Ancillary Data Production for SmallSats with SPICE

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What are 'ancillary data' and why we use it?

Ancillary data refers at least to a spacecraft trajectory and orientation (attitude) information.

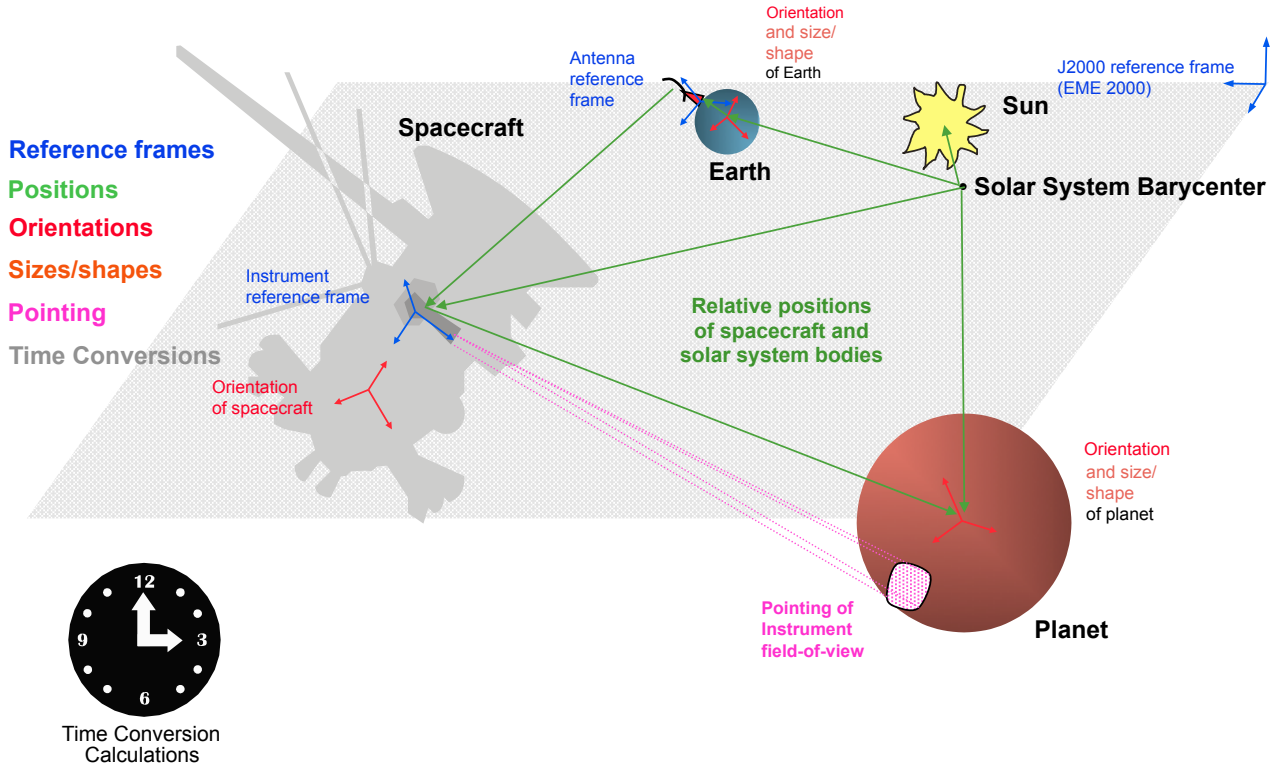
Ancillary data often includes some or all of:

- reference frame specification (not to confuse with reference system)
- instrument, mounting, alignment and field-of-view specifications
- target body physical and cartographical constants: size, shape, orientation, etc.
- data needed for time conversions

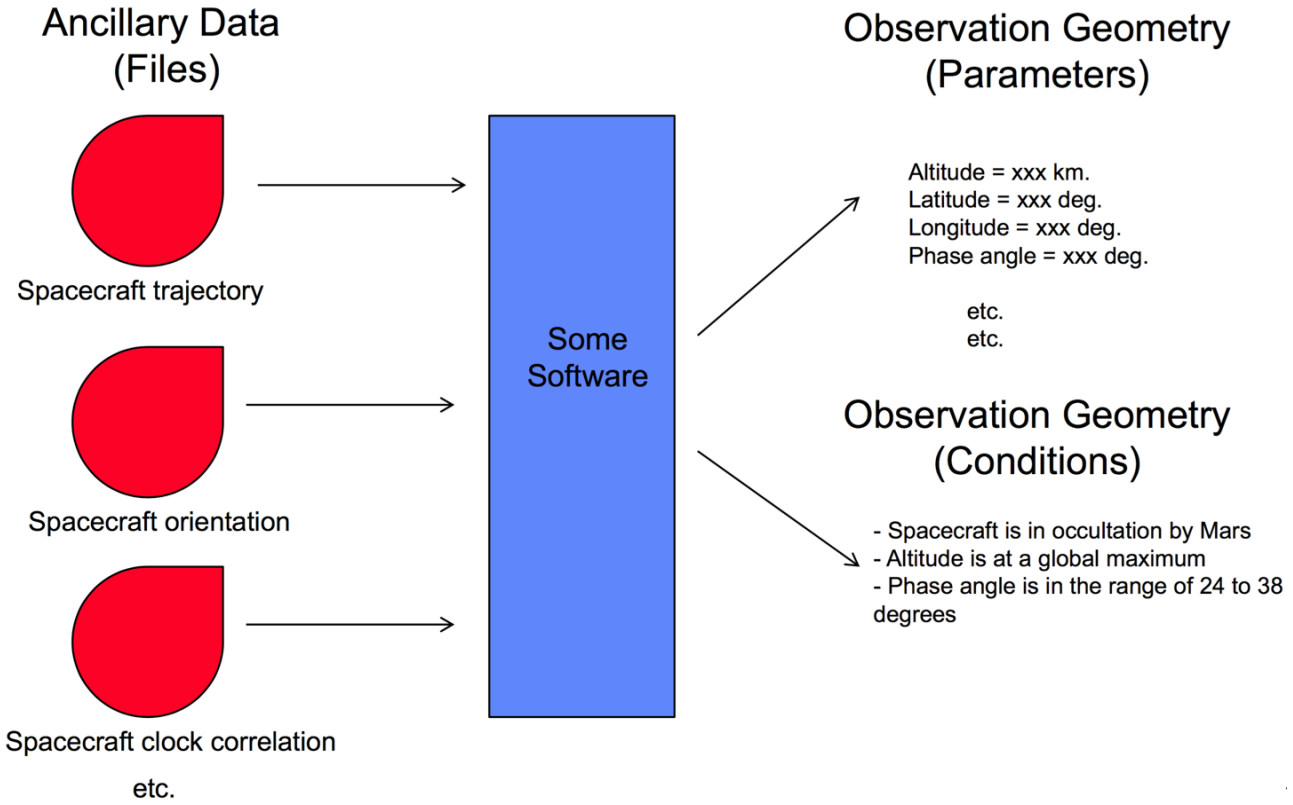
Ancillary data purposes are:

- help mission designers and scientists to converge on a mutually acceptable orbit design
- compute observation geometry parameters and conditions needed by operations engineers for tasks such as:
  - communications stations antenna coverage and pointing
  - thermal and power analyses
  - payload operations scheduling
- compute observation geometry parameters and conditions needed by the payload teams for operations such as:
  - observation planning
  - archive preparation
  - data analysis

What are 'ancillary data' and why we use it?



From ‘ancillary data’ to ‘observation geometry’



A minimal approach to Ancillary Data

For a minimal approach to Ancillary Data Minimal approach a project would provide:

- a table of reconstructed, time-tagged spacecraft position vectors
- a table of reconstructed, time-tagged spacecraft orientation quaternions

with the above tables using UTC time tags (sometimes called SCET)

The project leaves it to end users to use these data–probably some other data as well–in conjunction with the user's own-built software to compute needed observation geometry parameters.

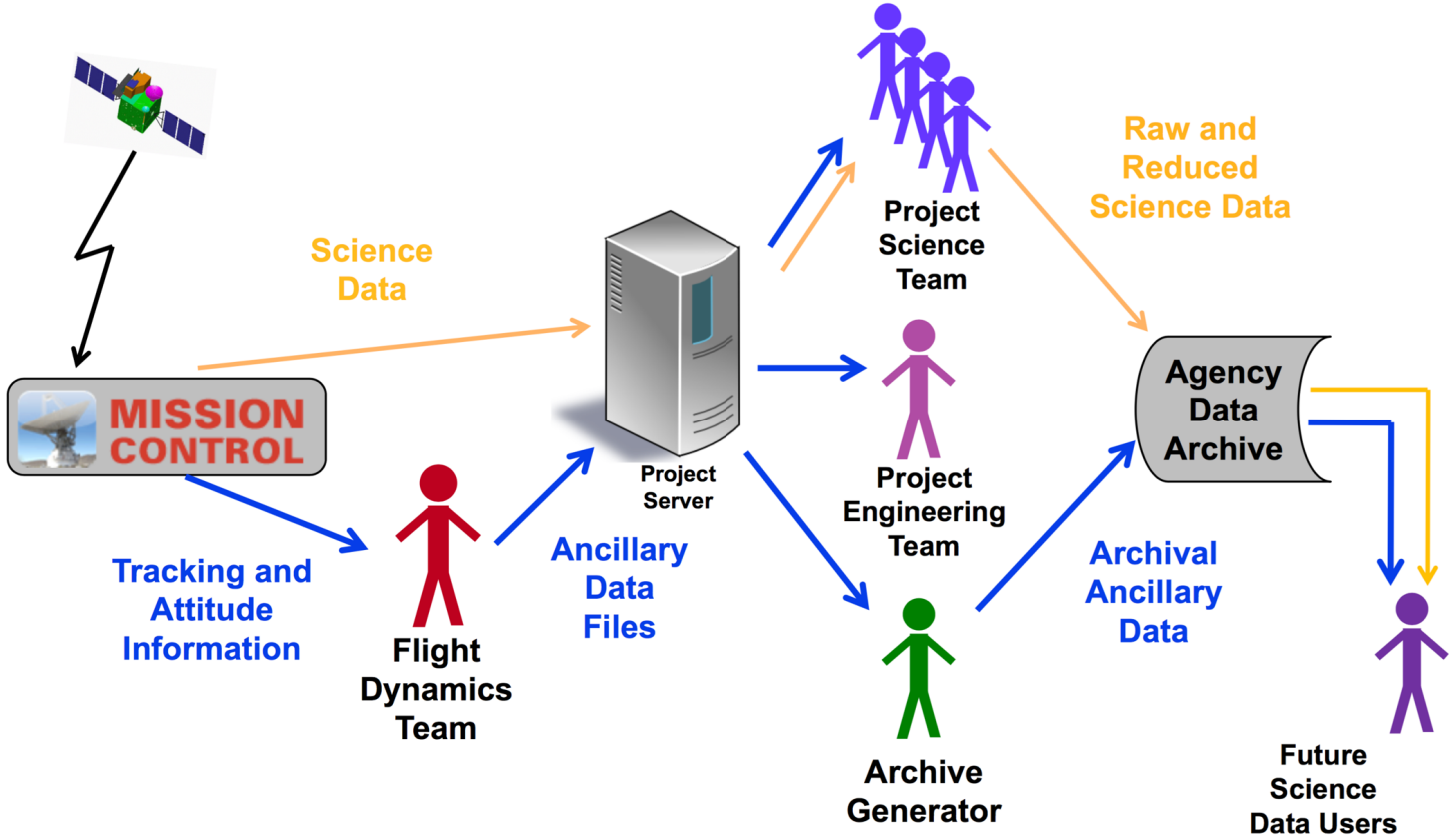
Advantages

- May utilize local tools and processes already in place
- Might minimize the direct cost to the project by possibly placing some of the cost burden on other sources
- Possibly minimizes some components of a project's schedule

Disadvantages

- Some ancillary data needed by some end users is not provided
  - Users must find the rest for themselves, or make it up. The archive could be rather sparse and so not of much help to scientists after the mission is over
- How to use the provided ancillary data, along with other data, to compute needed geometry parameters is largely left up to the end user. Requires special effort on the part of each instrument team, maybe even individual team members.

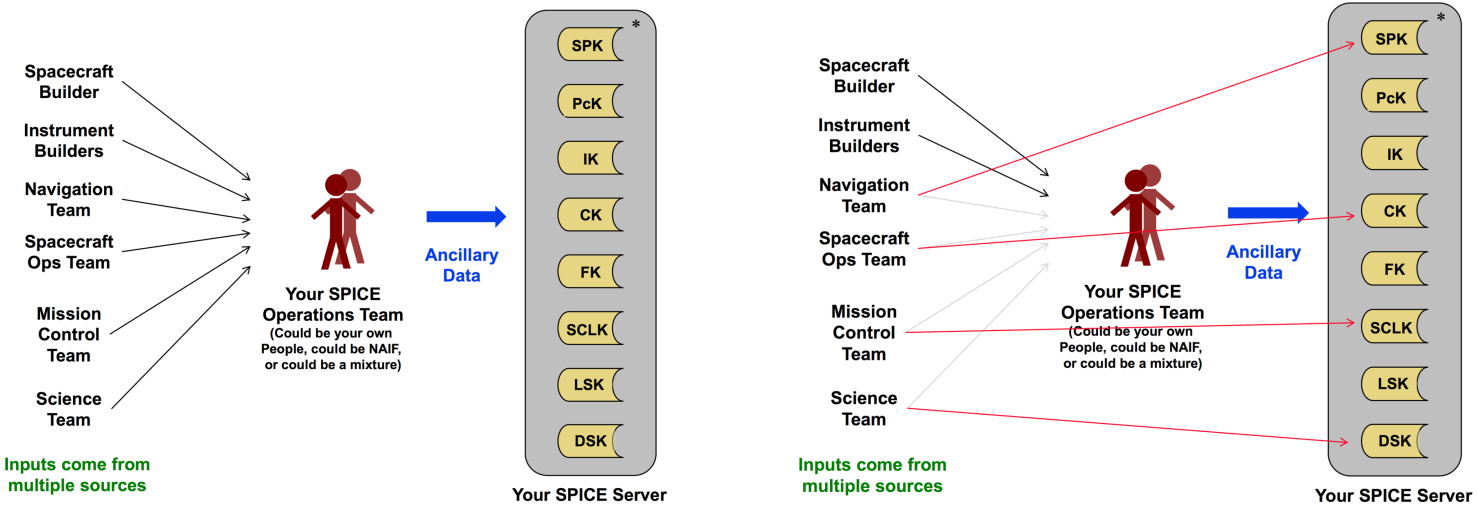
A minimal approach to Ancillary Data



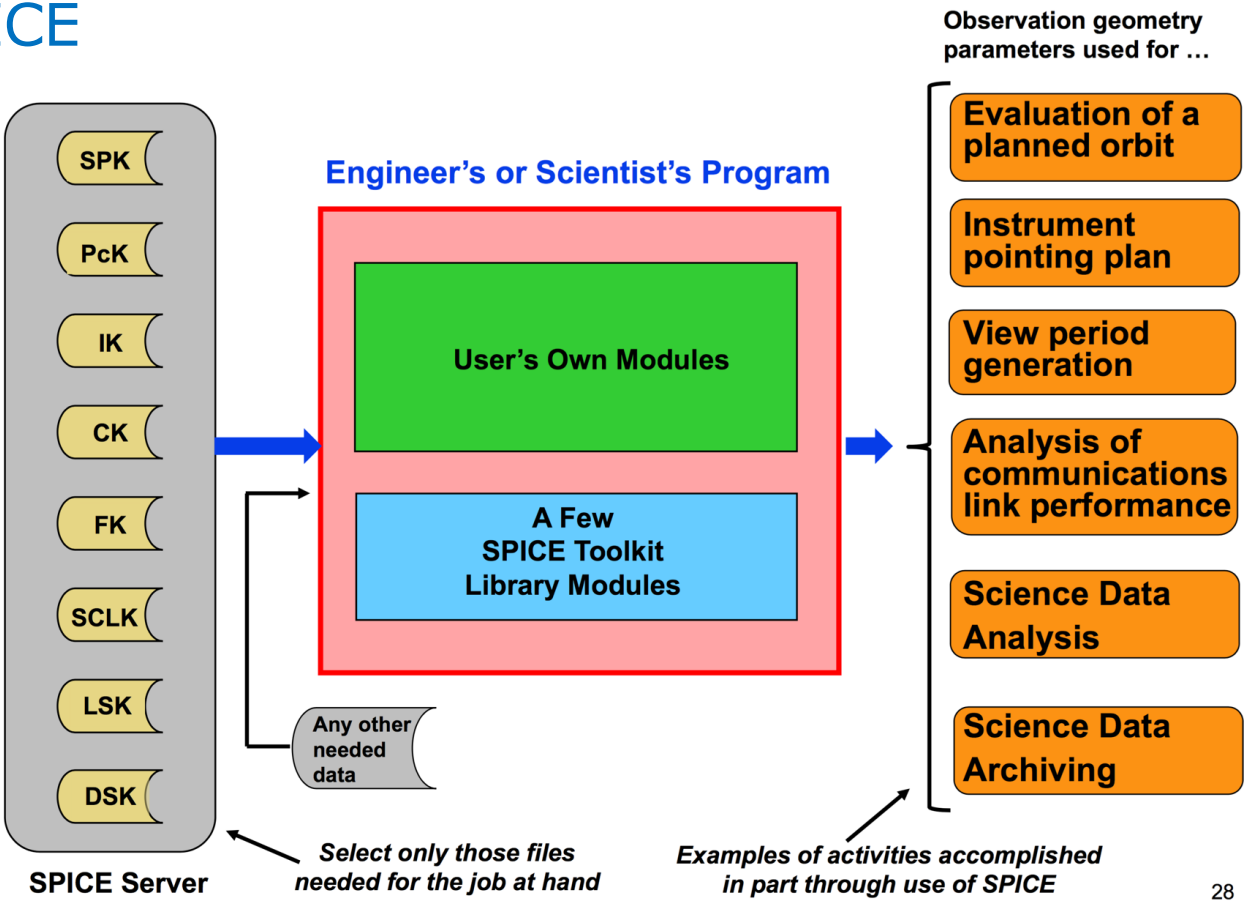
SPICE in a nutshell

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).

- SPICE provides users a large suite of SW used to read SPICE ancillary data files to compute observation geometry.
- SPICE is **open-source without ITAR restrictions**, tested, extensively used and provides tons of resources to learn it.
- SPICE is the recommended means of archiving ancillary data by NASA's PDS and by the IPDA



Using SPICE


Observation geometry parameters used for …
Evaluation of a planned orbit
Instrument pointing plan
View period generation
Analysis of communications link performance
Science Data Analysis
Science Data Archiving
Engineer's or Scientist's Program
User's Own Modules
A Few SPICE Toolkit Library Modules
Any other needed data
SPK
PcK
IK
CK
FK
SCLK
LSK
DSK
SPICE Server
Select only those files needed for the job at hand
Examples of activities accomplished in part through use of SPICE

Components of SPICE

Contents

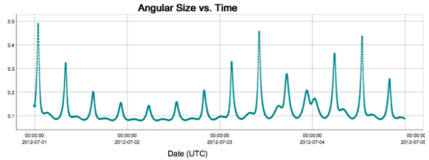
- **Library of subroutines (~1500)**
  - Just a few used within a customer's program to compute quantities derived from SPICE data files
- **Programs (19)**
  - SPICE data production
  - SPICE data management
- **Documentation**
  - Highly annotated source code
  - Technical Reference Manuals (23)
  - User Guides

Versions

- **Four languages**
  - Fortran
  - C
  - Interactive Data Language (IDL)
  - MATLAB
  - Also available:
    - » Java Native Interface (JNI)
    - » Python
- **Five platforms**
  - PC/Linux
  - PC/Windows
  - Sun/Solaris
  - Mac/OSX
- **Several compilers**
  - For the Fortran and C Toolkits

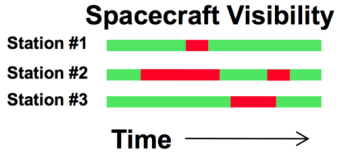
How is SPICE used?

Evaluation of a planned trajectory

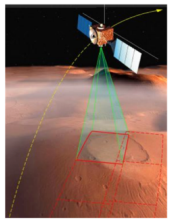


Angular size of Phobos as seen from the Mars Express spacecraft

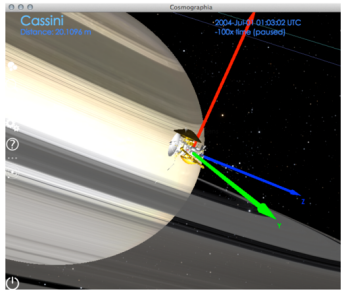
Mission engineering analyses



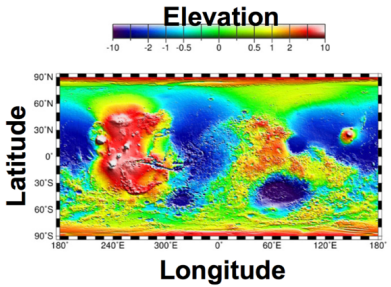
Planning an instrument pointing profile



Observation geometry visualization

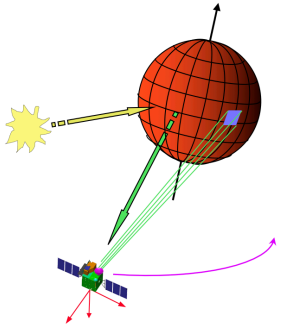


Science data archiving and analysis



What can one do with SPICE?

Compute many kinds of observation geometry parameters at selected times

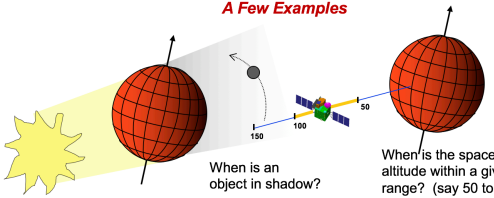


A Few Examples

- 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

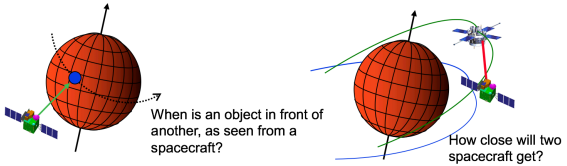
Find times when a specified "geometric event" occurs, or when a specified "geometric condition" exists

A Few Examples



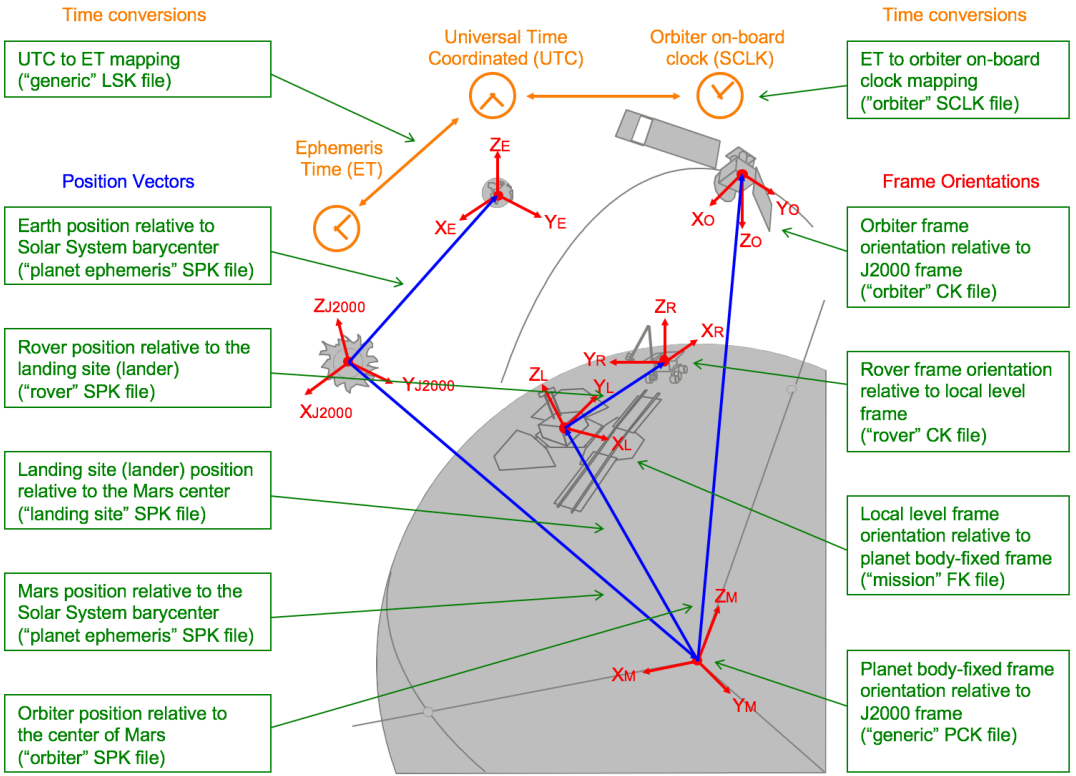
When is an object in shadow?

When is the spacecraft's altitude within a given range? (say 50 to 100 km)



When is an object in front of another, as seen from a spacecraft?

How close will two spacecraft get?



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 in Europe will be around 2020.

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

Concluding Remarks

- USE SPICE!

Concluding Remarks

- **POSTER: Open-Source Mission Planning Tool for University Satellites**.
  - Markus Grass, Marc Costa Sitjà, Jonas Keim
- **POSTER: The Earth's micro-meteoroid environment observed by a dust sensor on-board a CubeSat operated by students**.
  - Nicolas Altobelli, Marc Costa, Ralf Srama
- **DEMO: Out of the box tools for SmallSat operations with SPICE**
  - Marc Costa Sitjà

COMMUNICATE

- Everything is accessible from: **spice.esac.esa.int** (unfortunately not really up-to-date)
- You can follow us on twitter: @SpiceESA
- Contact the service via e-mail esa_spice@sciops.esa.int
- GitHub page: https://github.com/esaSPICEservice
- SPICE Kernels in Bitbucket: https://repos.cosmos.esa.int/socci/projects/SPICE_KERNELS
- You can also join the OpenPlanetary **slack** channel