How SPICE Helps Advance Planetary Science

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SPICE Provides Observation Geometry

- **"Observation geometry" calculations are those that help scientists and engineers determine:**
  - **where a spacecraft is located**
  - **what is the location, size, shape and orientation of the target being observed**
  - **how the spacecraft and its instruments are oriented (pointed)**
  - **how an instrument's field-of-view projects onto the target**
  - **and many more similar quantities.**

- **SPICE works with the various time systems used in computing observation geometry.**

What Are "Observation Geometry Data?"

Navigation and Ancillary Information Facility

Reference frames

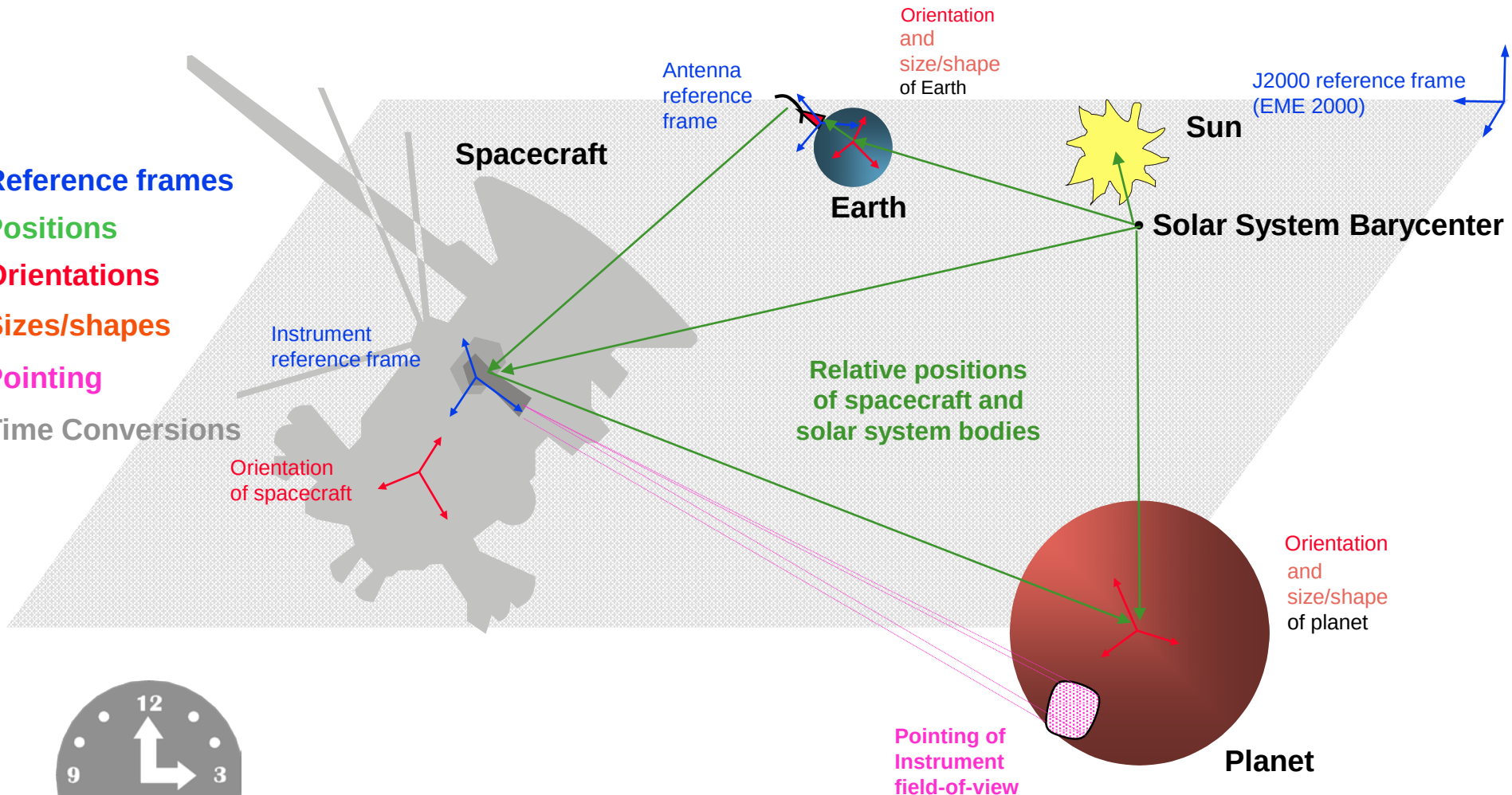
Positions

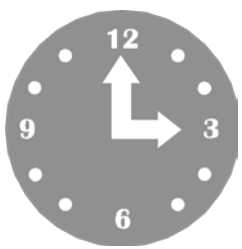
Orientations

Sizes/shapes

Pointing

Time Conversions





Time Conversion
Calculations

SPICE System Components

Navigation and Ancillary Information Facility

Ancillary data files ("kernels")……..

Software (SPICE Toolkit) ……..

Documentation ……..

Tutorials …….

Programming lessons …..

Training classes ……..

User consultation ……..

SPICE Toolkit Software

Navigation and Ancillary Information Facility

Contents

- **Library of subroutines (~1000)**
  - Just a few used within a customer's program to compute quantities derived from SPICE data files
- **Programs (14*)**
  - SPICE data production
  - SPICE data management
- **Documentation**
  - Highly annotated source code
  - Technical Reference Manuals (23)
  - User Guides

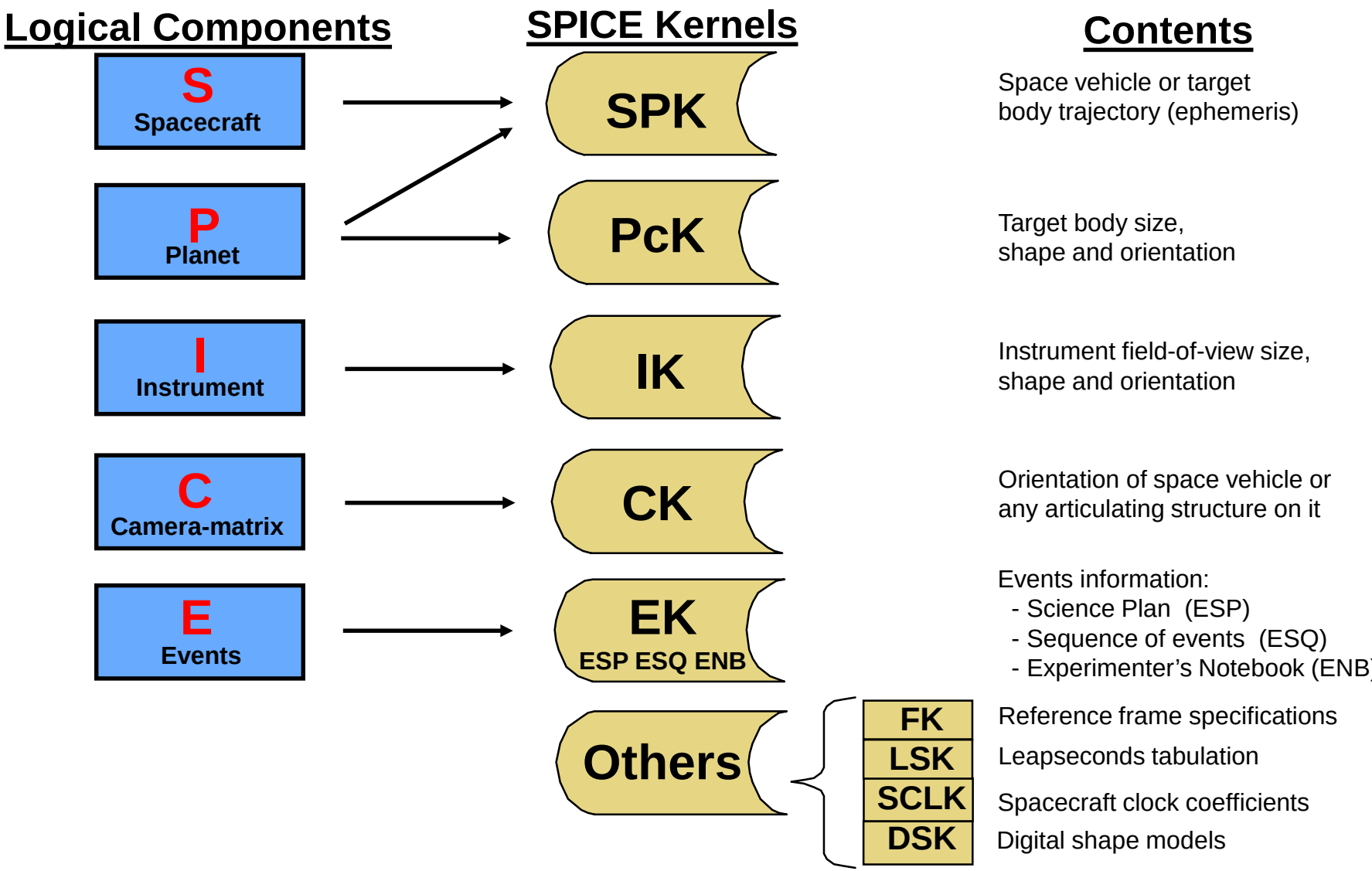
Versions

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

* 30 are available from the NAIF website

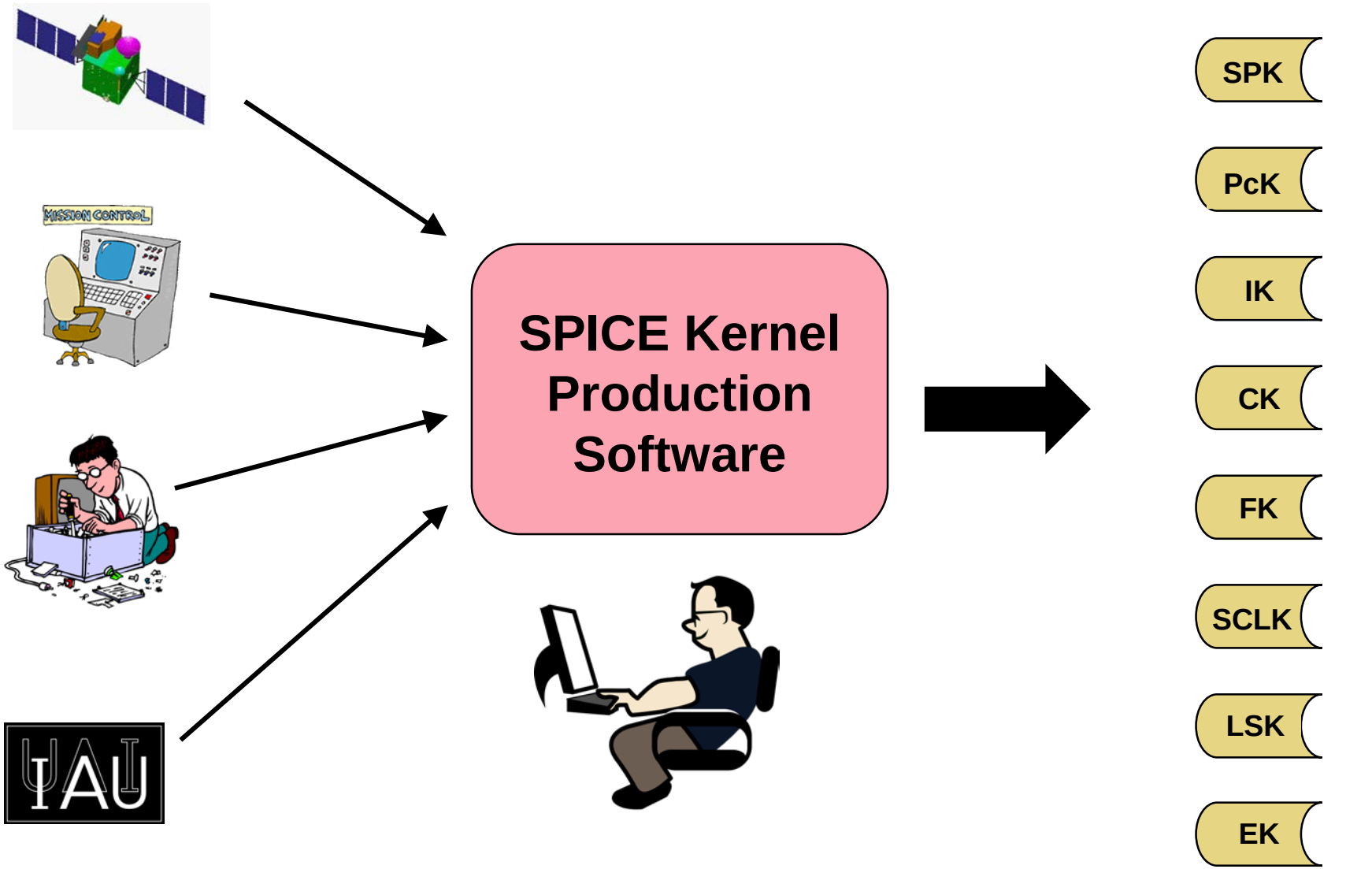
SPICE Kernels Overview

Navigation and Ancillary Information Facility



Producing SPICE Kernels

Navigation and Ancillary Information Facility



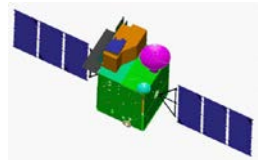
Source Data

SPICE Kernels

From Where do the Source Data Come?

Navigation and Ancillary Information Facility

- From the spacecraft



- From the mission control center

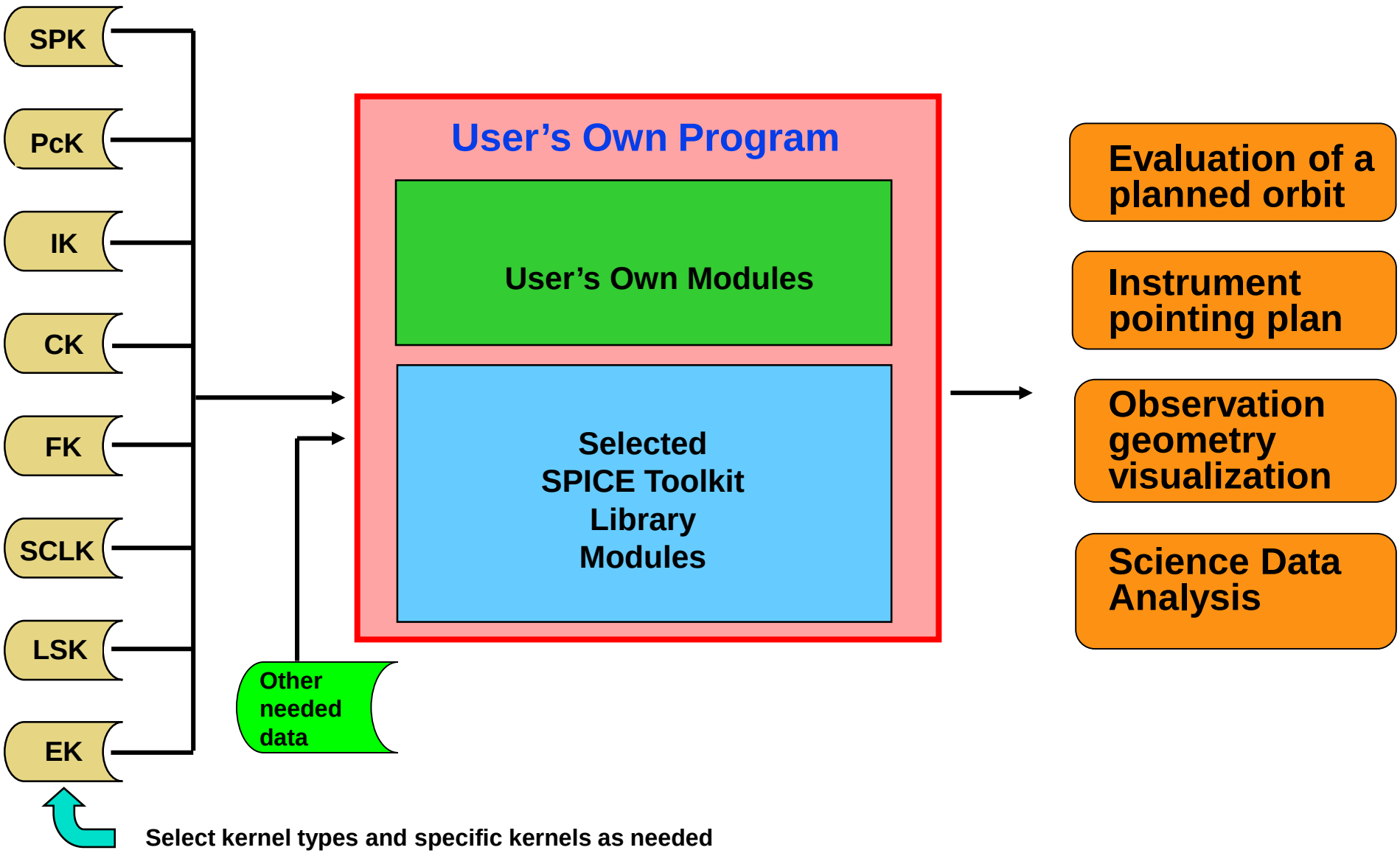
- From the spacecraft and instrument builders

- From science organizations

- SPICE is used to organize and package these data in a collection of ancillary data files–called "kernels"– used by scientists and engineers in computing observation geometry.

Calculating Observation Geometry

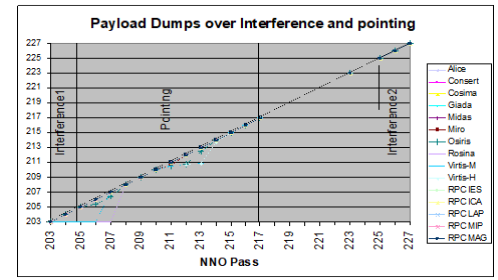
Navigation and Ancillary Information Facility



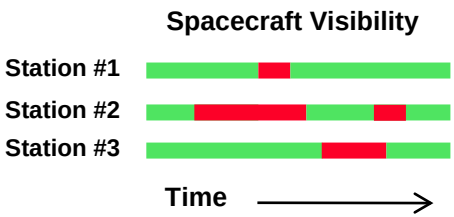
An Overview of How SPICE is Used

Navigation and Ancillary Information Facility

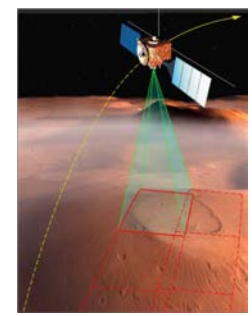
Evaluation of a planned trajectory



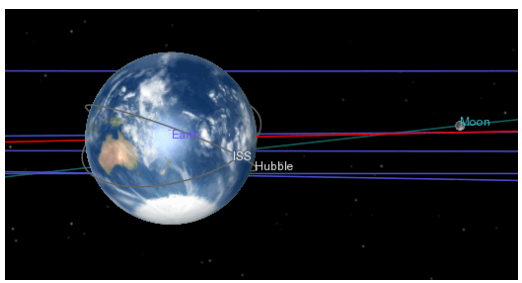
Mission engineering analyses



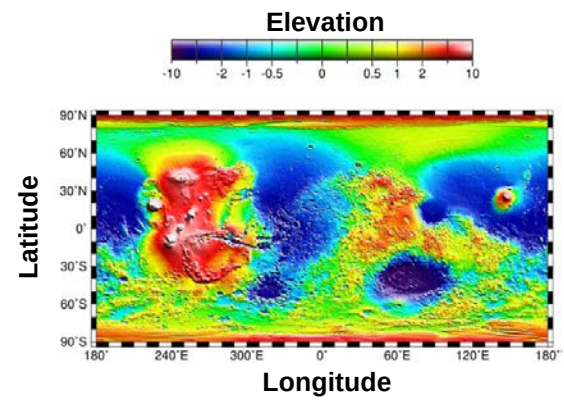
Planning an instrument pointing profile



Observation geometry visualization



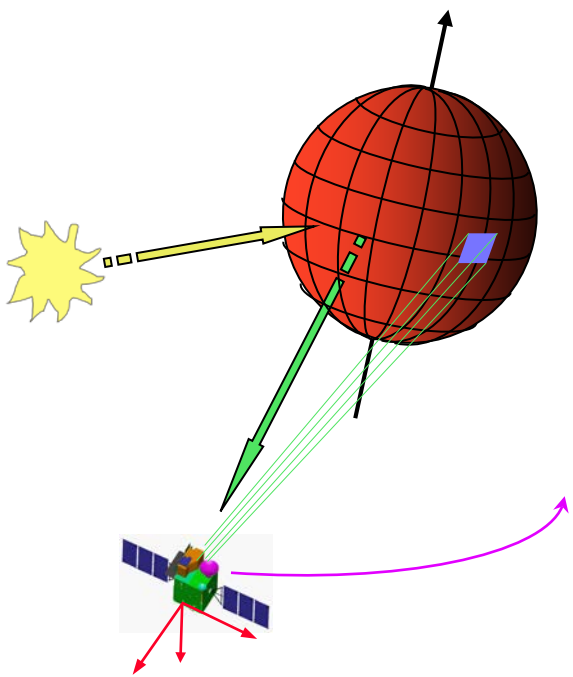
Science data archiving and analysis



What Can One Do With SPICE?

Compute many kinds of observation geometry parameters at selected times

A Few Examples



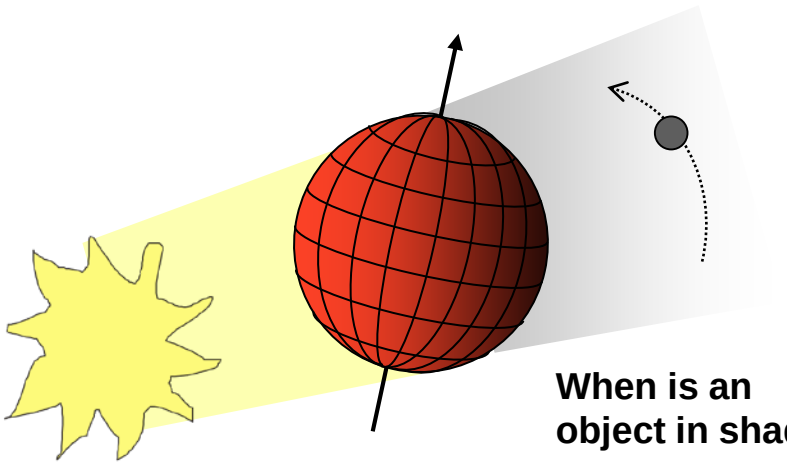
- **Positions and velocities of planets, satellites, comets, asteroids and spacecraft**
- **Size, shape and orientation of planets, satellites, comets and asteroids**
- **Orientation of a spacecraft and its various moving structures**
- **Instrument field-of-view location on a planet's surface or atmosphere**

What Can One Do With SPICE?

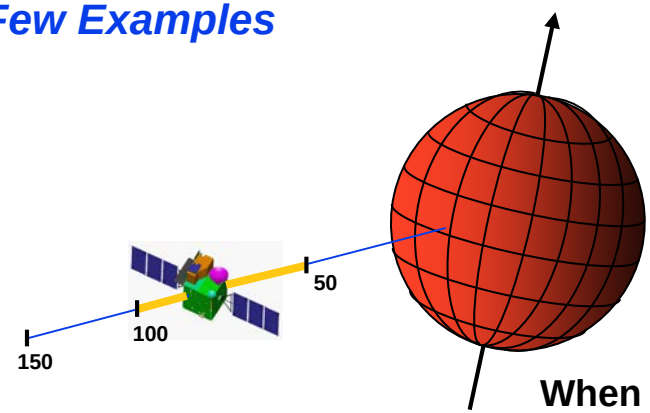
Navigation and Ancillary Information Facility

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

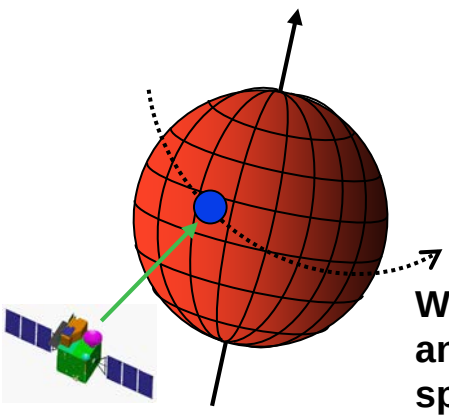
A Few Examples



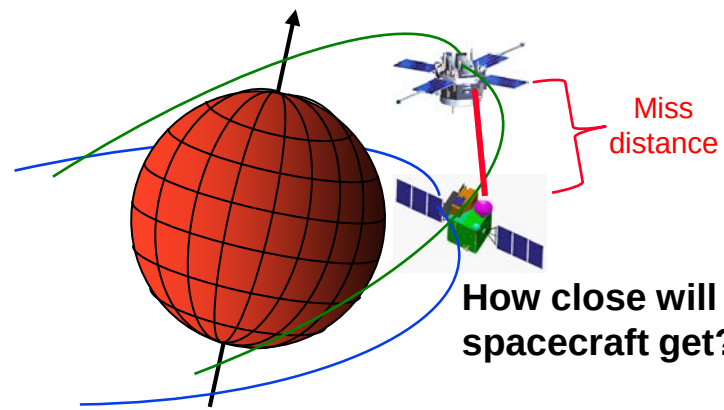
When is an object in shadow?



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?

SPICE System Characteristics - 1

- SPICE Toolkit software is portable between computers
- New Toolkits are released irregularly, as need and time permit
- Code is well tested before being released to users
- New Toolkits are always 100% backwards compatible
- Source code is provided, and is well documented
- Extensive user-oriented documentation is provided
- Software includes built-in exception handling
  - Catches most invalid inputs

SPICE System Characteristics - 2

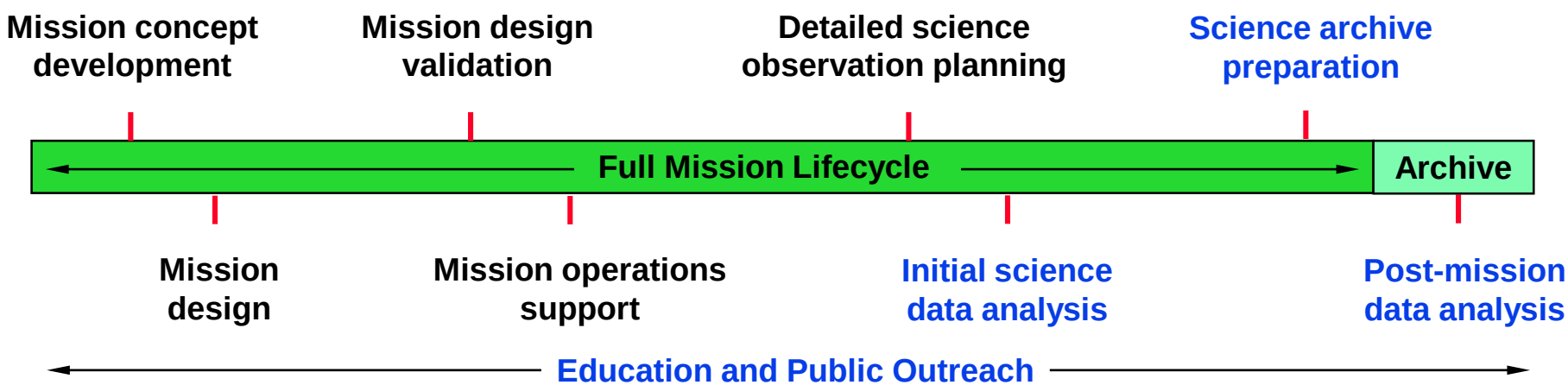
- All numeric computations are double precision
- Kernel files are portable between computers
- Kernel files are separable
  - Use only those you need for a particular application
- Kernel files are extensible
  - New data types can be added within a kernel family
- SPICE kernels and software are free of licensing and U.S. ITAR restrictions
  - Everyone is free to use SPICE
- No cost to individual end users

Supported Environments

- **The SPICE Toolkit has been ported to many popular "environments"**
  - **Each environment is characterized by…**
    - » **Language**
    - » **Hardware type (platform)**
    - » **Operating System**
    - » **Compiler (where applicable)**
    - » **Selected compilation options (32-bit or 64-bit)**
- **NAIF provides separate, ready-built SPICE Toolkit packages for each supported environment**
  - **If you need to port the Toolkit to a new environment yourself, consult with NAIF staff first**
- **Currently 47 different environments are supported**

Large Breadth of Use

- **The original focus of SPICE was on ancillary data and associated software needed by scientists for:**
  - **initial science data analysis**
  - **science archive preparation**
  - **post-mission data analysis**
- **The scope of SPICE usage has grown to cover the full mission lifecycle as well as archive uses.**
- **Also education and public outreach.**



Why Use SPICE?

- **Knowing observation geometry and events is an important element of:**
  - **space mission design,**
  - **selection of observation opportunities,**
  - **analysis of the science data returned from the instruments,**
  - **mission engineering activities, and**
  - **preparation of science data archives.**

- **Having proven, extensive and reusable means for producing and using ancillary data reduces cost and risk, and can help scientists and engineers achieve more substantive, accurate and timely results.**

SPICE Users

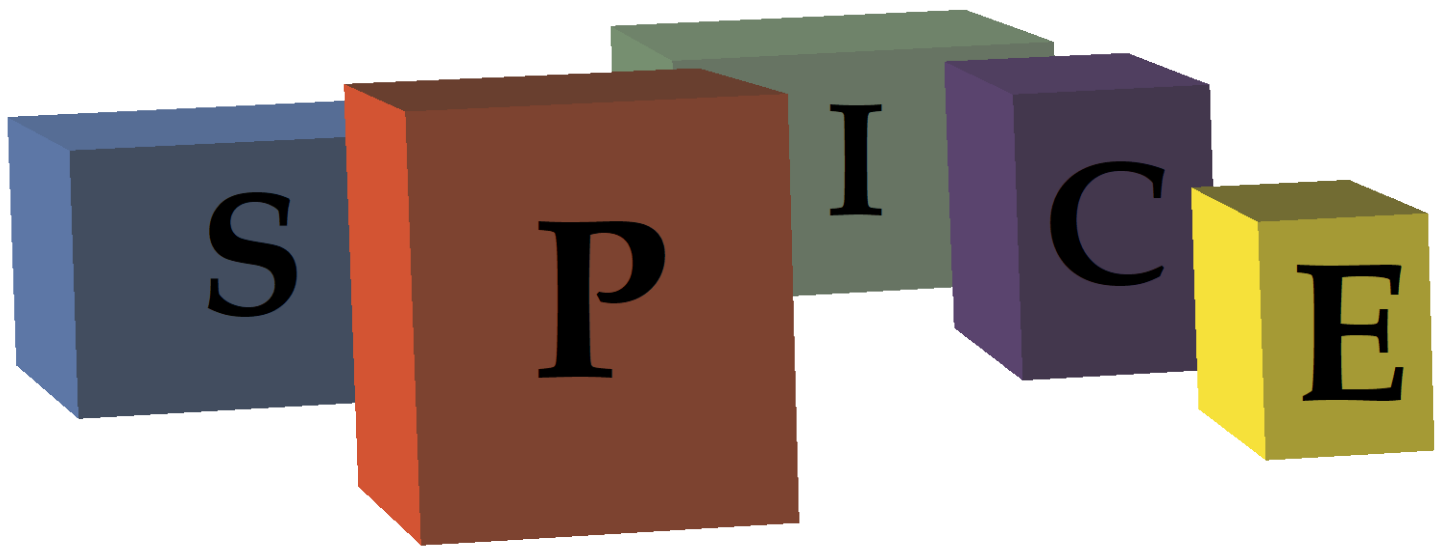
Navigation and Ancillary Information Facility

Data Restorations	Selected Past Users	Current/Pending Users	Possible Future Users
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	
Mariner 10 [L]	Mars Pathfinder	Mars Reconnaissance Orbiter	
Viking Orbiters [L]	NEAR	DAWN	ExoMars 2018 (ESA, RSA)
Viking Landers [L]	Deep Space 1	Mars Science Lab	Luna-Glob (RSA)
Pioneer 10/11/12 [L]	Galileo	Juno	NISAR (NASA and ISRO)
Haley armada [L]	Genesis	MAVEN	
Phobos 2 [L] (RSA)	Deep Impact	SMAP (Earth Science)	
Ulysses [L]	Huygens Probe (ESA) [L]	OSIRIS REx	***Examples of Users not Requesting NAIF Help***
Voyagers [L]	Stardust/NExT	InSight	Solar Probe Plus
Lunar Orbiter [L]	Mars Global Surveyor	Mars 2020	EUMETSAT GEO satellites [L]
Helios 1,2 [L]	Phoenix	Europa Clipper	MOM (ISRO)
	EPOXI		BepiColombo (ESA, JAXA)
	GRAIL	Lunar Reconnaissance Orbiter	JUICE (ESA)
	Messenger	New Horizons	Solar Orbiter (ESA)
	Phobos Sample Return (RSA) [F]	Mars Express (ESA)	Chang'e 3 (CNSA)
	Venus Express (ESA)	Rosetta (ESA)	Van Allen Probes [L]
	Chandrayaan-1 (ISRO)	ExoMars 2016 (ESA, RSA)	STEREO [L]
	Hayabusa (JAXA)	Akatsuki (JAXA)	Spitzer Space Telescope [L]
[L] = limited use	Kaguya (JAXA)	Hayabusa-2 (JAXA)	Kepler [L]
[S] = special services	LADEE	Space Launch Systems (HEOMD)	Hubble Space Telescope [S][L]
[F] = mission failed	ISO [S] (ESA)		Radioastron (RSA) [L]
	CONTOUR [F]	Planetary Data System	IBEX [L]
	Space VLBI [L] (multinational)	JPL Solar System Dynamics Group	James Webb Space Telescope [S][L]
Last updated: 9/24/15	Smart-1 (ESA)	NASA Deep Space Network [S]	Proba-3 (ESA)

- 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.
- NAIF has or had modest PDS-supplied funding to consult on assembly of a SPICE archive.
- NAIF has PDS funding to help NASA funded scientists using SPICE data that have been officially archived at the NAIF Node of the PDS.

Building Blocks for Your Applications

The "SPICE" ancillary information system can serve as a set of blocks for building tools for implementing tools supporting multi-mission, international space exploration programs



SPICE: the ancillary information system that NAIF builds and often operates.
NAIF: the JPL entity responsible for development and deployment of SPICE.
NAIF Node of the PDS: one responsibility of the NAIF Group--archiving and providing long-term access to SPICE data for the worldwide science community.