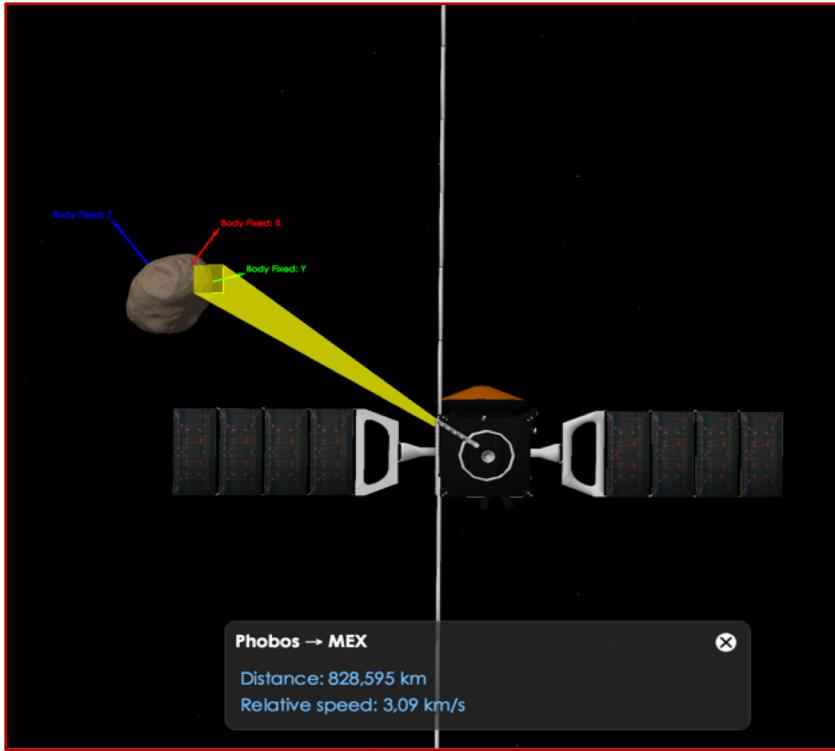
Lines of code? 75



ftp://spiftp.esac.esa.int/temp/acardesin/spirec_sketch-hrsc_head-phobos.html

Using SPICE

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



ESA SKD Status



Mission	Status	BitBucket	Archive	WGC	Cosmo	Frames and sensors	Predicted Orbit & Attitude	Reconstructed Orbit & Attitude	OBT conversion	S/C Element and Payload Orientation
ExoMars2016	OPERATIONAL		PDS4							
Mars Express	OPERATIONAL		PDS3							
BepiColombo	OPERATIONAL		PDS4							
Solar Orbiter	STUDIES									
JUICE	STUDIES		PDS4							
ExoMarsRSP	STUDIES		PDS4							
Hera	STUDIES		PDS4							
EnVision	STUDIES		PDS4							
Rosetta	LEGACY		PDS3							
Venus Express	LEGACY		PDS3							
SMART-1	LEGACY		PDS3							
Chandrayaan-1	LEGACY		PDS3							
(Cassini-) Huygens	LEGACY		PDS3							
Giotto	LEGACY		PDS3							

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Christophe Arviset, Marc Costa, ESA SPICE Service | IPDA Face-to-face meeting | 12/07/2018 | Slide 21



European Space Agency

SKDs in the PSA/PDS

PDS3 SPICE datasets and PDS4 SPICE bundles for the archive produced by the ESS are/will be available from the PSA UI, the PSA FTP server and the NAIF FTP server. They are to be published every 4-6 months.

PDS3 Archives

- Current PDS3 Archived SPICE datasets available:
 - Rosetta **Last updated 2019-08**
 - Mars Express **Last updated 2013-05** Next increment ~ Fall 2019
 - Venus Express **Last updated 2013-02** Final increment ~ Summer 2020

PDS4 Archives

- First PDS4 SPICE Bundle **ExoMars2016 was released this summer.**
- BepiColombo will follow spring 2020.

DOIs

- We are the first service to fully implement DOIs for ESA Science, all DOIs available here:
<https://www.cosmos.esa.int/web/spice/data>
- We encourage (ask) you to cite the ESS DOIs in all the work that you publish in which you have used ESA SPICE data.
- DOIs are available for both Operational and Archived SKDs.

What is next for ESS ?

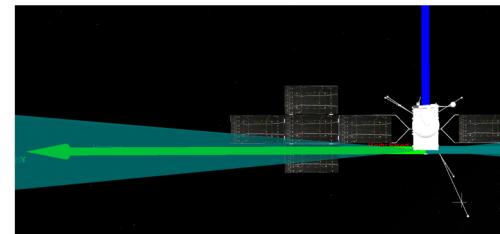
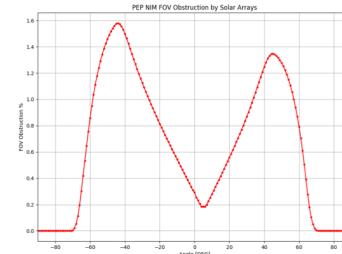
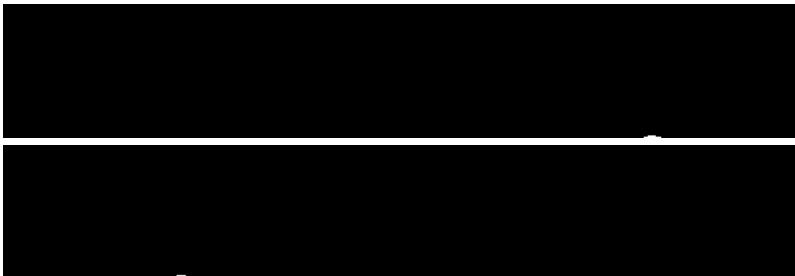


- First and final review and implementation of several SPICE Kernel Datasets: BepiColombo, Mars Express and Venus Express
- Consolidation of the existing Operational Pipeline for all missions (BitBucket, etc.)
- Generation of non-SPICE Ancillary Data PDS3 Datasets and PDS4 Bundles for the archive
- Development of a SPICE Validation Pipeline (including reporting publicly available)
 - A beta version is available here: spice.esac.esa.int/status
- Consolidation of ESS Python packages for the public
- Implementation of DSKs for extended bodies in all SKDs including:
 - Targets (Small Bodies, planet DEMs, etc)
 - Spacecrafts (Bus, rotating Solar Arrays, HGAs, etc)

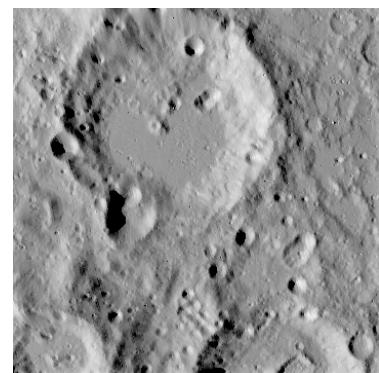
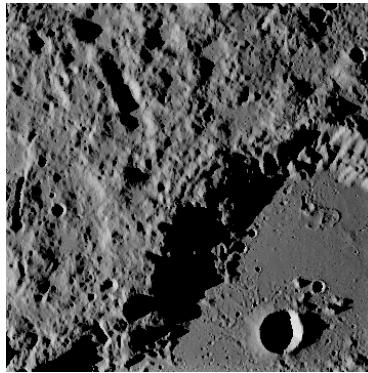
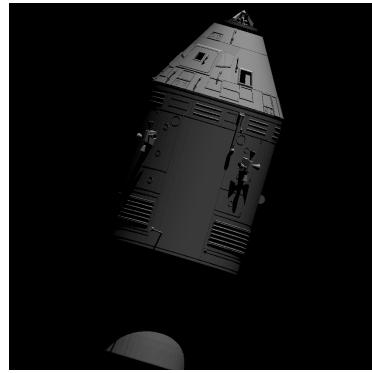
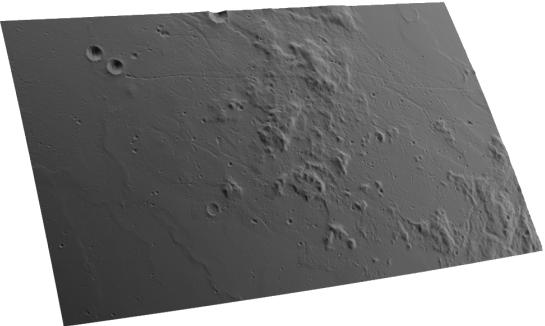
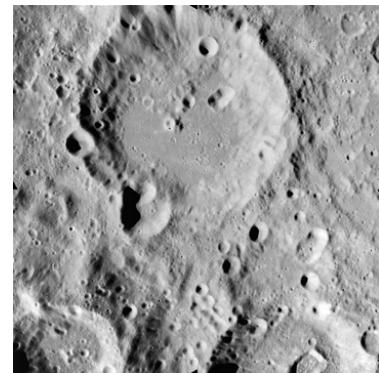
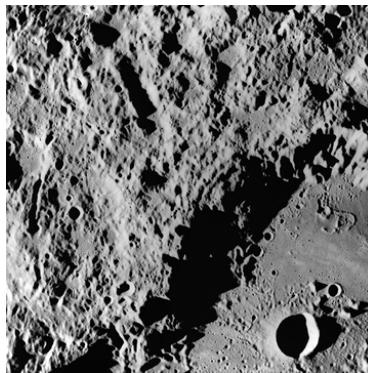
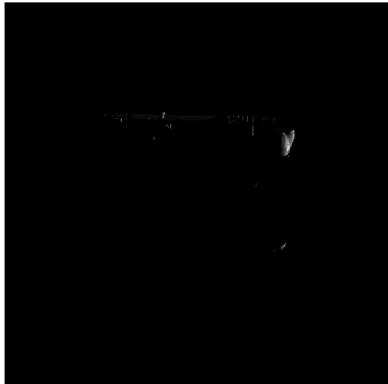
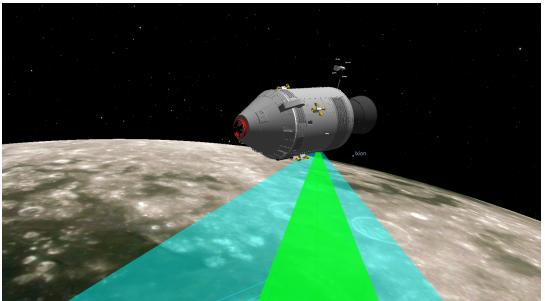
What is next for ESS ?



- First and final review and implementation of several SPICE Kernel Datasets: BepiColombo, Mars Express and Venus Express
- Consolidation of the existing Operational Pipeline for all missions (BitBucket, etc.)
- Generation of non-SPICE Ancillary Data PDS3 Datasets and PDS4 Bundles for the archive
- Development of a SPICE Validation Pipeline (including reporting publicly available)
 - A beta version is available here: spice.esac.esa.int/status
- Consolidation of ESS Python packages for the public
- Implementation of DSKs for extended bodies in all SKDs including:
 - Targets (Small Bodies, planet DEMs, etc)
 - Spacecrafts (Bus, rotating Solar Arrays, HGAs, etc)



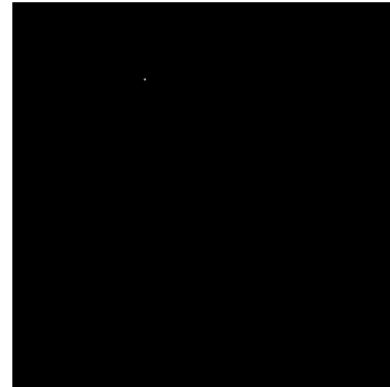
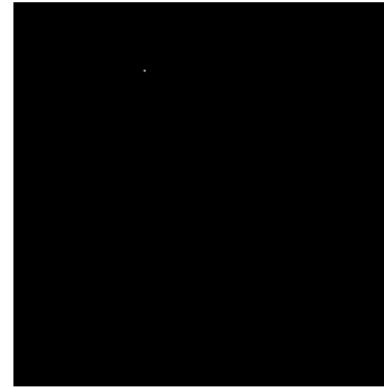
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 - Targets (Small Bodies, planet DEMs, etc)
 - Spacecrafts (Bus, rotating Solar Arrays, HGAs, etc)
- Providing reconstructed attitude:



Keeping in touch



<https://github.com/esaSPICEservice>

<https://twitter.com/SpiceEsa>

<https://tinyurl.com/y77bxntk>

COMMUNICATE

- Everything is accessible from: <http://spice.esac.esa.int>
- Contact the service via e-mail esa_spice@sciops.esa.int
- Stay tuned. You can join one the mission-specific mailing list: spice_mex@sciops.esa.int
- You can also join the OpenPlanetary Slack channel: <http://openplanetary.co>

COLLABORATE

- If you are a SPICE Kernel producer or a bi-product of your investigations are Ancillary Data (Reconstructed Trajectory, S/C Orientation, Natural Body Ephemeris) please contact us and share your data with the community.