Solar System geometry tools with SPICE for ESA's planetary missions

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16/03/2016 ICATT

Issue/Revision: 1.0
Reference: Presentation Reference
Status: Issued

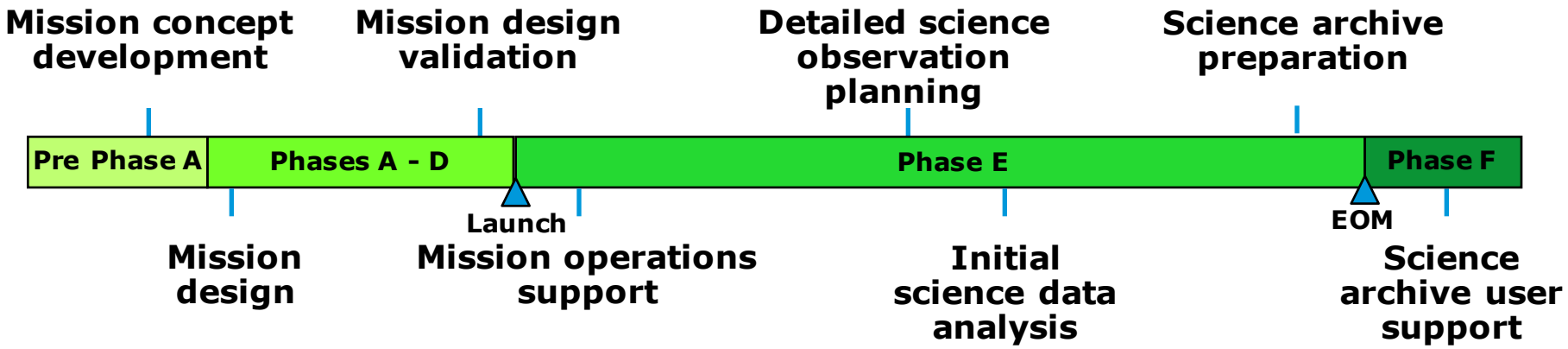
SPICE be good

- 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

- Space flight projects need a set of "ancillary data" to support:
  - Mission design
  - Science Ground Segment design, development and testing
  - Flight engineering operations
  - Science observation planning
  - Quick look science data analysis
  - Science data archive preparation
  - And maybe most important of all: science data analysis!



- We use ancillary data in the whole mission lifecycle.

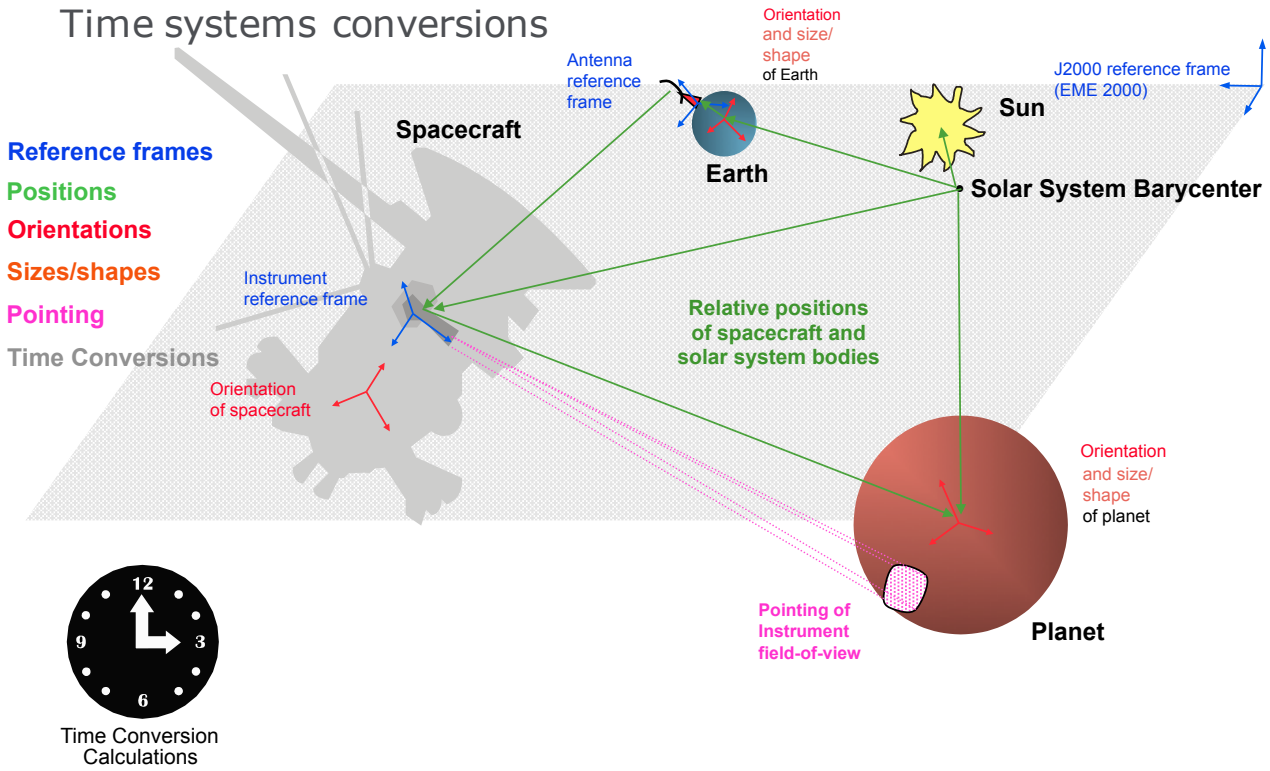
Ancillary Data

- When we talk about ”ancillary data” we talk, *minimum* of spacecraft trajectory and orientation
- An in-house “minimal” model can be put in place: personnel will need to produce, validate, dsitribute and archive reconstructed sc orbit and attitude data but... The big picture is complex:
  - Almost everyhting moves and/or rotates (with multiple sources providing different values)
  - Many reference frmes (defined multiple times) are used
  - Many coordinate systems are uses (without standard definitions)
  - Size and shape estimates of target bodies do change
  - Several time systems are used
  - National/inter-project interest might be in conflict.

- Maybe Dogbert the consultant was wrong.

Ancillary Data

- Ancillary data also includes:
  - Reference frame (aka coordinate system) specs
  - Instrument specs (mounting alignment and field-of-view specs)
  - Target body (planets, small bodies) physical and cartographic constants
  - Time systems conversions

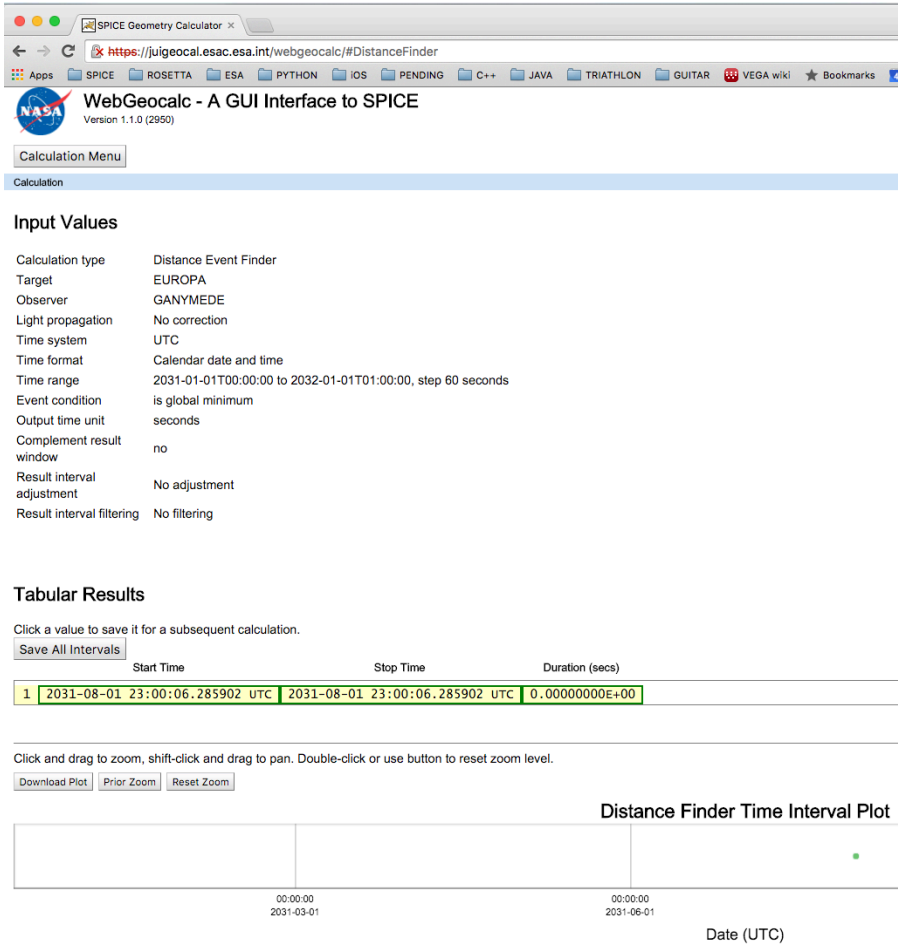


SPICE in a nutshell

- SPICE provides users a large suite of SW used to read SPICE ancillary data files to compute observation geometry
- SPICE 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.
- SPICE is the recommended means of archiving ancillary data by NASA's PDS and by the International Planetary Data Alliance
- SPICE ancillary data comes from:
  - The Spacecraft
  - MOC/SGS
  - Spacecraft manufacturer and Instrument teams
  - Science Organisations
- SPICE is used to organise and package these data in a collection of files called "**kernels**"
- SPICE includes SW for writing, reading kernels and computing observation geometry from kernels

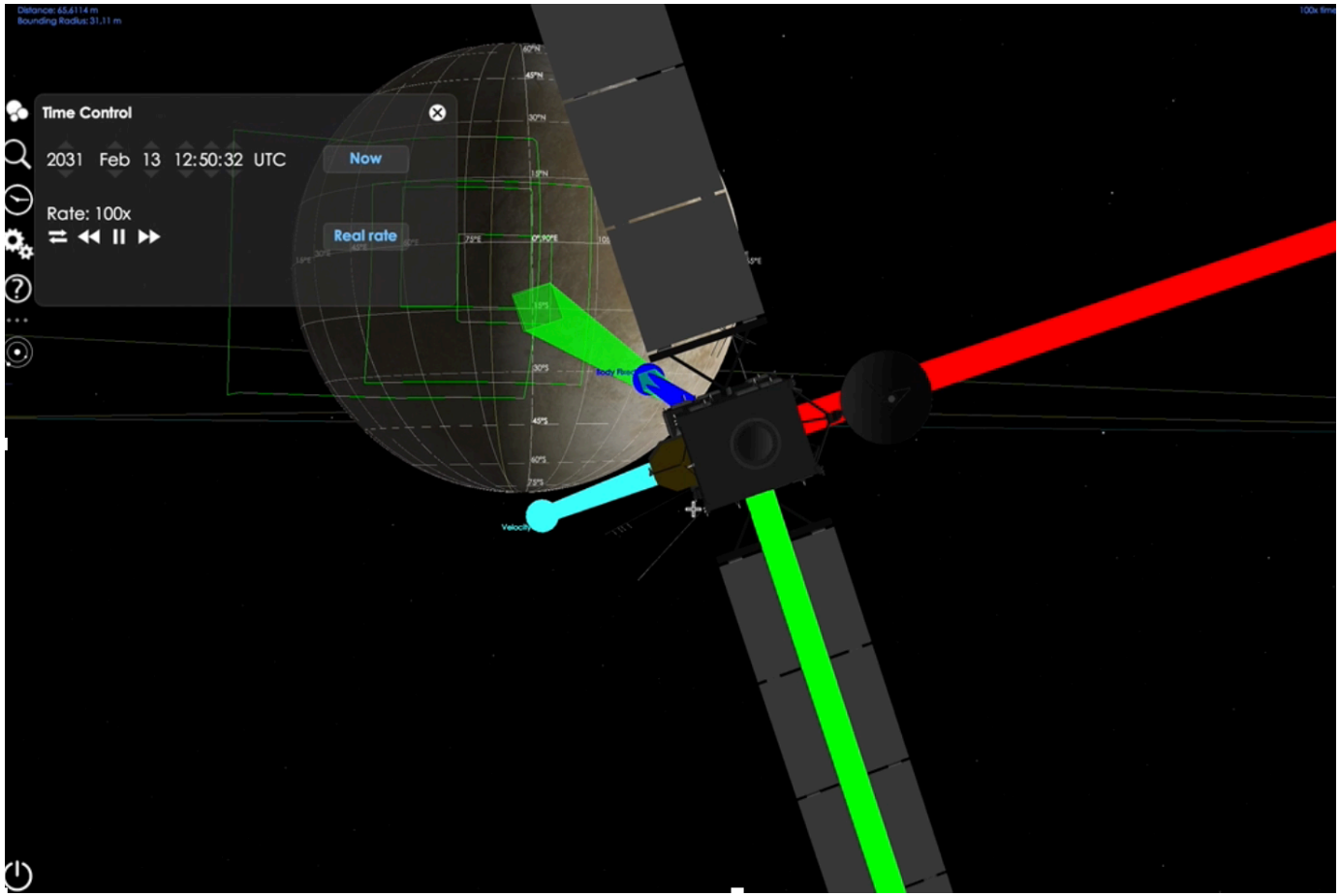
SPICE tools - WebGeoCalc

- WebGeoCalc demo



SPICE tools - Cosmographia

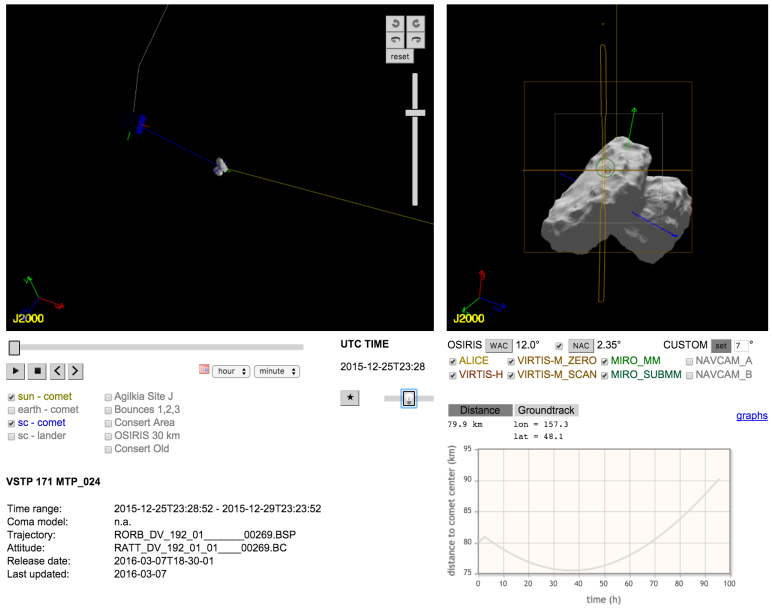
- Cosmographia demo

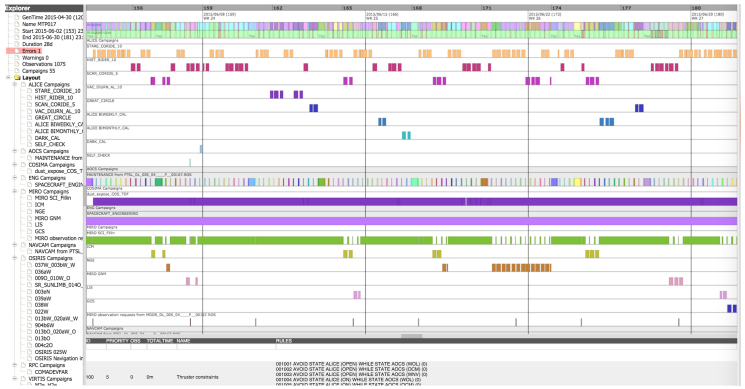


SPICE tools – Rosetta SGS tools

SPICE tools are used are usde in the Long Term Plan planning cycle which features interations between liaision sicientists and the instrument teams to produce a skeleton plan for the Medium Term Plan periods:

- **3dtool**: web-based tool used to analyze the feasibility –in terms of science obsercations- of the early skeleton trajectories that SGS was designing during the Rosetta Escort phase.
- **Flying potato:** helps the instrument teams operations engineers to generate pointing snippets for observations that are used to build up the Pointing Timeline requests for FD.
- **ASPEN:** automated and semi-automated scheduling software
- **Cost function:** quantifies the total amount of nadir available for a consolidated Attitude timeline: the In-Situ instrument teams evaluate it.

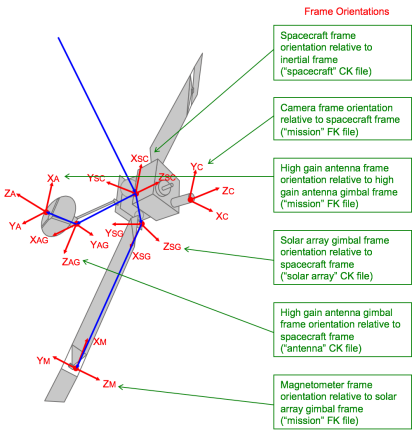


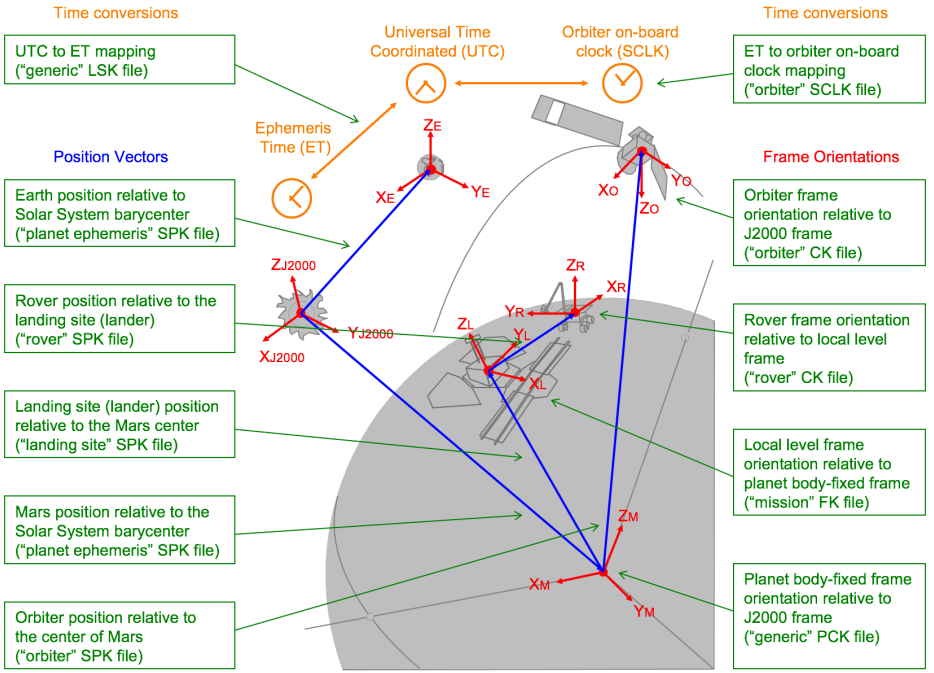


SPICE kernels

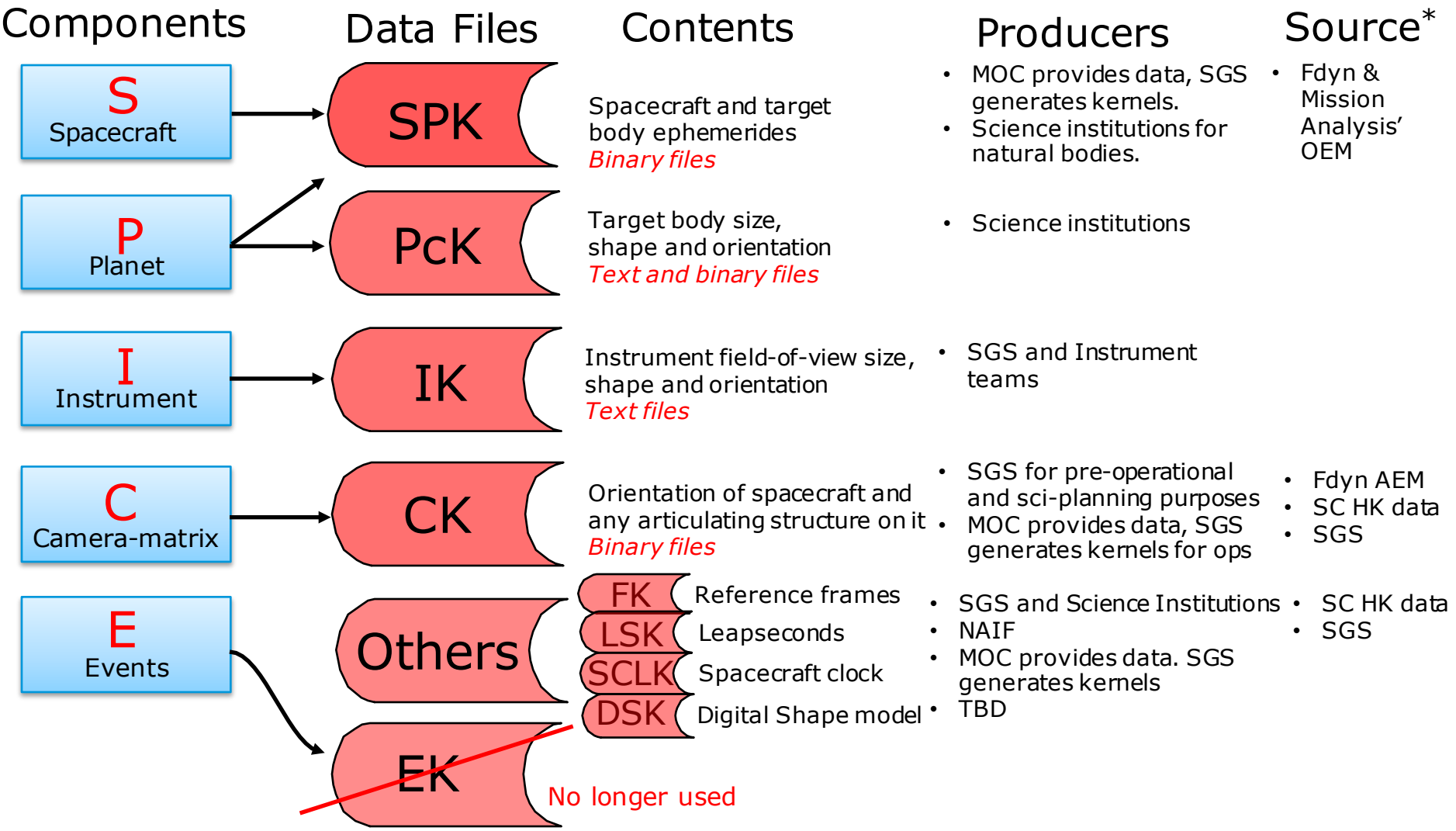
Cosmographia setup for JUICE and the following kernels:

- KERNELS/lsk/naif0009.tls
- KERNELS/spk/mantra.jup_a5d_140a_lau_fin_bet_500.bsp
- KERNELS/spk/de405.bsp
- KERNELS/spk/jup230.bsp
- KERNELS/ck/quaternions_europa_flybys.bc
- KERNELS/sclk/juice_YYMMDD_step.tcp
- KERNELS/pck/pck00010.tpc
- KERNELS/fk/juice_v01.tf
- KERNELS/ik/juice_janus_v00.ti



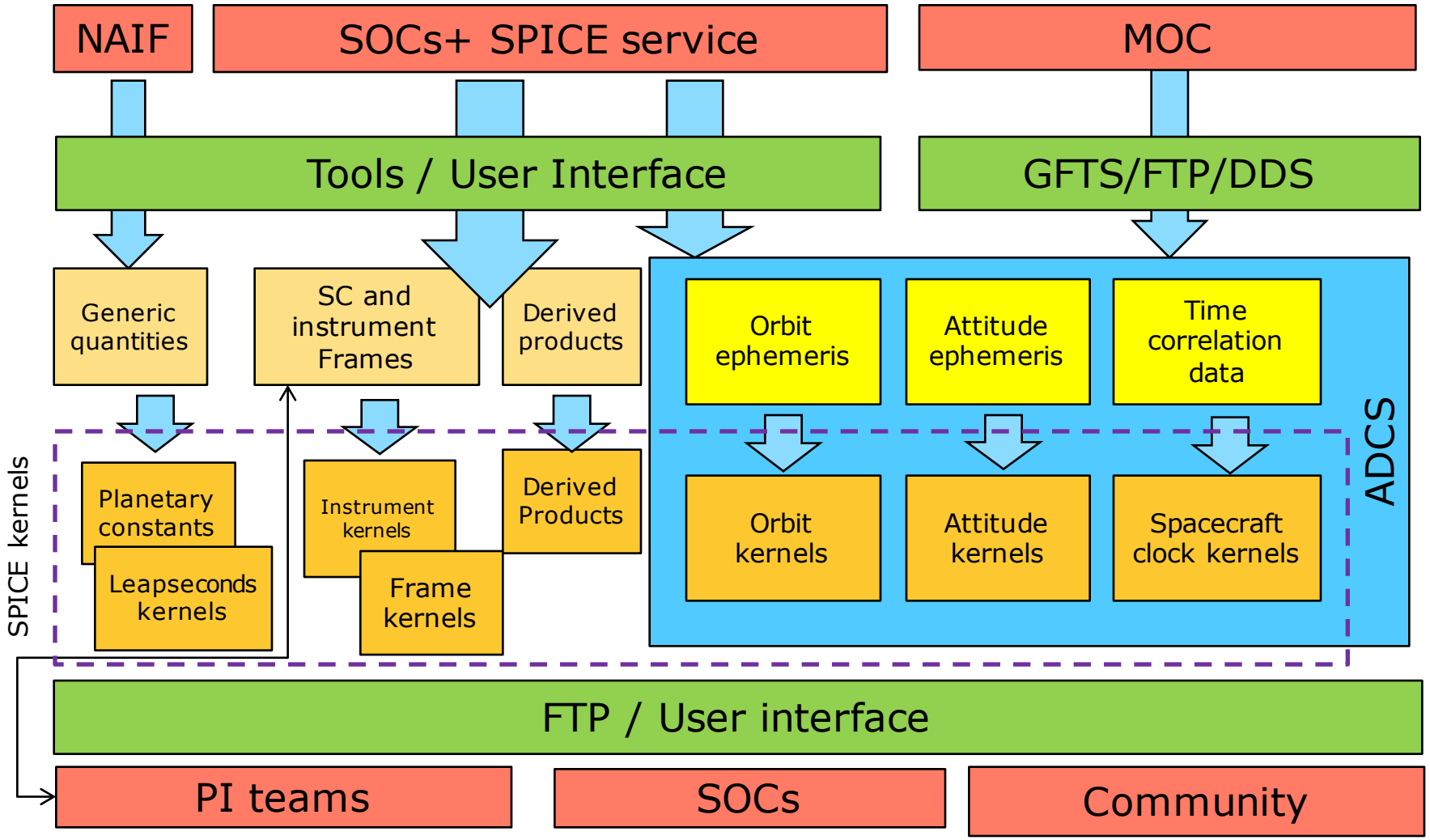


SPICE kernels

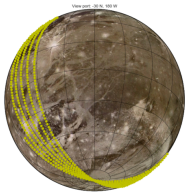


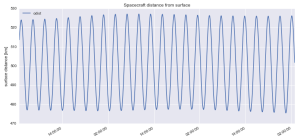
*For binary data. Text files are manually produced.

SPICE kernels



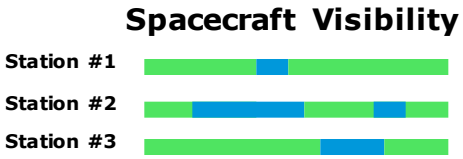
Conclusion





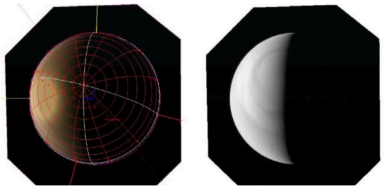
Evaluation of a planned trajectory

- BepiColombo and Juice: Suite of tools and scripts, webgeocalc



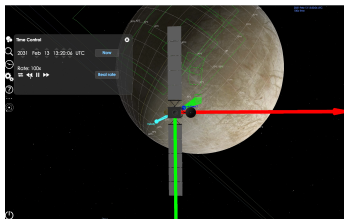
Mission engineering analyses

- Rosetta: ASPEN



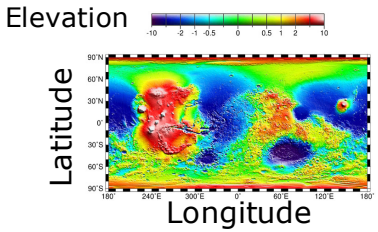
Planning an instrument pointing profile

- Rosetta: Flying potato, 3dtool, Cost Function



Observation geometry visualization

- VEX, MEX, Juice: SOLab, Cosmographia



Science data archiving and analysis

EXTRA Slides – SPICE status at ESAC

- Currently:
  - VEX, MEX, Rosetta, EM16, BepiColombo, Solar Orbiter, JUICE are serviced
  - Pipeline in place for VEX, MEX, Rosetta to generate operational kernels
  - FTP with all kernels available
  - Existing suite of tools/scripts/pipelines
  - WebGeoCalc for JUICE and BepiColombo

- In development:
  - Pipeline for EM16, BepiColombo, JUICE and Solar Orbiter to generate operational kernels
  - Extension and consolidation of adhoc suite of tools/scripts/pipelines
  - Dedicated SPICE servers for kernels
  - WebGeoCalc for all serviced missions
  - Cosmographia for all serviced missions