



Updates on SPICE for ESA Missions

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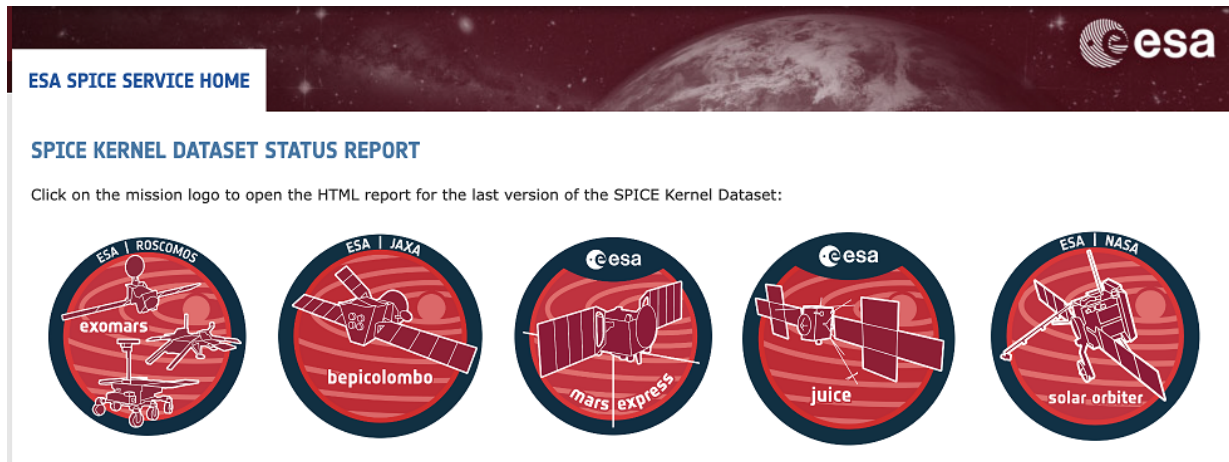
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Introduction: SPICE is an information system the purpose of which is to provide scientists the observation geometry needed to plan scientific observations and to analyze the data returned from those observations. SPICE is comprised of a suite of data files, usually called kernels, and software -mostly subroutines [1]. The user incorporates a few of the subroutines into his/her own program that is built to read SPICE data and compute needed geometry parameters for whatever task is at hand. Some examples of geometry parameters typically computed are range or altitude, latitude and longitude, illuminations angles (phase, incidence and emission), instrument pointing and field-of-view calculations, reference frame transformations, and coordinate system conversions. SPICE is also very adept at time conversions.

The ESA SPICE Service: The ESA SPICE Service (ESS) leads the SPICE operations for ESA missions. The group generates the SPICE Kernel Datasets (SKDs) for missions in development (ExoMars Rover, Hera, Comet-Interceptor, EnVision, M-Matisse), missions in operations (Mars Express, ExoMars 2016, BepiColombo, Solar Orbiter, INTEGRAL and JUICE) and legacy missions (Venus Express, Rosetta and SMART-1). Moreover, ESS provides SPICE support Kernels for Gaia and James Webb Space Telescope. The generation of SKDs includes the development and operation of software to convert ESA orbit, attitude, payload telemetry and spacecraft clock correlation data into the corresponding SPICE format. ESS also provides consultancy and support to the Science Ground Segments of the planetary missions, the Instrument Teams and the science community. The access point for the ESS activities, data and latest news can be found at the following site <https://www.cosmos.esa.int/web/spice>. ESS works in partnership with NAIF.

Providing the best data: The quality of the data contained on a SKD is paramount. Bad SPICE data can lead to the computation of wrong geometric quantities which can jeopardize science results. ESS, in collaboration with NAIF, is focused on providing the best SKDs possible. Kernels can be classified as Setup Kernels (FK kernels defining Reference Frames of a given S/C, IK kernels describing all parameters defining a given instrument, PCK or Planetary Constants Kernels, LSK or Leapseconds Kernels, and DSK kernels defining Digital Shape models of S/C components and celestial bodies) and Time-varying Kernels (SPK and CK kernels providing Trajectory and Attitude data, SCLK providing Time Correlation Data, and MK or Meta-kernel). Setup kernels are iterated with the different stakeholders involved in the determination of the data contained in those kernels (Instrument Teams, Science Ground Segments, etc.) while Time-varying kernels are automatically generated by the ESS SPICE Operational Pipeline to produce the Operational kernels that are used in the day-to-day work of the missions in operations (planning and data analysis). Moreover, a

validation step has been integrated with the pipeline to perform a series of Quality, Consistency and Validity checks before the new kernels are released. These Time-varying kernels are also peer-reviewed a posteriori for the consolidation of SKDs that are archived in the PSA and PDS.



JUICE SPICE Kernel Dataset Status

SKD version: v450_20240507_002

Creation: 2024-05-07T19:19:58 by ESA SPICE Service (ESAC/ESA).

Validation Results

ID	Description	Level	Threshold	Result
XM-C1	Metakernel is valid	Consistency		OK!
XM-C2	Frame chain	Consistency		OK!
XM-C3	Rotation matrices	Consistency		OK!
XM-C4	Fields of view	Consistency		OK!
XM-V1	Time deviation	Validity/Error	50ms	OK!
XM-V1-BIS	Time correlation	Validity/Error	500ms	OK!
XM-Q2	S/C Clock Drift	Quality/Evolution		OK!
XM-V3	Predicted Quaternions to CK error	Validity/Warning	5 mdeg	OK!
XM-V4	Measured Quaternions to CK error	Validity/Warning	5 mdeg	OK!
XM-V5	OEM to SPK error	Validity/Error	100 m & 250 m/s	OK!
XM-V7-JUICE	JUICE Solar Array (SA) Angles	Validity/Error	100 mdeg	OK!
XM-Q3	Attitude Error	Quality/Data	500 mdeg	OK!
XM-Q3-BIS	Commanded Attitude Error	Quality/Data	500 mdeg	OK!

Figure 1: SPICE Validation reports home and example of JUICE tests results.

Status of the Kernel Datasets: The current status and latest developments of the SKDs for the before mentioned missions will be described in this contribution. In general, the ESS is reviewing the legacy and operational datasets and developing the ones for future missions. It is worth mentioning the launch of JUICE in April 2023 and the forthcoming launch of Hera in October 2024.

SPICE Kernels Archived in the PSA. ESS is also responsible for the generation of PDS3 and PDS4 formatted SPICE Archives that are published by the PSA. ESS in close collaboration with NAIF, peer-reviews the operational kernels for the PSA [2] in order to publish being compliant with the

Planetary Data System (PDS) standards and uses them in the processes that require geometry computations. The latest PDS4 SPICE Bundles are produced using the NAIF PDS4 Bundler tool [3].

Extended Services: ESS offers other services beyond the generation and maintenance of SPICE Kernel Datasets, such as instances and configuration for WebGeocalc and Cosmographia for the ESA missions, and additional software packages for geometric data exploitation.

SPICE-Enhanced Cosmographia. NAIF offers for public use a SPICE-enhanced version of the open source visualization tool named Cosmographia. This is an interactive tool devoted to 3D visualizations of celestial bodies ephemerides and shape models, spacecraft trajectories and orientations, movable parts position, and instrument field-of-views and footprints. ESS provides the framework and configuration required to load the ESA missions in Cosmographia, this contribution will demonstrate its usage for the ESA Planetary missions.

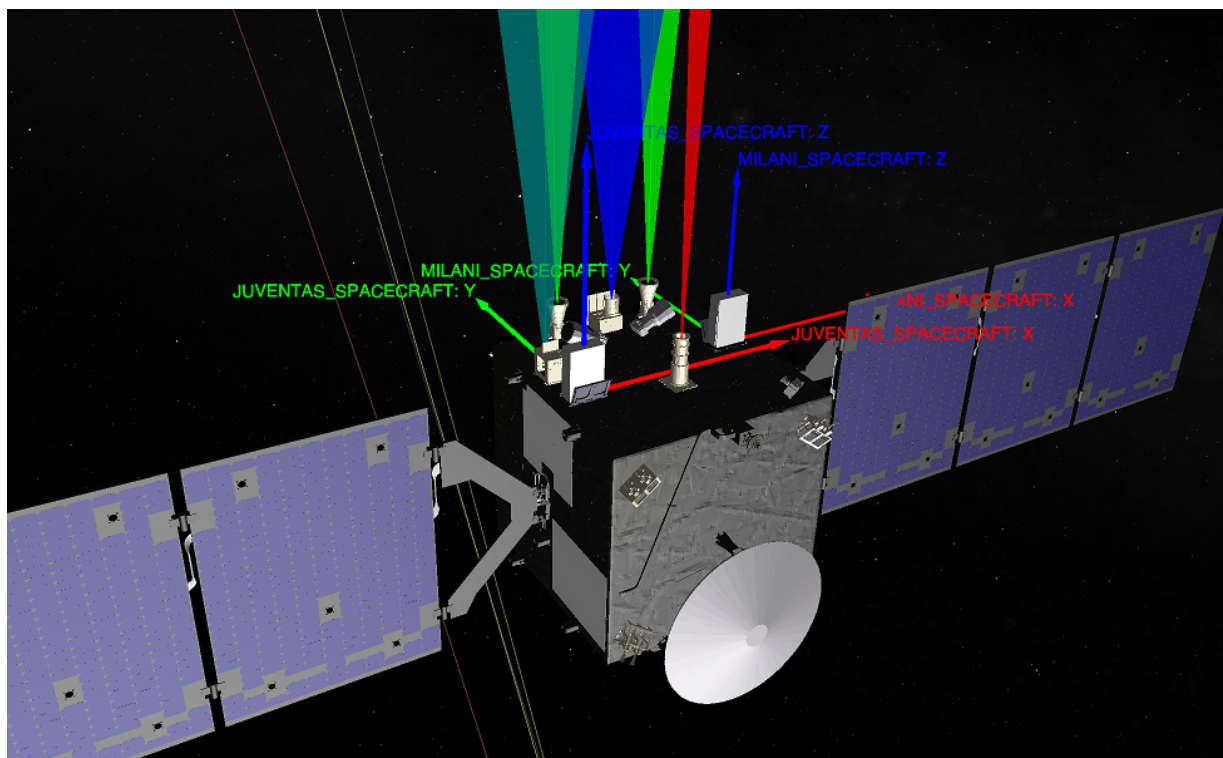


Figure 2: Hera spacecraft, docked Milani and Juventas, and its instruments in Cosmographia.

WebGeocalc. The WebGeocalc tool (WGC) provides a web-based graphical user interface to many of the observation geometry computations available from the SPICE APIs. A WGC user can perform SPICE computations without the need to write a program; just a web browser is required. WGC is provided to the ESS by NAIF. This contribution will outline the WGC instances for ESA missions.

References: [1] Acton C. (1996) *Planet. And Space Sci.*, 44, 65-70. [2] Bessel, S. et al., (2017) *Planet. And Space Sci.* [3] Sitja, M. C. (2022) *Journal of Open Source Software*