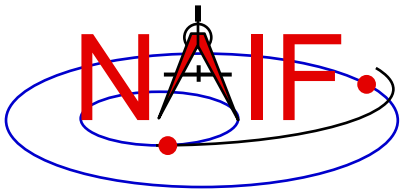


Navigation and Ancillary Information Facility

An Overview of SPICE

NASA's Observation Geometry System for Space Science Missions

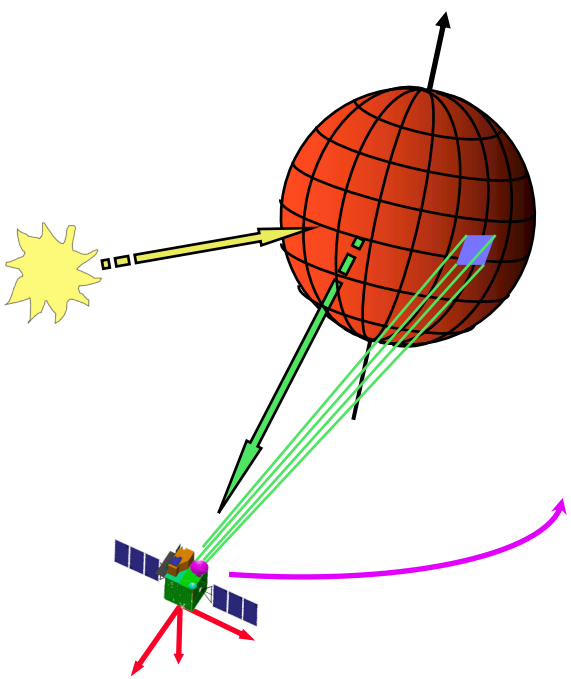
June 2019

What Can One Do With SPICE?

Navigation and Ancillary Information Facility

Compute many kinds of observation geometry parameters at selected times

Examples



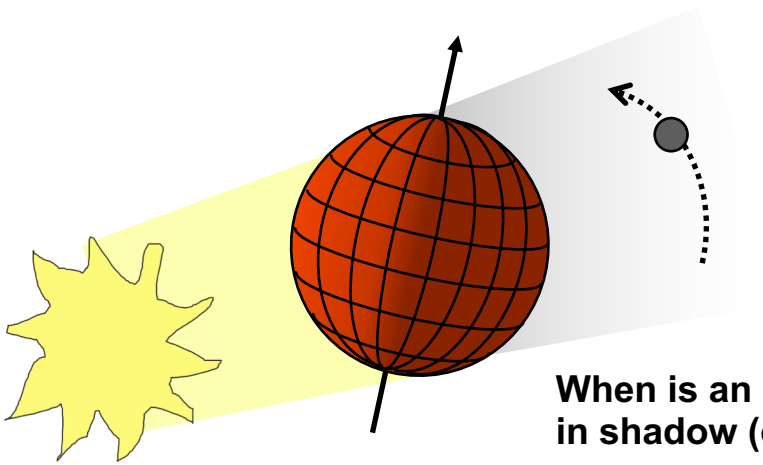
- **Positions and velocities of planets, satellites, comets, asteroids and spacecraft**
- **Size, shape and orientation of planets, satellites, comets and asteroids**
- **Orientation of a spacecraft and its various moving structures**
- **Instrument field-of-view location on a planet's surface or atmosphere**

What One Can Do With SPICE

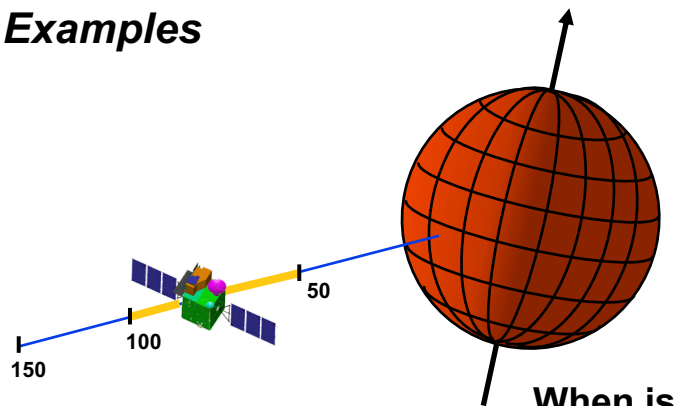
Navigation and Ancillary Information Facility

Find times when a specified "geometric event" occurs

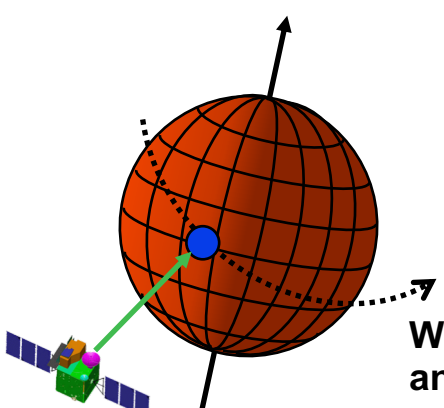
Examples



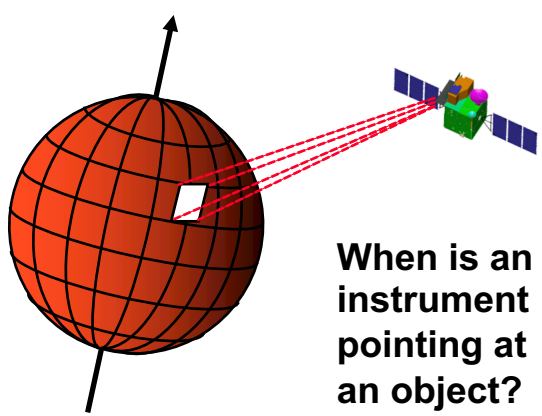
When is an object in shadow (occultation) ?



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 (transit)?

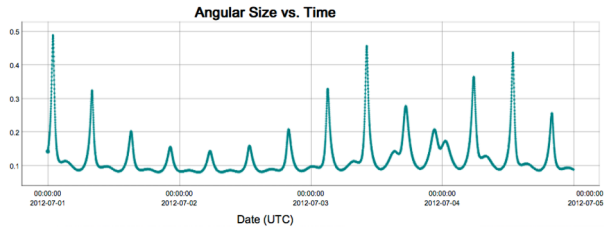


When is an instrument pointing at an object?

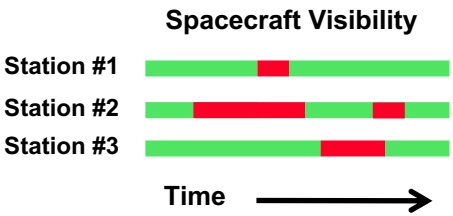
Examples of How SPICE Is Used

Navigation and Ancillary Information Facility

Evaluation of a planned trajectory

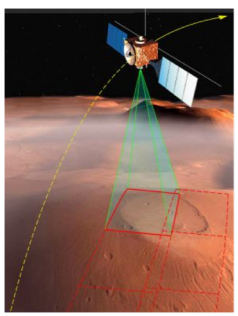


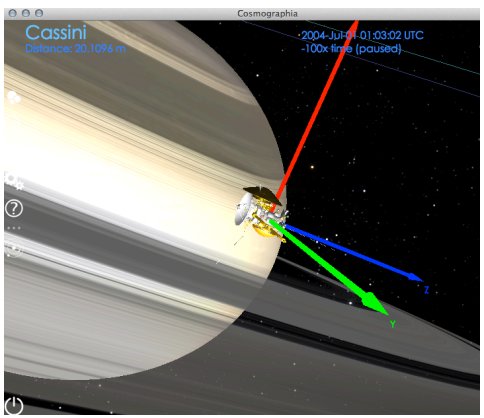
Angular size of Phobos As seen from the MEX spacecraft



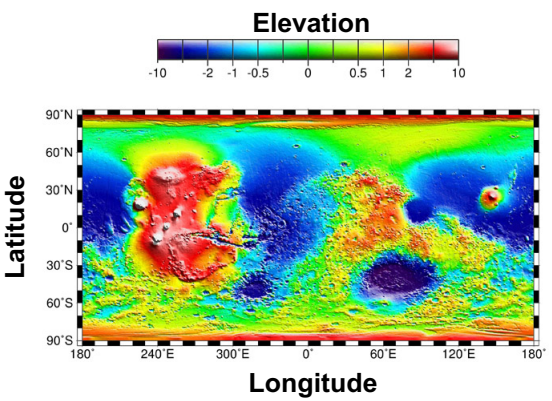
Mission engineering analyses

Planning an instrument pointing profile





Observation geometry visualization



Science data archiving and analysis

SPICE Pictorial Summary

Navigation and Ancillary Information Facility

From assorted sources

Planet ephemeris

S/C trajectory

S/C orientation

SPICE Utility Programs

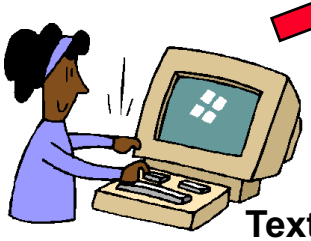
SPICE Kernels (Data)

Your Program

Your Modules

A Few SPICE Modules

Distances
Velocities
Altitudes
Latitudes
Longitudes
Lighting Angles
etc., etc.



Text editor

Spacecraft geometry

Instrument geometry

Planet size, shape, orientation

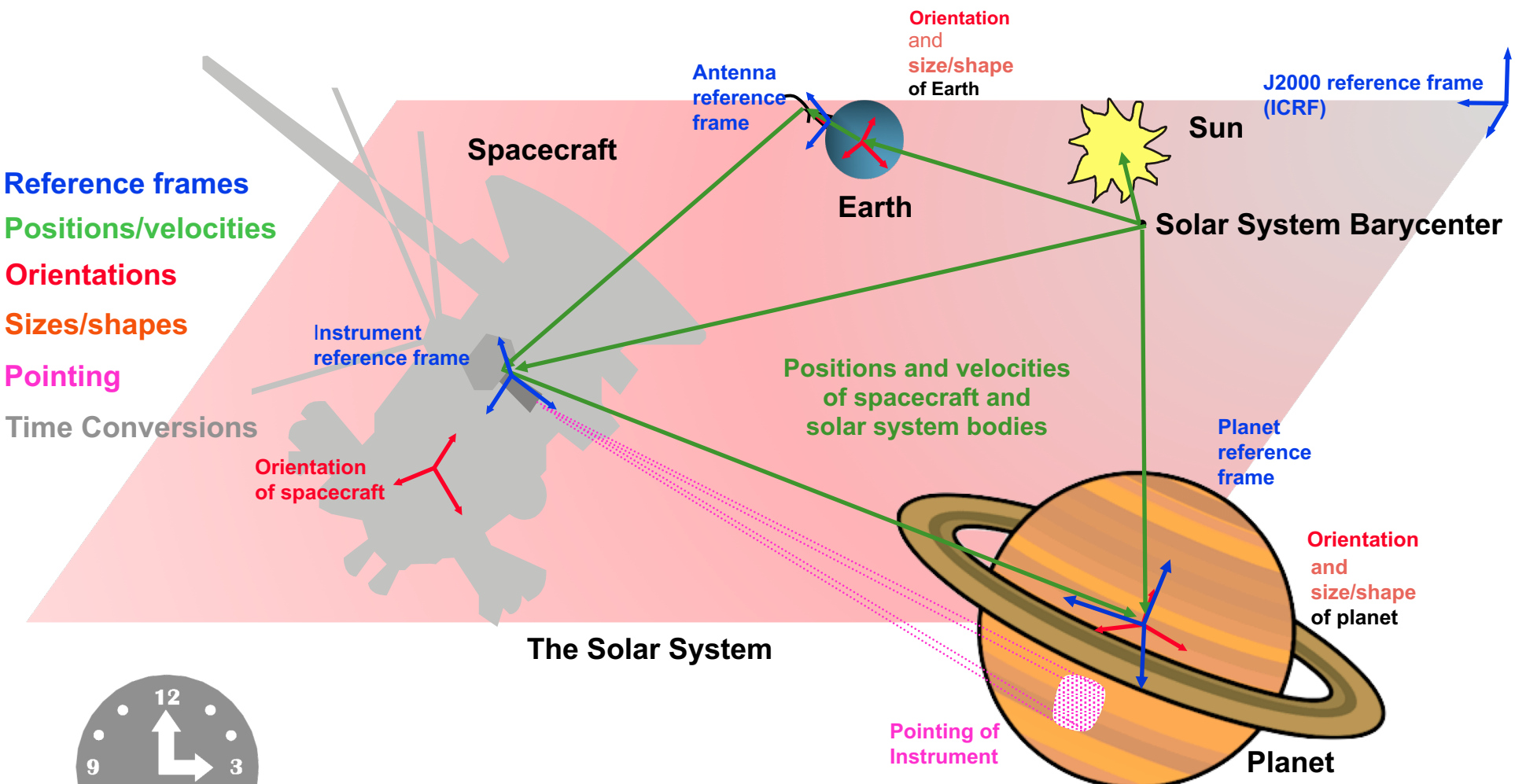
From assorted sources

Ancillary Data Files

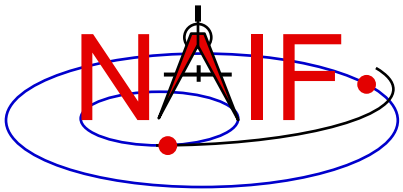
Observation Geometry Parameters or Time Intervals

What are "Ancillary Data?"

Navigation and Ancillary Information Facility



Time Conversion Calculations



How Use Ancillary Data?

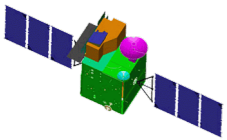
Navigation and Ancillary Information Facility

- **Ancillary data** are those that help scientists and engineers determine **observation geometry**, such as:
  - 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
  - where on the surface the instrument was looking
- The text above uses past tense, but doing the same functions for future times to support mission planning is equally applicable

From Where do Ancillary Data Come?

Navigation and Ancillary Information Facility

- From the spacecraft

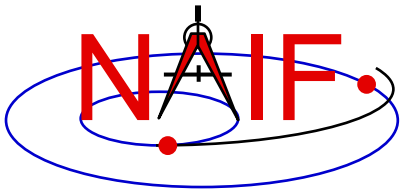


- From the mission control center

- From the spacecraft and instrument builders

- From science organizations

- SPICE is used to organize and package these data in a collection of stable file types–called "kernels"–used by scientists and engineers



Why Use SPICE?

- **Knowing observation geometry and geometric 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 a 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 System Components

Navigation and Ancillary Information Facility

Ancillary data files (“kernels”)……..……

1100
1010
0101

Software (SPICE Toolkit) ……..

Documentation ……..…..

Tutorials ……..…..

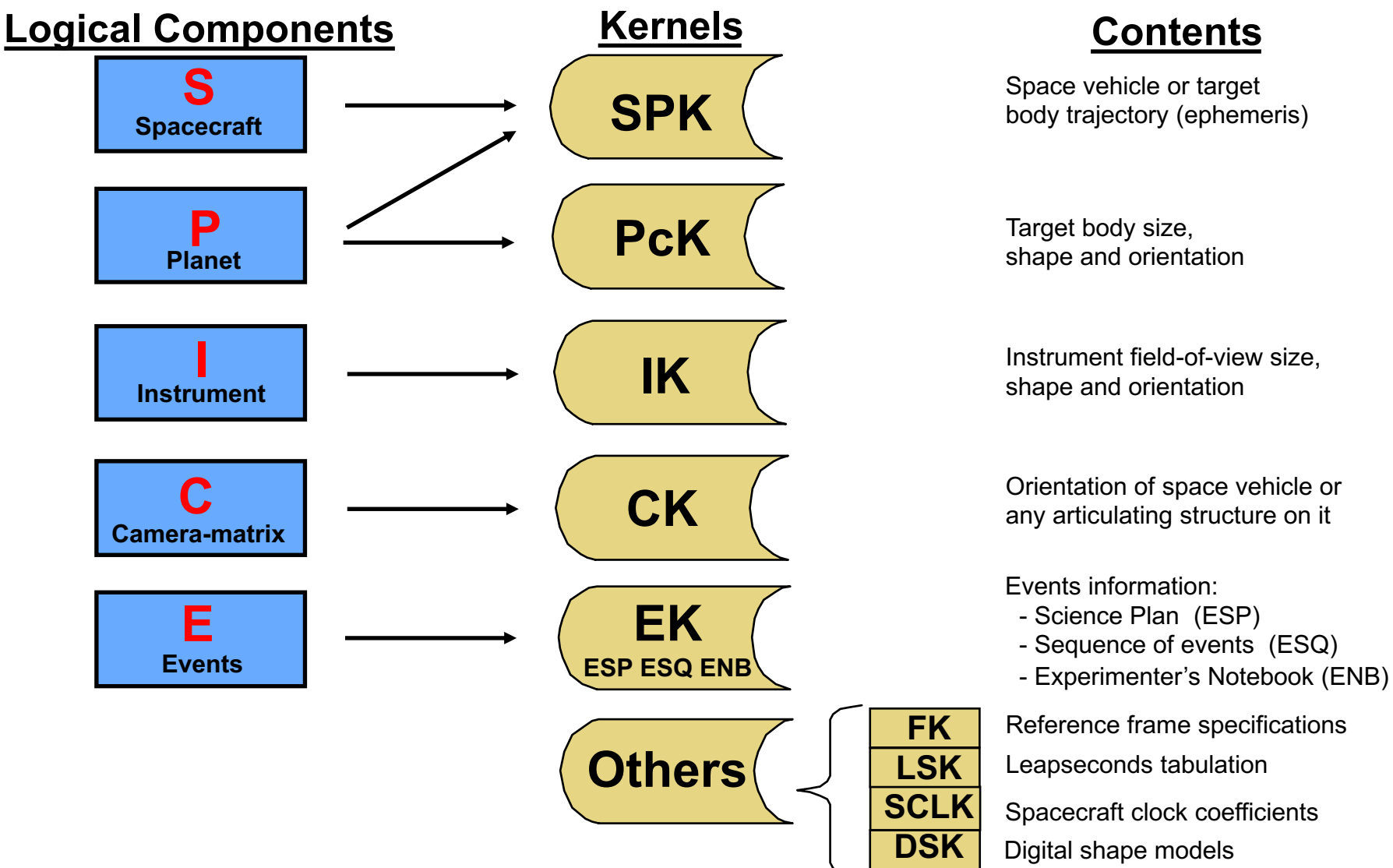
Programming lessons …..

Training classes ……

User consultation ……..…..

SPICE Data Overview

Navigation and Ancillary Information Facility



SPICE Kernels Details- 1

Navigation and Ancillary Information Facility

SPK

- Space vehicle ephemeris (trajectory)
- Planet, satellite, comet and asteroid ephemerides
- More generally, position of something relative to something else

PcK

- Planet, satellite, comet and asteroid orientations, sizes, shapes
  - See also DSK
- Possibly other similar "constants" such as parameters for gravitational model, atmospheric model or rings model

IK

- Instrument field-of-view size, shape, orientation
- Possibly additional information, such as internal timing

SPICE Kernels Details- 2

Navigation and Ancillary Information Facility

CK

- Instrument platform (e.g. spacecraft) attitude
- More generally, orientation of something relative to a specified reference frame

EK

3 components

- "Events," broken into three components:
  - ESP: Science observation plans
  - ESQ: Spacecraft & instrument commands
  - ENB: Experiment "notebooks" and ground data system logs

EK is not much used

SPICE System Data - 3

Navigation and Ancillary Information Facility

FK

- **Frames**
  - Definitions of and specification of relationships between reference frames (coordinate systems)
    - Both “fixed” and “dynamic” frames are available

LSK

- **Leapseconds Tabulation**
  - Used for UTC <--> TDB (ET) time conversions

SCLK

- **Spacecraft Clock Coefficients**
  - Used for SCLK <--> TDB (ET) time conversions

DSK

- **Shape models (tessellated plate model and digital elevation model*) (DSK)**

*DEM portion under development

UTC = Coordinated Universal Time TDB = Barycentric Dynamical Time ET = Ephemeris Time SCLK = Spacecraft Clock Time

SPICE Toolkit Software

Navigation and Ancillary Information Facility

Contents

- **Library of subroutines**
  - But typically just a few are used within a customer's program to compute quantities derived from SPICE data files
- **Programs**
  - SPICE data production
  - SPICE data management
- **Documentation**
  - Highly annotated source code
  - Technical Reference Manuals
  - User Guides

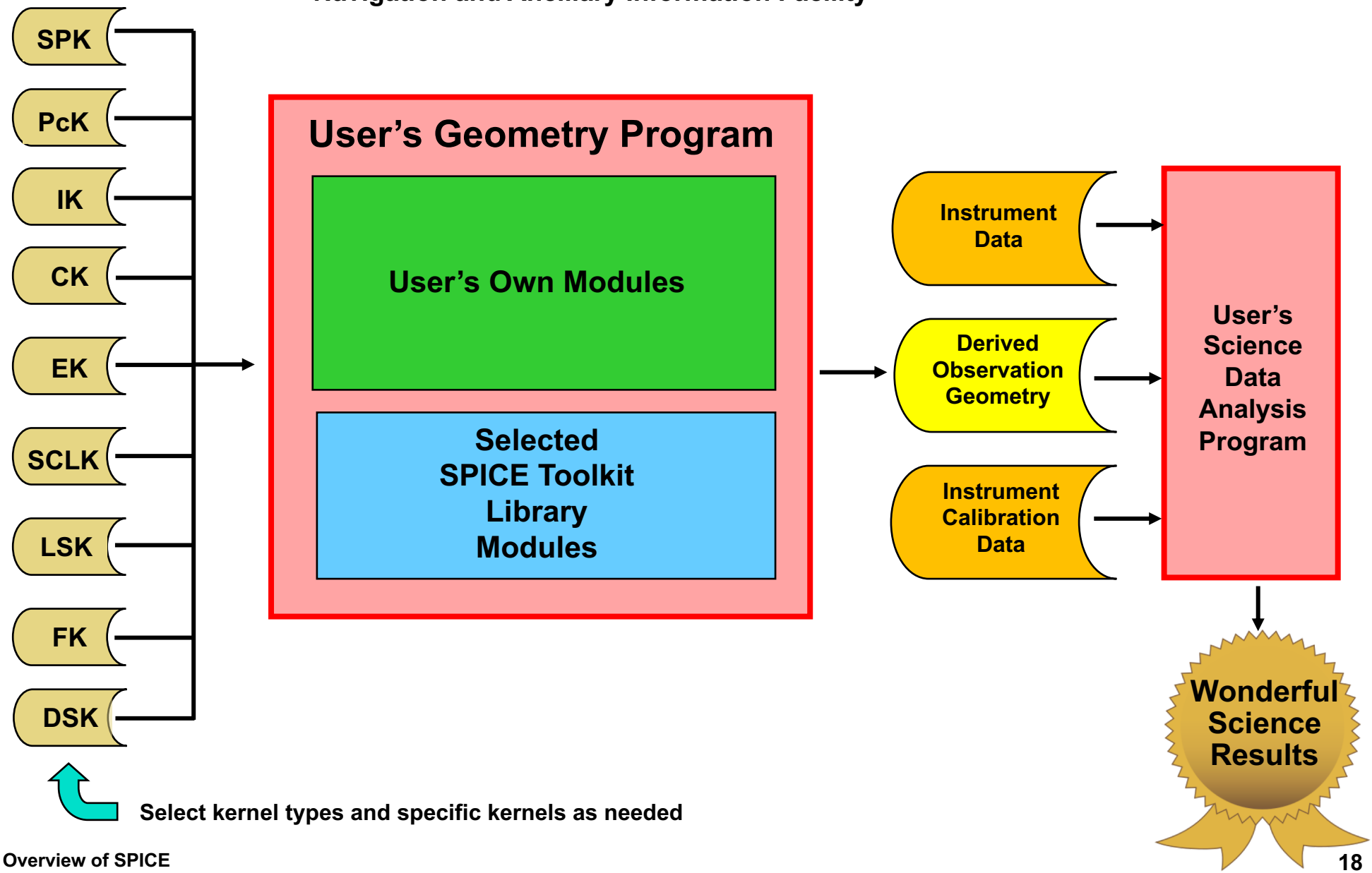
Versions

- **Nine languages**
  - Fortran 77
  - C
  - IDL
  - MATLAB
  - Java Native Interface (JNI)
  - Python, Ruby, Swift, Julia (provided by 3rd parties)
- **Four platforms**
  - PC/Linux
  - PC/Windows
  - Sun/Solaris
  - Mac/OSX
- **Several compilers**
  - For the Fortran and C Toolkits

All combinations provided by NAIF are fully built and individually tested before being made available to customers

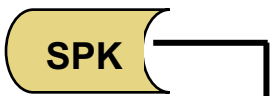
Using SPICE:
Science Data Analysis Example

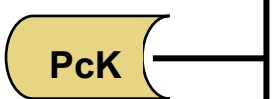
Navigation and Ancillary Information Facility

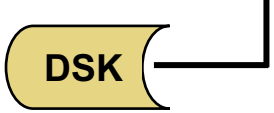


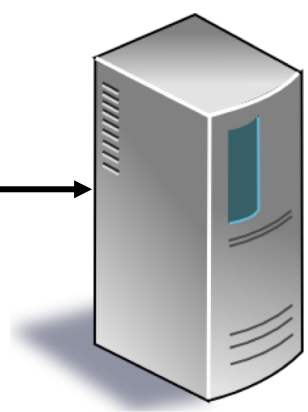
Using SPICE:
Science Data Peer Review Example

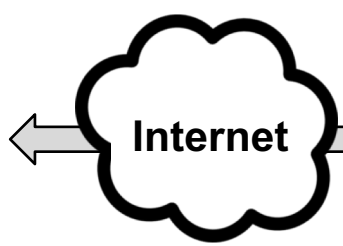
Navigation and Ancillary Information Facility

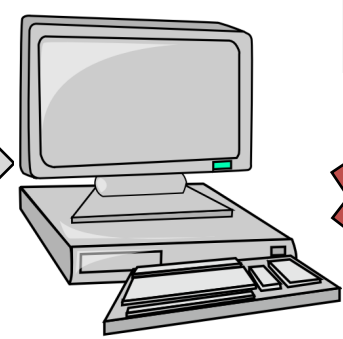












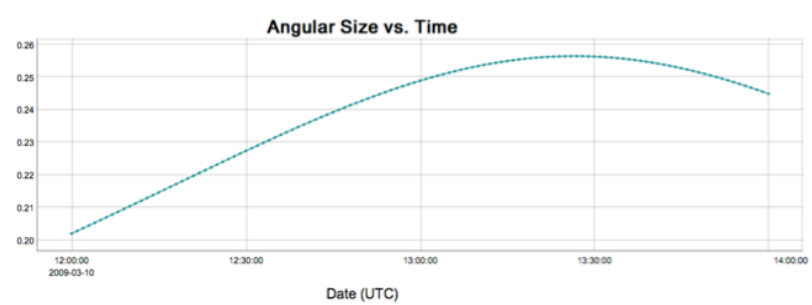
Tabular Results

Click a value to save it for a subsequent calculation.

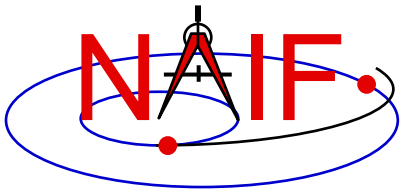
	UTC calendar date	Angular Size (deg)
1	2009-03-10 12:00:00.000000 UTC	0.20212256
2	2009-03-10 12:01:00.000000 UTC	0.20294481
3	2009-03-10 12:02:00.000000 UTC	0.20377024
4	2009-03-10 12:03:00.000000 UTC	0.20459871
5	2009-03-10 12:04:00.000000 UTC	0.20543007
6	2009-03-10 12:05:00.000000 UTC	0.20626418
7	2009-03-10 12:06:00.000000 UTC	0.20710088
8	2009-03-10 12:07:00.000000 UTC	0.20794000
9	2009-03-10 12:08:00.000000 UTC	0.20878138
10	2009-03-10 12:09:00.000000 UTC	0.20962484
11	2009-03-10 12:10:00.000000 UTC	0.21047019
12	2009-03-10 12:11:00.000000 UTC	0.21131725
13	2009-03-10 12:12:00.000000 UTC	0.21216581

Numeric Results

Graphic Results



Angular size of Phobos as seen from the Mars rover "SPIRIT"

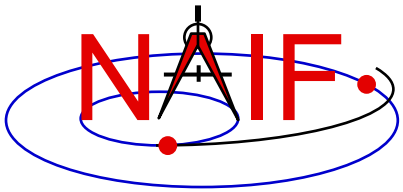


SPICE System Characteristics - 1

- SPICE Toolkit software is portable between computers
- New Toolkits are released irregularly, when enough new capability warrants it
- Code is very 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
- 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

Navigation and Ancillary Information Facility

- 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

Building Blocks for Your Applications

Navigation and Ancillary Information Facility

The “SPICE” observation geometry system can serve as a set of building blocks for constructing tools supporting multi-mission, international space exploration programs.