SPICE for ESA Planetary Missions

Geometry and visualization support to studies, operations and data analysis

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ESA SPICE Service

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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:

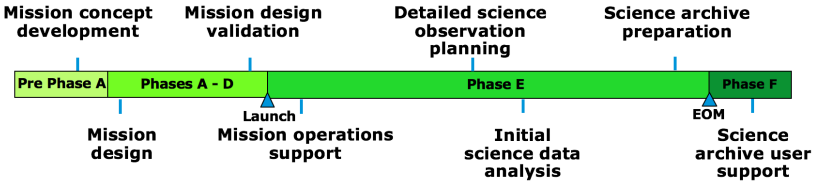
where the **spacecraft** was **located**

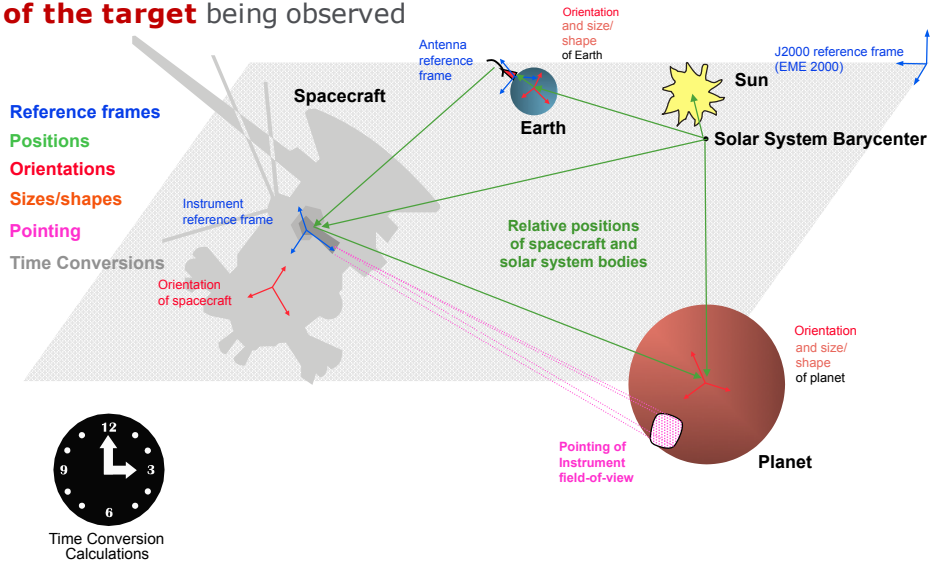
how the spacecraft and its instruments were **oriented** (pointed)

what was the **location, size, shape and orientation of the target** being observed

what **events were occurring** on the spacecraft

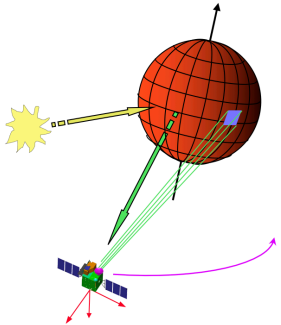
- SPICE provides users a large suite of SW used to read SPICE ancillary data files to compute observation geometry.
- The ancillary data (kernels) comes from: The S/C, MOC/SGS, S/C manufacturer and Instrument teams, Science Organizations.





SPICE in a nutshell

Compute many kinds of observation geometry parameters at selected times

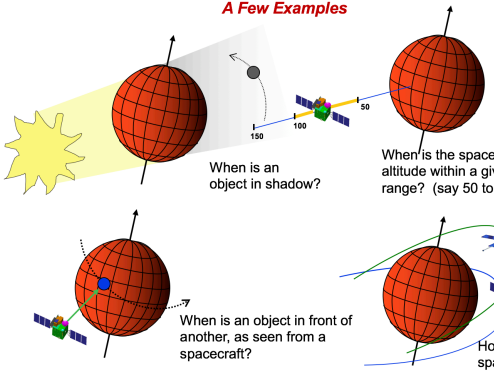


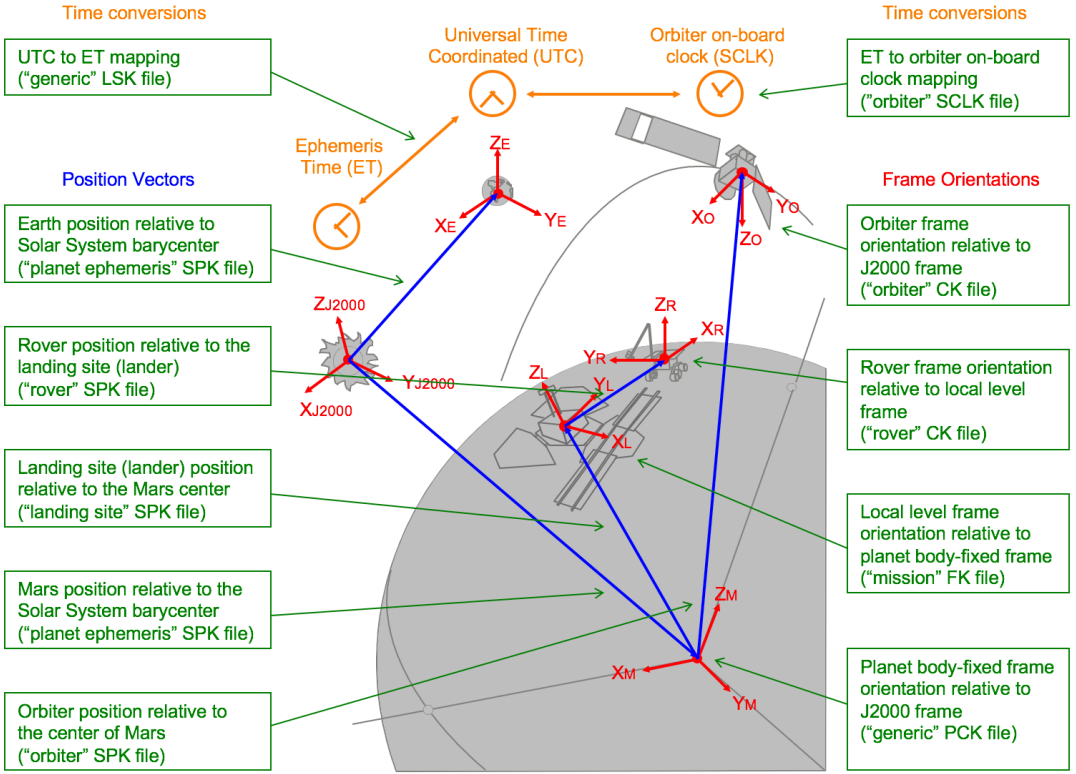
A Few Examples

- 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





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

ESA SPICE Service are: Marc Costa Sitja, Bjoern Greiger, Alfredo Escalante (trainee)

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. Last training 19-22 June2018.

Next training opportunity is on Wednesday 19th @ 105 minute session

Recording of last SPICE Training will be made available in **YouTube**

SPICE Kernel Dataset

- **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 ranging from long term predicted trajectory and orientation to measured attitude. The SKD contains all the kernels that have ever been generated for the mission.

- The following information is included in the different kernels included in the SKD:
  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. Generic quantities such as Planetary Constants and leapseconds (**PCK, DSK, LSK**)
  4. Predicted trajectory and as-planned or default orientation for the rover (**SPK, CK**)
  5. Reconstructed trajectory and orientation and on-board measured orientation for S/C
  6. OBT to UTC/CAL time conversion (**SCLK**)
  7. Orientation of S/C parts (**CK** from HK Telemetry)
  8. Position of scans or turn-tables or articulations of payload (**CK** from HK Telemetry

- Typically a user will work with a subset of the SKD (operational, archived, planning, etc.)

SKD Version Control and Distribution

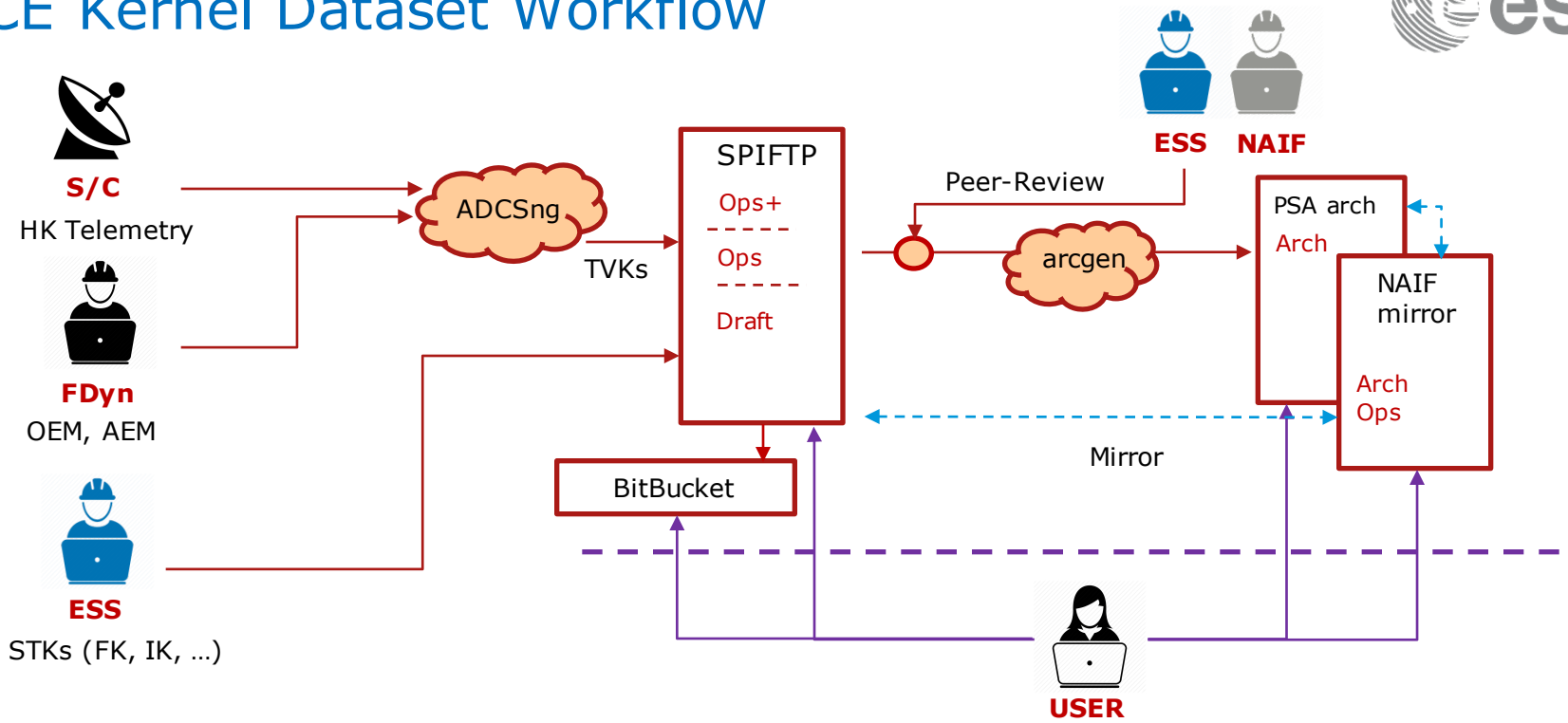
- **Kernels in a SKD can be classified in two main types**:
  - **Setup kernels (STK)** [**FK, IK, PCK, LSK, DSK**] are developed by ESS and are reviewed and iterated with the SGS and with the Instrument Teams when need be during the whole duration of the mission.
  - **Time-varying kernels (TVK)** [**SPK, 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 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 BitBucket Git repository with a given subset of the SPICE Kernels (operational, planning, archived etc.). **Https://repos.cosmos.esa.int/socci/projects/SPICE_KERNELS**
  - A permanent link to a ZIP file that contains the the latest operational subset of the SPICE Kernels (as in BitBucket) (in the future we are exploring using Nexus repos and Dockers, if you have any advise or ideas please come to us)

- It Is also important to distinguish in 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 Planetary Data System and IPDA).

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 trajectoryorientation information to science operations engineers and scientists.

ESA SKD Status (last EPSC)

Mission	Ref Frames FOV LOS	Predicted Orbit Attitude	Measured Attitude	Reconstructed Attitude	OBT conversion	S/C Element Orientation	Payload Orientation	Archived?
Mars Express								
ExoMars2016								
Rosetta								
Venus Express								
BepiColombo								
Solar Orbiter*								
JUICE								
ExoMarsRSP*								
SMART-1								
Chandrayaan-1								
(Cassini-)Huygens								
Giotto								

Available, SPICE Kernels Datasets:

Releases and support to the community is provided

*Private SKDs

ESA SKD Status (Current)

Mission	Ref Frames FOV LOS	Predicted Orbit Attitude	Measured Attitude	Reconstructed Attitude	OBT conversion	S/C Element Orientation	Payload Orientation	Archived?
Mars Express								
ExoMars2016								
Rosetta								
Venus Express								
BepiColombo								
Solar Orbiter*								
JUICE								
ExoMarsRSP*								
SMART-1								
Chandrayaan-1								
(Cassini-)Huygens								
Giotto								

Available, SPICE Kernels Datasets:

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ESA SKD Status (next EPSC?)

Mission	Ref Frames FOV LOS	Predicted Orbit Attitude	Measured Attitude	Reconstructed Attitude	OBT conversion	S/C Element Orientation	Payload Orientation	Archived?
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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 web and the PSA server and from the NAIF.

PDS3 Archives

- Current PDS3 Archived SPICE datasets available:
  - Mars Express **Last updated 2013-05-29** Next increment ~ Fall 2018
  - Rosetta **Last updated 2016-03-31** Next increment ~ Early 2019
  - Venus Express **Last updated 2013-02-13** Next increment ~ Early 2019
- The ESS still has not generated any PDS3 Archived SPICE Kernel Dataset increment, as soon as the process is started, the Rosetta and Venus Express datasets will be quasi complete (pending post-operational enhancements e.g.: reconstructed attitude, improved shapes for 67P…) and Mars-Express will recover the usual 6 months increment cadence.
- In the meanwhile instrument teams and other actors are encouraged to use the operational kernels.

PDS4 Archives

- First PDS4 SPICE Bundle will be **ExoMars2016 and will be released autum 2018**.
- During the summer a first snippet will be generated by the ESS and ingestion in the PSA will be tested.
- BepiColombo, ExoMarsRSP and JUICE will follow.

ESA SPICE and PDS4

- The PDS4 approach with SPICE is to minimize the effort required to archive SPICE kernels; the idea is to apply minimal changes to an operational SPICE Kernel Dataset. The rationale behind is that SPICE has proven to already be very well documented.

- ESS will follow the same approach that NAIF does for the PDS4 Archived kernels. The PDS4 SPICE Bundle consists of:
  - Document Collection:
    - Documents describing the project's SPICE archive (full description in spiceds_v*.html),
    - PDS4 collection labels, collection inventory tables.
  - SPICE Kernel Collection:
    - Project's SPICE kernels and **meta-kernels**,
    - PDS4 collection labels, collection inventory tables.
  - *Miscellaneous Collection:*
    - Not 100% consolidated yet

- For PDS4 it is unlikely that increments can be provided in a daily basis like the rest of the Observational products of the archive. The SKD need to be peer-reviewed before every increment. There will be releases every 4-6 months as in the PDS3 SPICE datasets. All the public data will have the corresponding SPICE kernels available.

- More details available at the PSA PDS4 Archiving Guide, available under request.

Concluding Remarks

- We are moving towards providing the best SPICE Kernels for ESA Planetary Missions possible and also finding the best way to distribute them.
- In the coming months the Rosetta, MEX and VEX Archived Dataset will be consolidated and ExoMars 2106 kernels will start being routinely produced.
- Kernels Dataset releases are announced in the mailing lists and release notes are available.

COMMUNICATE

- Everything is accessible from: **spice.esac.esa.int** (unfortunately not really up-to-date)
- Contact the service via e-mail esa_spice@sciops.esa.int
- 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.
- I am open to suggestions to other communication channels (twitter?)

COLLABORATE

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

Seminar on Solar System Geometry with SPICE

- 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 is developed and maintained by the Navigation and Ancillary Information Facility (NAIF) team of the Jet Propulsion Laboratory (NASA). NAIF and the ESA SPICE Service provide SPICE Training Courses on a yearly basis, these are three-day courses which are hosted either nearby Pasadena (California, USA) or nearby Madrid (Spain).

- The ESA SPICE Service offers an open Short Course on SPICE aimed at scientists and engineers who want to be introduced to SPICE or who might be considering attending a complete SPICE Training.

- During this course a brief introduction to SPICE will be provided and it will be followed by a practical hands-on lesson of a SPICE application based on a Mars-Express remote sensing observation scenario. We will also go through WebGeocalc, SPICE-Enhanced Cosmographia 3D Visualization Software and the Python package spiops.

- A Linux Virtual Machine will be distributed with everything required pre-installed. The used programming language will be Python. People who would like to use IDL, Matlab, C or FORTRAN are also welcome but they should come with their environment setup for SPICE.

- TIME: 14:00 – 15:45