

Solar System geometry with SPICE for ESA's planetary missions

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SPICE be good

- SPICE is an information system that uses *auxiliary 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).

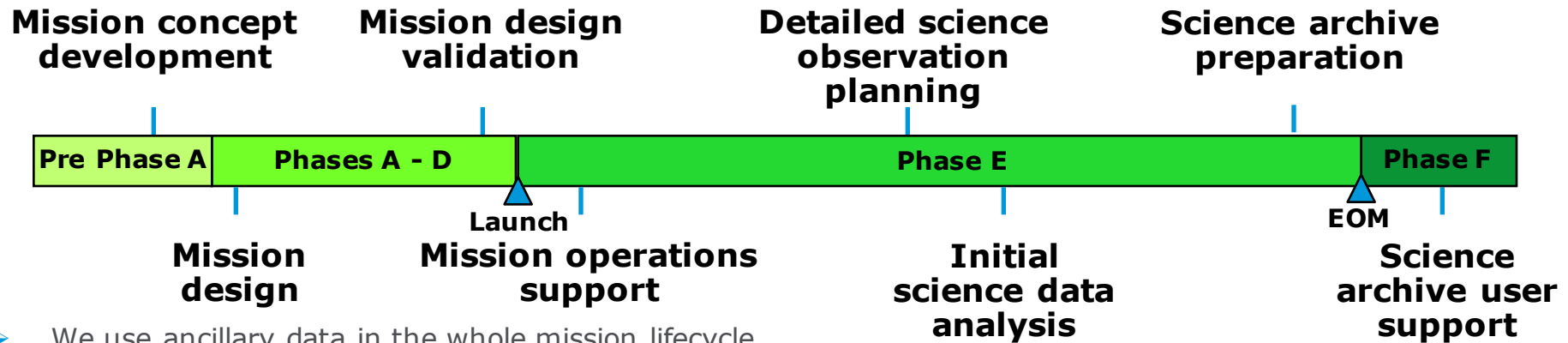


- What do we understand by *auxiliary data*?

Ancillary Data



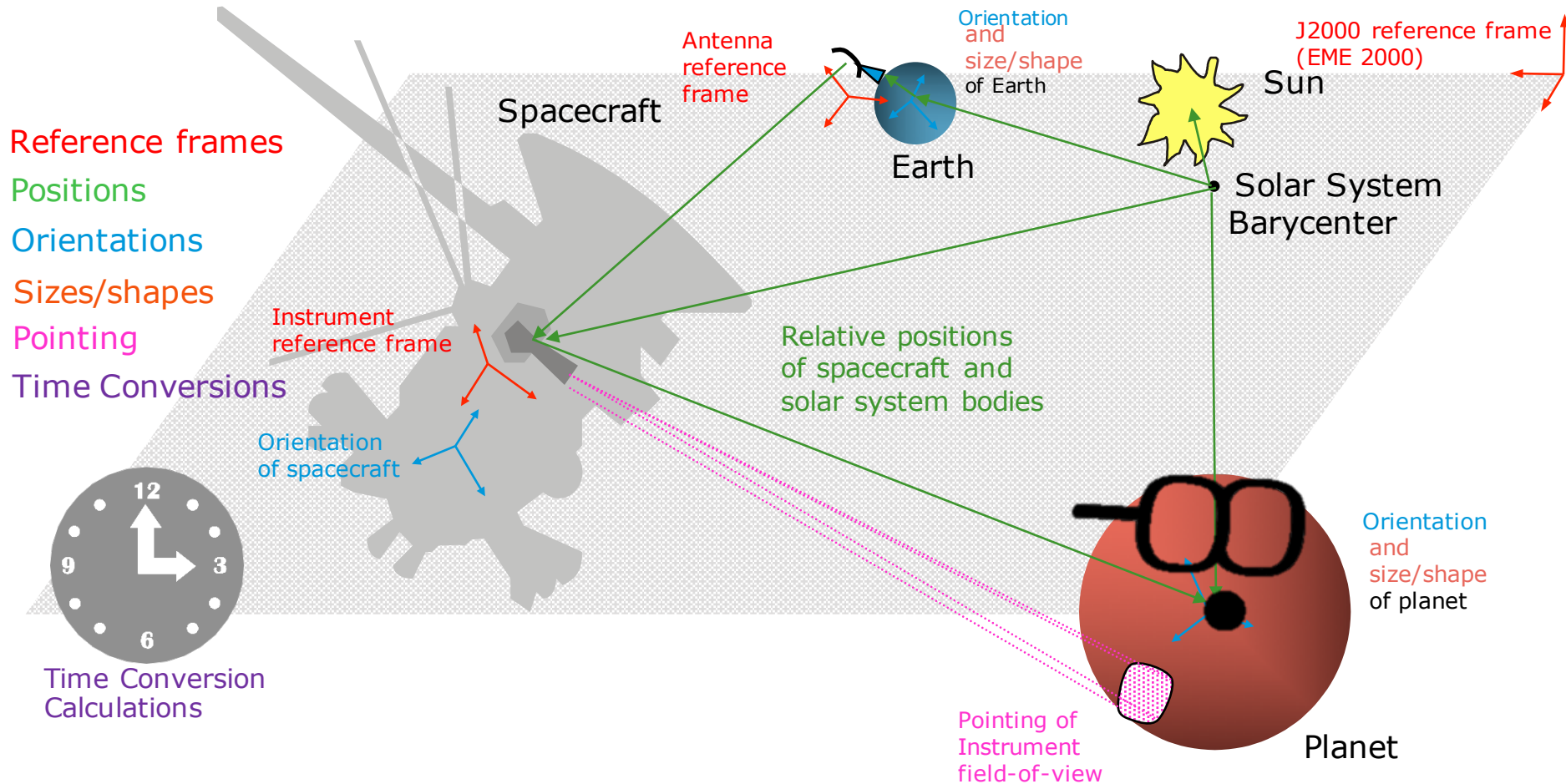
- “Ancillary data” are those that help scientists and engineers determine:
 - where the spacecraft was located
 - how the spacecraft and its instruments were oriented (pointed)
 - what was the location, size, shape and orientation of the target being observed
 - what events were occurring on the spacecraft or ground that might affect interpretation of science observations
- In the above we’ve used past tense, but doing the same functions for future times to support mission planning is equally applicable



- We use ancillary data in the whole mission lifecycle.

Ancillary Data

- When we talk about “ancillary data” we talk, *minimum* of spacecraft trajectory and orientation.

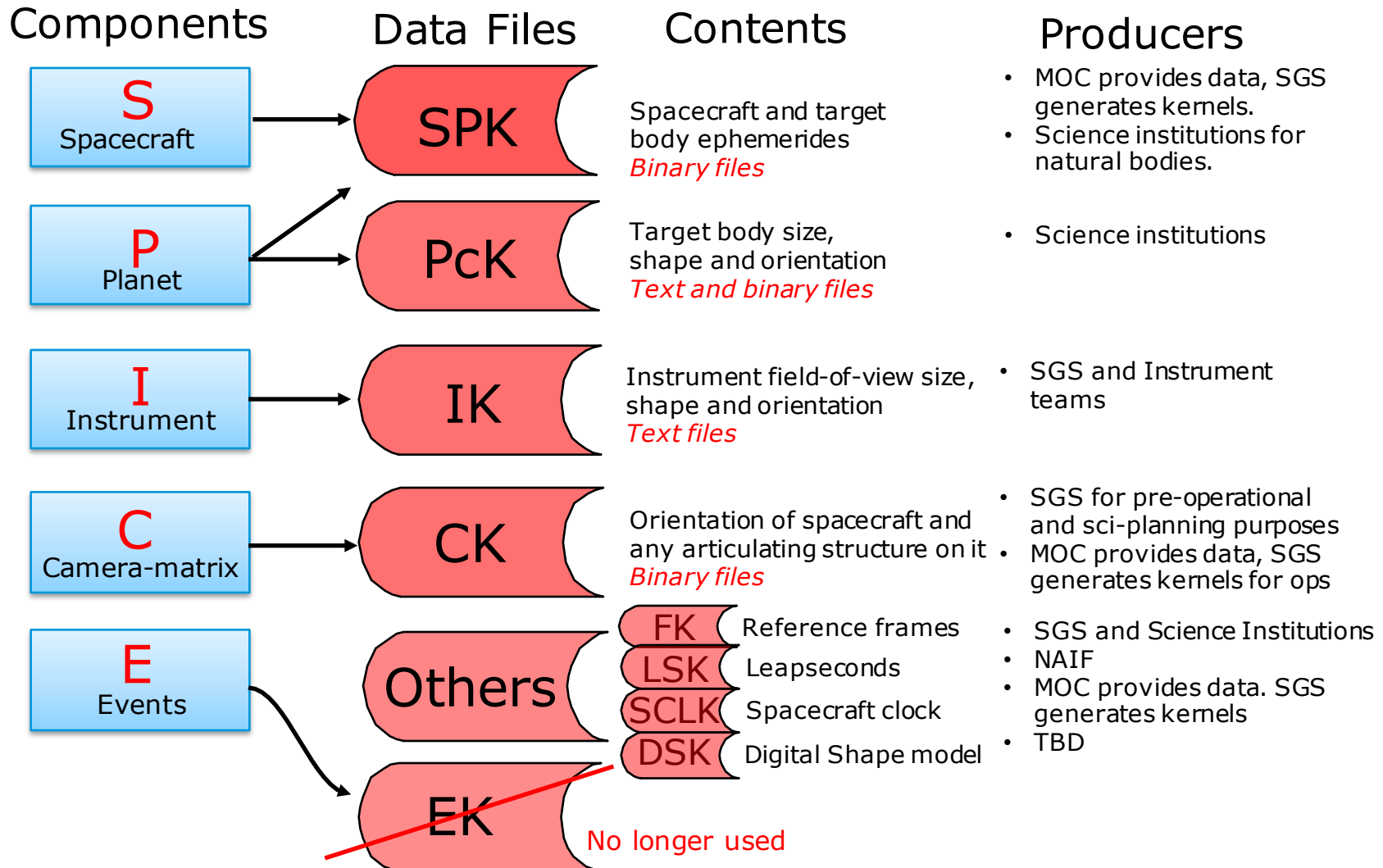


SPICE in a nutshell



- **SPICE** provides users a large suite of SW used to read SPICE ancillary data files to compute observation geometry and events. It is multi-mission and can be used in any kind of planetary mission* (flyby, orbiter, lander, rover..)
- **SPICE** is open, very well tested, extensively used and provides tons of resources to learn it and implement it. Recommended means of archiving ancillary data by IPDA and PDS
- **SPICE** ancillary data comes from:
 - The Spacecraft
 - MOC/SGS
 - Spacecraft manufacturer and Instrument teams
 - Science Organizations
- **SPICE** components are:
 - Ancillary data files (“kernels”)
 - Software (SPICE Toolkit)
 - Documentation (tons)
 - Training classes with tutorials and programming lessons
 - User Consultation

SPICE kernels



The ExoMars 2016 Kernel collection

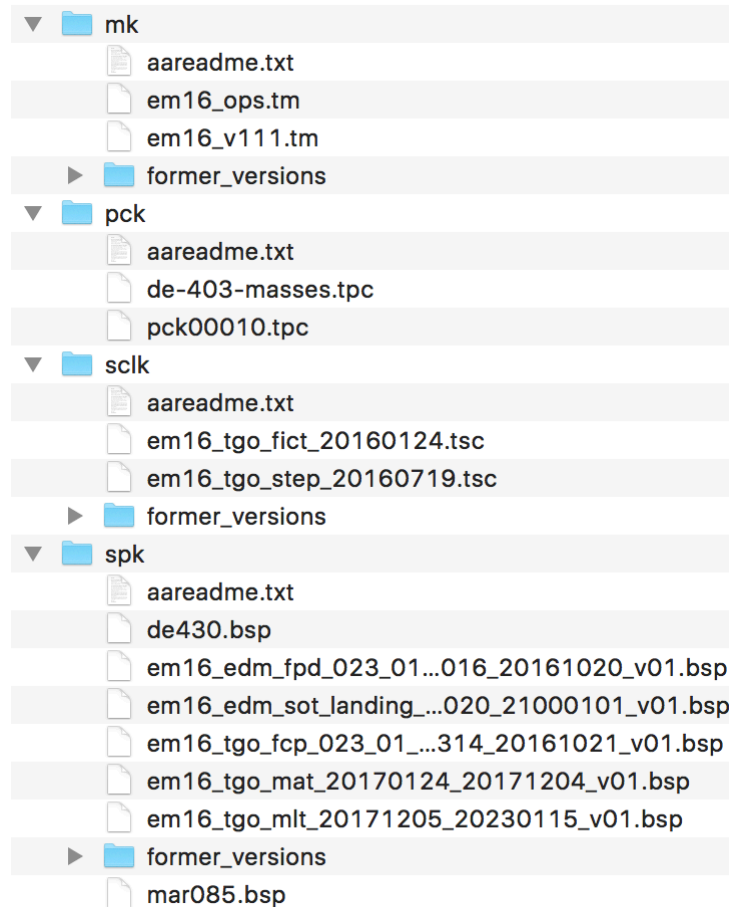
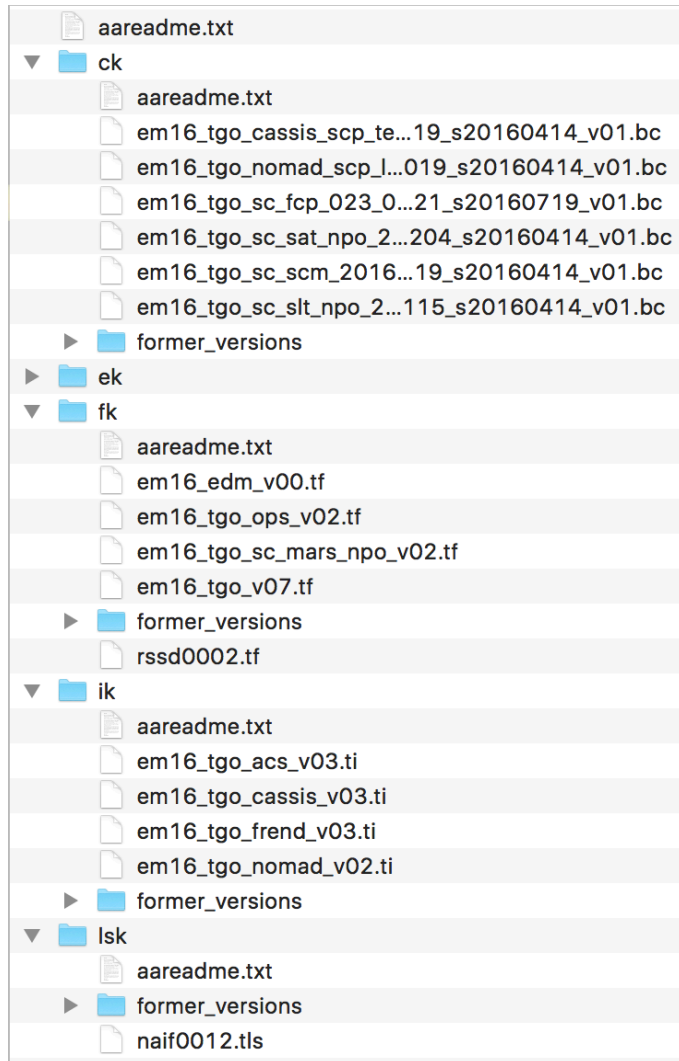


- Access it via ftp directly or navigate your way through:
 - spice.esac.esa.int or <http://www.cosmos.esa.int/spice>
- The ESA Home for SPICE contains some information on the ESA SPICE Service and the available SPICE kernel collections.

Index of /data/SPICE/EM16/kernels

Name	Size	Date Modified
[parent directory]		
aareadme.txt	7.0 kB	8/19/16, 9:34:00 AM
ck/		9/9/16, 8:47:00 AM
ek/		6/7/16, 10:25:00 PM
fk/		8/19/16, 9:34:00 AM
ik/		9/8/16, 2:53:00 PM
lsk/		8/19/16, 9:34:00 AM
mk/		9/9/16, 8:47:00 AM
pck/		8/19/16, 9:34:00 AM
scik/		9/9/16, 8:47:00 AM
spk/		9/8/16, 2:51:00 PM

The ExoMars 2016 Kernel collection



WebGeoCalc and Cosmographia



- **WebGeocalc (WGC)** is a web-based graphical user interface to SPICE. Many observation geometry computations available in SPICE through a standard web browser.
 - Useful for validation of computations and quick analysis of trajectory and attitude.
- **SPICE-enhanced Cosmographia** is an interactive tool; 3D visualization of S/C trajectory, orientation and instrument field-of-views and footprints. Open source. Useful for kernel validation and observation visualization.

DEMO

- Occultations during the Europa Fly-bys for RIME operations
- We use WebGeoCalc to obtain the dates of the Europa fly-bys (altitude 2561)
- We grab the resulting time windows and we search for Occultations of Jupiter by Ganymede from JUICE
- We open Cosmographia and we show the scenario.

SPICE for ESA Missions



- SPICE kernels can be found in different places and can be of three different nature
 - Pre-operational / operational / archived
 - NAIF (PDS Node) / **ESA SPICE Server** / **PSA** / Other Agencies portals

Kernel Dataset	ESA server	NAIF server	PSA Archive	Mission status	Kernel status
ExoMars 2016	Present	Present	Not present soon	Operational	Consolidated
Rosetta	Present	Present	Present	Operational	Consolidated*
Mars Express	Present	Present	Changing soon	Operational	Consolidated*
Venus Express	Present	Present	Changing soon	Post Operations	Final Review*
BepiColombo	Changing soon	Not present soon	Not present soon	Studies	In development
JUICE	Present	Not present soon	Not present soon	Studies	Consolidated
Solar Orbiter	Not present soon	Not present soon	N/A	Studies	Early development
SMART-1	Changing soon	Present	Present	Legacy	Not reviewed
Chandrayaan-1	Changing soon	Present	N/A	Legacy	Not reviewed
AIM	Not present soon	Not present soon	N/A	Early studies	Aware of existence



SPICE Operational Kernels - current



<i>Data Restorations</i>	<i>Selected Past Users</i>	<i>Current/Pending Users</i>	<i>Possible Future Users</i>
Apollo 15, 16 [L]	Magellan [L]	Cassini Orbiter	NASA Discovery Program
Mariner 2 [L]	Clementine (NRL)	Mars Odyssey	NASA New Frontiers Program
Mariner 9 [L]	Mars 96 (RSA) [F]	Mars Exploration Rover	ExoMars 2018 (ESA, RSA)
Mariner 10 [L]	Mars Pathfinder	Mars Reconnaissance Orbiter	ARM (HEOMD)
Viking Orbiters [L]	NEAR	DAWN	<i>Examples of External Users</i>
Viking Landers [L]	Deep Space 1	Mars Science Lab	Emirates Mars Mission (UAE via LASP)
Pioneer 10/11/12 [L]	Galileo	Juno	Bevo-2 CubeSat (U.T. Austin, Texas A&M)
Haley armada [L]	Genesis	MAVEN	Space Launch Systems (HEOMD)
Phobos 2 [L] (RSA)	Deep Impact	SMAP (Earth Science)	Proba-3 (ESA)
Ulysses [L]	Huygens Probe (ESA) [L]	OSIRIS REX	Solar Probe Plus
Voyagers [L]	Stardust/NExT	InSight	EUMETSAT GEO satellites [L]
Lunar Orbiter [L]	Mars Global Surveyor	Mars 2020	MOM (ISRO)
Helios 1,2 [L]	Phoenix	Europa Clipper	BepiColombo (ESA, JAXA)
	EPOXI	NISAR (NASA/ISRO; Earth Science)	JUICE (ESA)
	GRAIL	Lunar Reconnaissance Orbiter	Solar Orbiter (ESA)
	Messenger	New Horizons	Chang'e 3 ? (CNSA)
	Phobos Sample Return (RSA) [F]	Mars Express (ESA)	Van Allen Probes [L]
	Venus Express (ESA)	Rosetta (ESA)	STEREO [L]
	Chandrayaan-1 (ISRO)	ExoMars 2016 (ESA, RSA)	Spitzer Space Telescope [L]
	Hayabusa (JAXA)	Akatsuki (JAXA)	Kepler [L]
[L] = limited use	Kaguya (JAXA)	Hayabusa-2 (JAXA)	Hubble Space Telescope [S][L]
[S] = special services	LADEE		Radioastron (RSA) [L]
[F] = mission failed	ISO [S] (ESA)		IBEX [L]
	CONTOUR [F]	Planetary Data System	James Webb Space Telescope [S][L]
	Space VLBI [L] (multinational)	Planetary Science Archive (ESA)	JPL's Solar System Dynamics Group [S][L]
Last updated: 12/3/15	Smart-1 (ESA)	NASA Deep Space Network [S]	International Astronomical Union [L]

■ NAIF has or had project-supplied funding to support mission operations, consultation for flight team members, and SPICE data archive preparation. NAIF also has PDS funding to help scientists and students with using SPICE data that have been officially archived at the NAIF Node of the PDS.

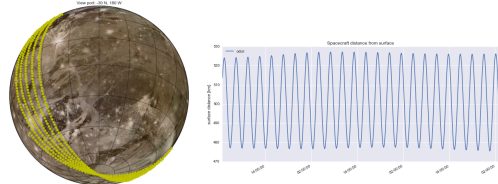
■ NAIF has or had NASA funding to support a foreign partner in SPICE deployment and archive review, and to consult with flight team SPICE users.

■ NAIF has token funding to consult with kernel producers at APL. APL provides support to science teams.

AU ■ NAIF has or had modest PDS-supplied funding to consult on assembly of a SPICE archive.

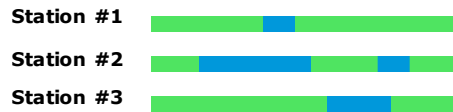
ES ■ NAIF has PDS funding to help NASA funded scientists using SPICE data that have been officially archived at the NAIF Node of the PDS.

Conclusion

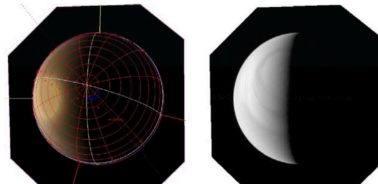


Evaluation of a planned trajectory

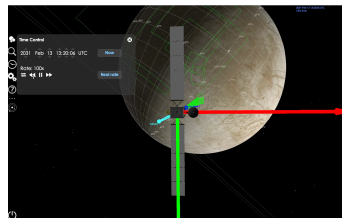
Spacecraft Visibility



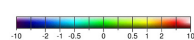
Mission engineering analyses

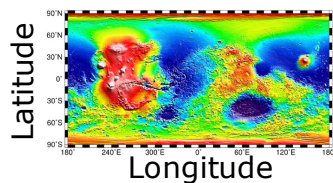


Planning an instrument pointing profile



Observation geometry visualization

Elevation 



Science data archiving and analysis