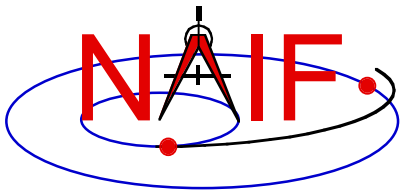


Navigation and Ancillary Information Facility

SPICE Overview

August 9, 2003

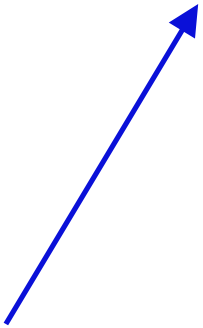
The SPICE system has been developed by the Jet Propulsion Laboratory, California Institute of Technology,
under contract with the National Aeronautics and Space Administration

Space Science Data: Two Kinds

Navigation and Ancillary Information Facility

Science Instrument Data
including calibration data

Ancillary or Engineering Data



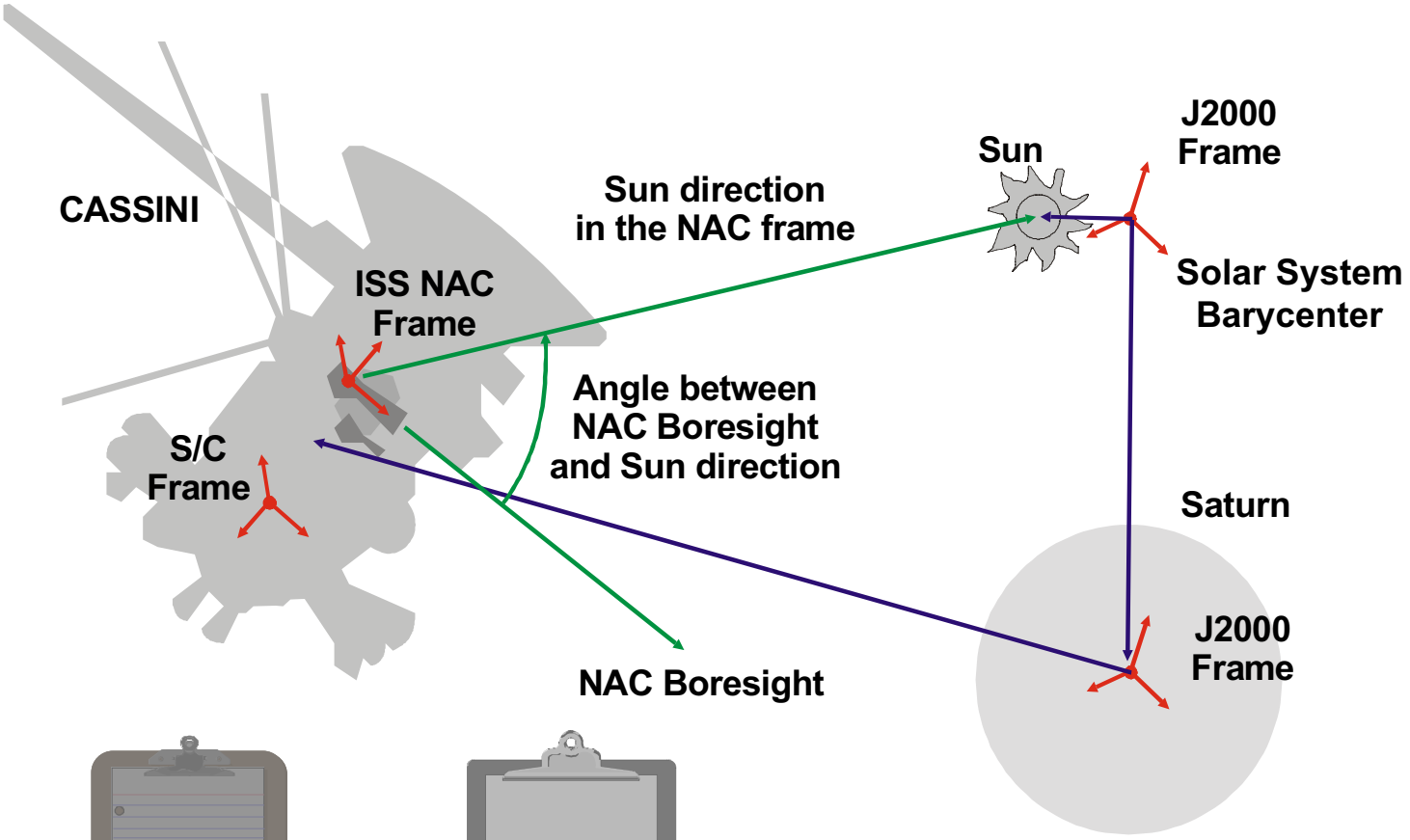
SPICE deals with these data

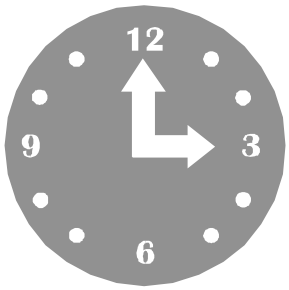
- Some from the spacecraft
- Some from the mission control center
- Some from the spacecraft and instrument builders
- Some from scientists

The Subjects of SPICE

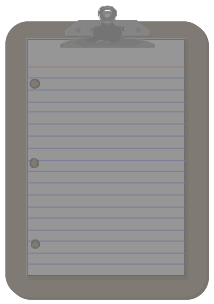
Navigation and Ancillary Information Facility

SPICE Deals with Observation Geometry,Time and Events

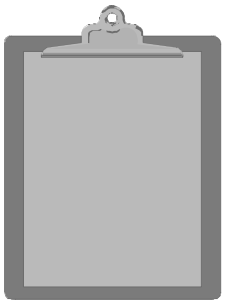




SCLK or SCET



Today's Plan of Events

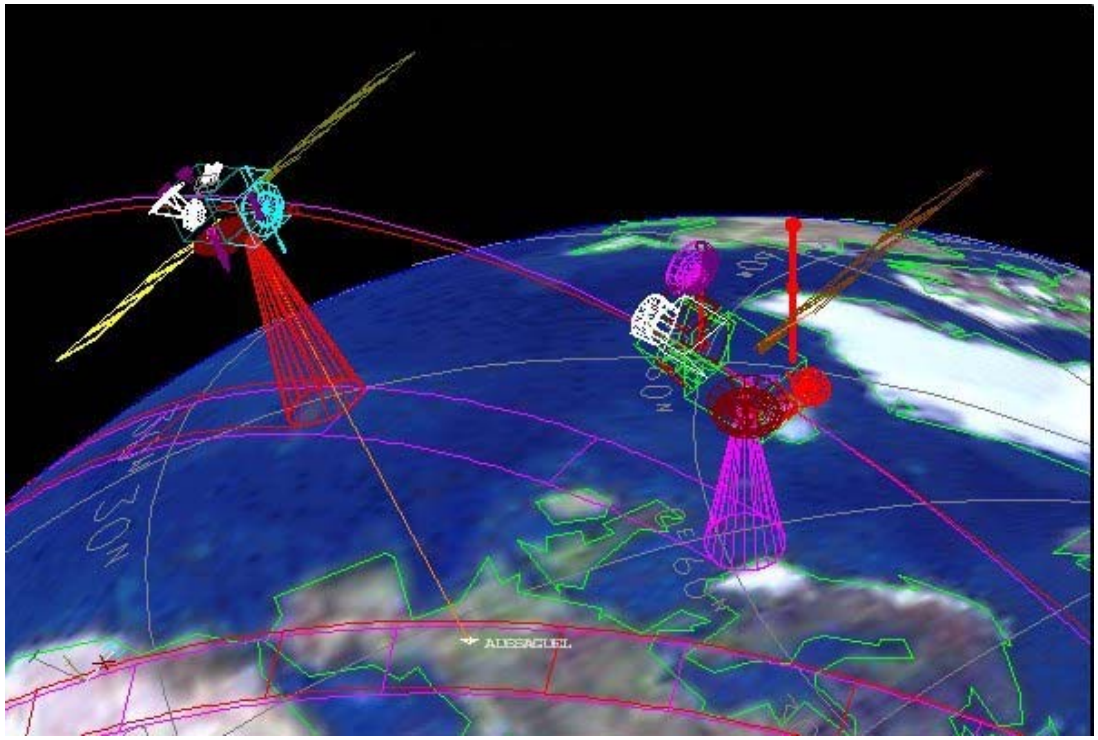


Log of Yesterday's Events

ISS = Imaging Science System:
- NAC = Narrow Angle Camera
- WAC = Wide Angle Camera

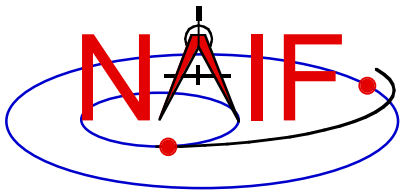
Why SPICE?

Navigation and Ancillary Information Facility



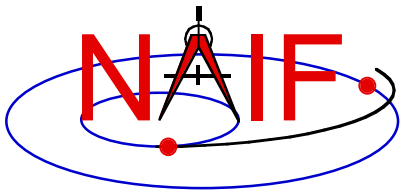
Knowing observation geometry and events is an important element in the design of space missions and in the analysis of the science data returned from the instruments.

Having standard methods for producing and using ancillary data reduces cost and risk, and can help scientists achieve more meaningful and accurate results.



What are “Ancillary Data”?

- **“Ancillary data” are those that help scientists and engineers determine:**
  - **when and how an instrument was acquiring data**
  - **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 other relevant events were occurring on the spacecraft or ground that might affect interpretation of:**
    - » **science observations**
    - » **spacecraft systems performance**



SPICE System Components

- **The principal SPICE system components are two**
  - **Data files, often called “kernels” or “kernel files”**
  - **Software, known as the SPICE Toolkit**
    - » **The principal component is an extensive subroutine library**
    - » **Also included are some:**
      - **broadly useful application programs**
      - **utility programs**
      - **examples of how to use SPICE Toolkit subroutines**
- **Also part of SPICE are:**
  - **standards**
  - **documentation**
  - **customer support**
  - **system maintenance and continuing development**

Genesis of the SPICE Acronym*

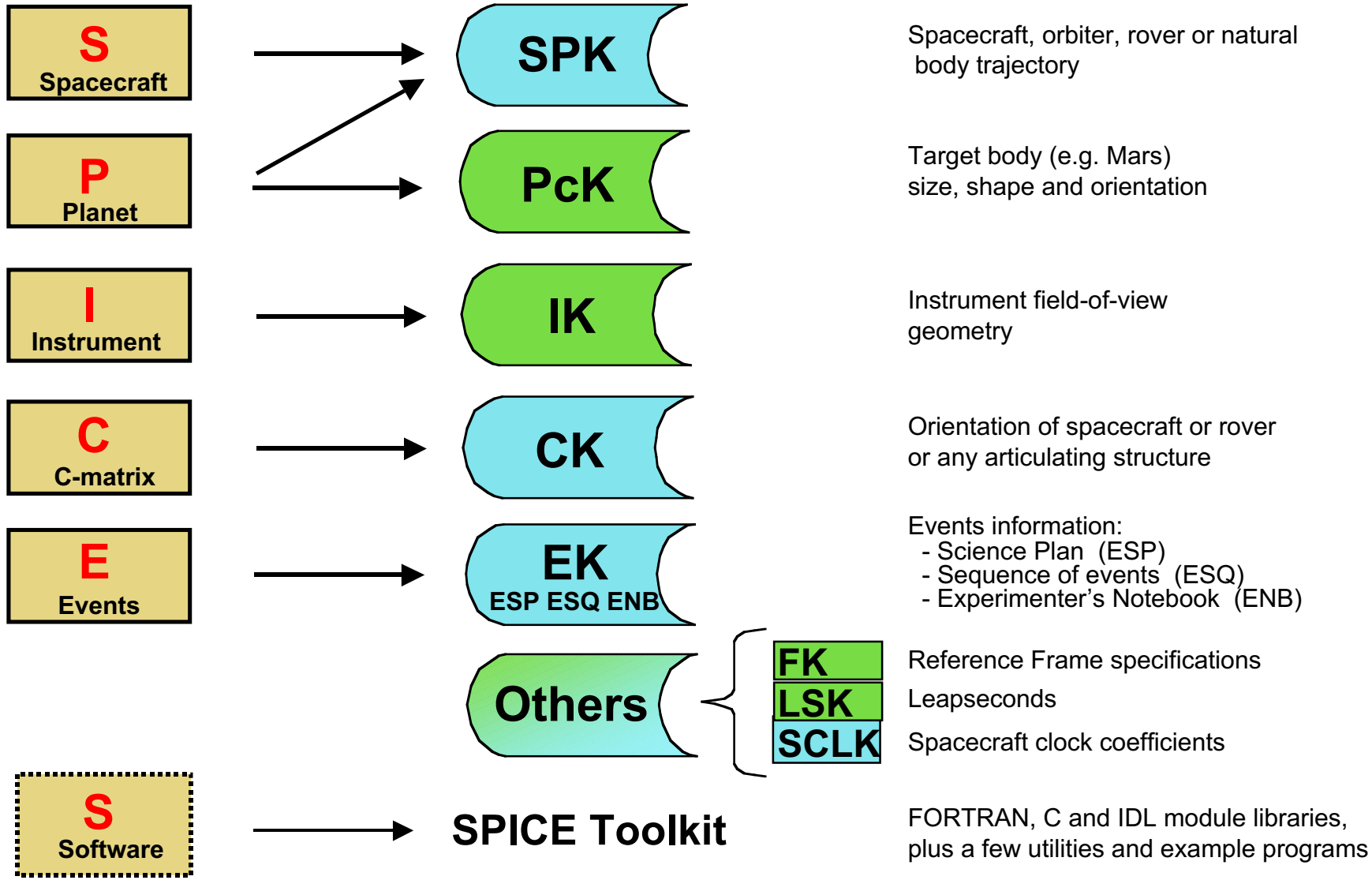
Navigation and Ancillary Information Facility

S	**S**pacecraft
P	**P**lanet
I	**I**nstrument
C	**C**-matrix
E	**E**vents

*** Coined by Dr. Hugh Kieffer, USGS Astrogeology Branch, Flagstaff AZ**

Logical versus Physical View

Navigation and Ancillary Information Facility



SPICE System Contents - 1

Navigation and Ancillary Information Facility

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

- Planet, satellite, comet and asteroid orientations, sizes, shapes
- Possibly other similar “constants” such as parameters for gravitational model, atmospheric model or rings model

- Instrument information such as:
  - Field-of-View specifications
  - Internal timing

SPICE System Contents - 2

Navigation and Ancillary Information Facility

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

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

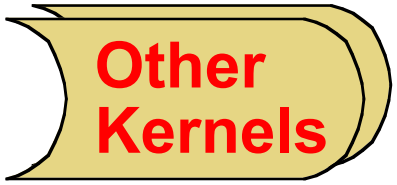
SPICE System Contents - 3

Navigation and Ancillary Information Facility

- **Frames Definitions**
  - Definitions of and specification of relationships between reference frames (coordinate systems)

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

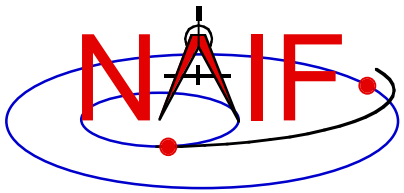
- **Spacecraft Clock Coefficients**
  - Used for SCLK <--> ET time conversions



- **Mission (mappings between names and ID codes)**
- **Star (sky) catalog***
- **Plate model for irregular bodies***

* = under development

UTC = Universal Time Coordinated ET = Ephemeris Time SCLK = Spacecraft Clock Time



SPICE System Contents - 4

Navigation and Ancillary Information Facility

SPICE Toolkit

FORTRAN

C

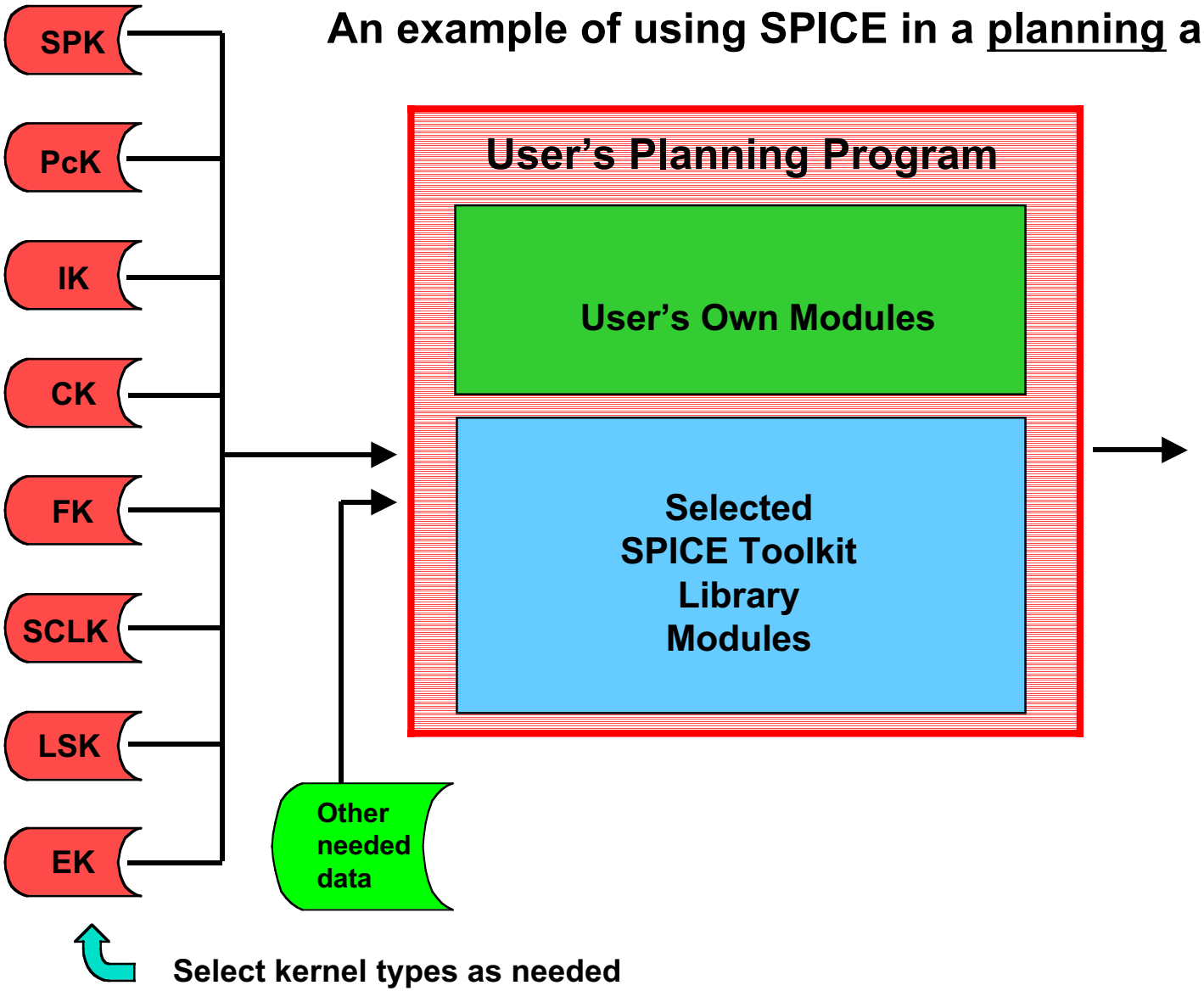
IDL (in final testing)

- **Library of modules used to:**
  - **write binary SPICE kernel files**
  - **read all (binary and text) SPICE kernel files**
  - **compute quantities derived from SPICE kernel data**
- **Example (“cookbook”) programs**
- **Utility programs**
  - **Kernel summarization or characterization**
  - **Kernel management**
- **Application programs (a few)**
  - **e.g. “chronos” time conversion application**
- **Kernel production programs (a few)**
  - **e.g. “mkspk” trajectory generator**

Using SPICE Library Modules

Navigation and Ancillary Information Facility

An example of using SPICE in a planning activity



- Instrument pointing plan

or

- Observation geometry visualization

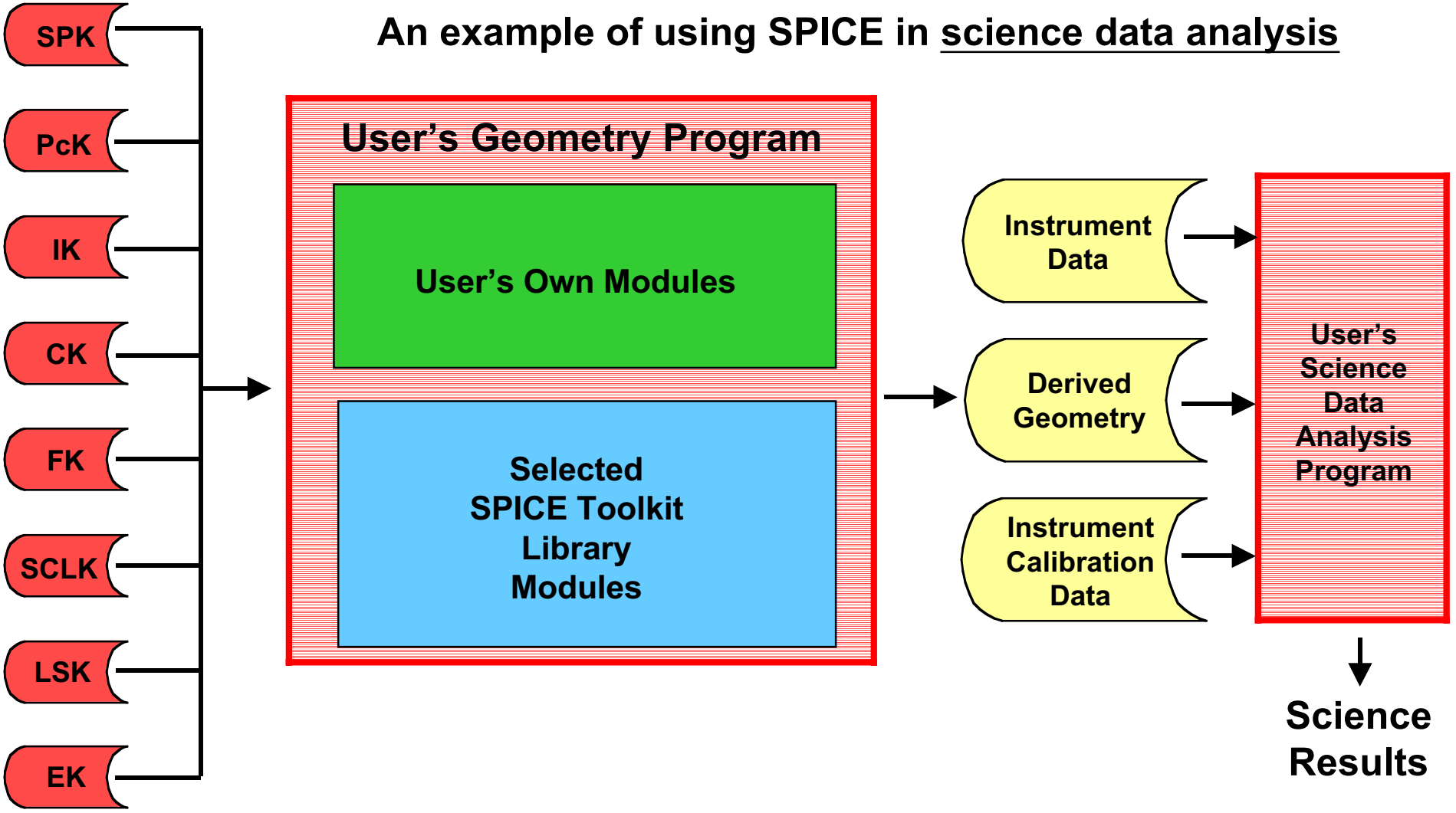
or

- Analysis of expected communications link performance

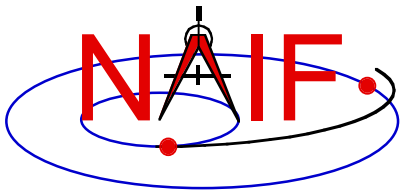
Using SPICE Library Modules

Navigation and Ancillary Information Facility

An example of using SPICE in science data analysis



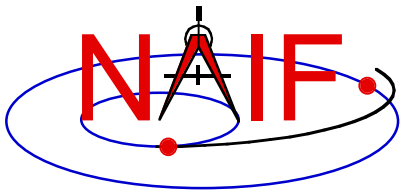
Select just those SPICE files needed for your particular task



SPICE System Characteristics - 1

Navigation and Ancillary Information Facility

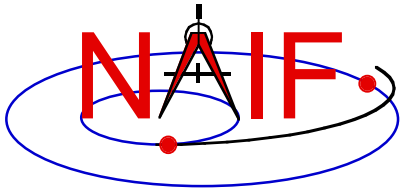
- Portable SPICE kernel files
- Portable SPICE Toolkit software
  - Already ported to and tested on most popular platforms
    - » PC/Win, PC/Linux, Mac/OS9, Mac/OSX, Sun, SGI, HP, Alpha, VAX
- Focus is on the customer
  - Code is well tested before being released to users
  - Once released, code functionality is never changed or removed
    - » Except NAIF does reserve the right to fix bugs
  - Extensive user-oriented documentation is provided
    - » Includes highly documented source code
  - The Toolkit contains some example (“cookbook”) programs
  - An extensive set of SPICE tutorials is available



SPICE System Characteristics - 2

Navigation and Ancillary Information Facility

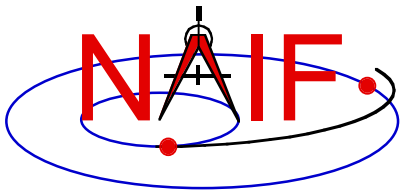
- Computations are double precision
- System includes built-in exception handling
  - Catches most invalid inputs
  - Offers a traceback and configurable action upon detection of a problem
- Gives you access to most of JPL's integrated ephemerides for spacecraft and natural bodies (planets, satellites, comets, asteroids)
- 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 family
  - New kinds of kernels can be developed
- Broad applicability and good value
  - Multimission and multidiscipline (see list of major projects)
  - SPICE development and maintenance costs are shared across many customers



SPICE System Characteristics - 3

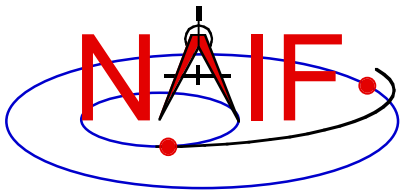
- **The SPICE Toolkit is generally free to individual users**
  - Core SPICE system development is funded by NASA's Office of Space Science
  - NASA flight projects fund NAIF to adapt and deploy SPICE in support of NASA’s planetary missions and some cooperative missions
  - NASA provides consultation and some tools for agencies using SPICE SPK files to schedule Deep Space Network stations

- **Very few restrictions on distribution and use of SPICE software and SPICE files**
  - Distribution of SPICE software is generally not restricted under U.S. Government regulations
  - Commercial use of SPICE software is encouraged, under appropriate licensing agreement with Caltech/JPL
  - SPICE software is copyrighted © by the California Institute of Technology



Supported Platforms

- **The SPICE Toolkit has been ported to a wide variety of popular "environments"**
  - **Each environment is characterized by**
    - » **Hardware type (platform)**
    - » **Operating System**
    - » **Compiler**
    - » **Sometimes even selected compilation options**
- **NAIF provides separate, already built SPICE Toolkit packages for each supported platform**
  - **(Don't try porting the Toolkit to some new environment yourself… unless you first consult with NAIF staff)**



For What Jobs is SPICE Used ?

Navigation and Ancillary Information Facility

Increasing mission maturity (time)

- Mission planning, modeling and visualization
- Pre-flight mission evaluation from a science perspective
- Detailed science observation planning
- Mission operations engineering functions
- Science data analysis, including correlation of results between instruments, and with data obtained from other missions
- Data archiving, for future use by others

The original focus of SPICE

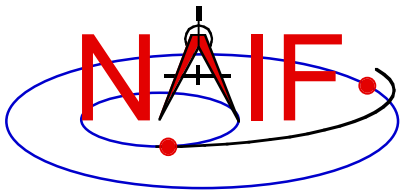
- Education and Public outreach

Examples - 1
What Can You Do With SPICE ?

Navigation and Ancillary Information Facility

- **Mission Design**
  - Compute all interesting orbit properties; compare these with those of another design, or with another mission
  - Evaluate possibilities for relay link times and duration

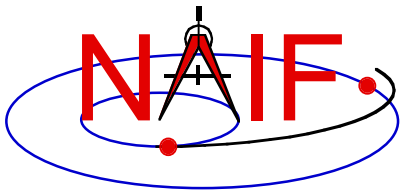
- **Science**
  - Compute instrument footprint geometry; compare with that from another instrument on the same or a different spacecraft
  - Design specific observations to be acquired
  - Compute observation geometry needed to analyze your data, such as:
    - » Lighting angles
    - » Location (LAT/LON) of instrument footprint
    - » Range and local time



Examples - 2
What Can You Do With SPICE ?

- **Mission Operations**
  - Predict or evaluate telecommunications link performance
  - Analyze spacecraft orientation history
  - Determine elevation and rise/set times of sun and tracking stations
  - Compute location and lighting conditions for a rover

- **Visualization, Education and Public Outreach**
  - Provide geometry used to drive web pages giving interesting parameters such as ranges, velocities, time of day on Mars
  - Provide geometry for animations showing orbiter location and orientation, instrument footprint projected on the surface, and locations of surface assets or natural features of interest
  - Help get upper class students involved in space mission design



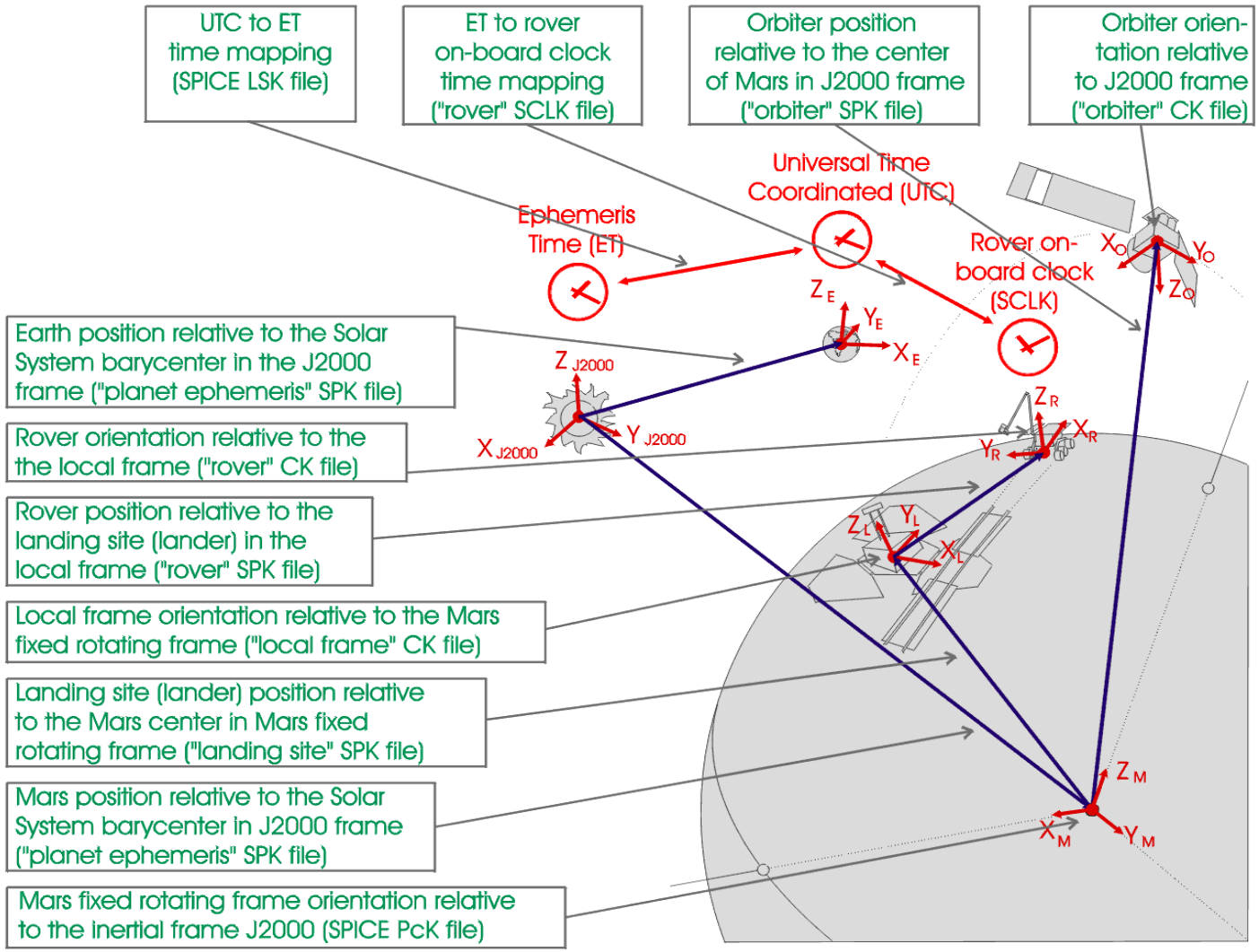
What Vehicle Types Can Be Supported ?

- **Cruise/Flyby**
  - Remote sensing
  - In-situ measurement
  - Instrument calibration
- **Landers**
  - Remote sensing
  - In-situ measurements
  - Rover or balloon relay
- **Orbiters**
  - Remote sensing
  - In-situ measurement
  - Communications relay
- **Rovers**
  - Remote sensing
  - In-situ sensing
  - Local terrain characterization
- Balloons*
  - **Remote sensing**
  - **In-situ measurements**

* Not yet demonstrated

Global SPICE Geometry

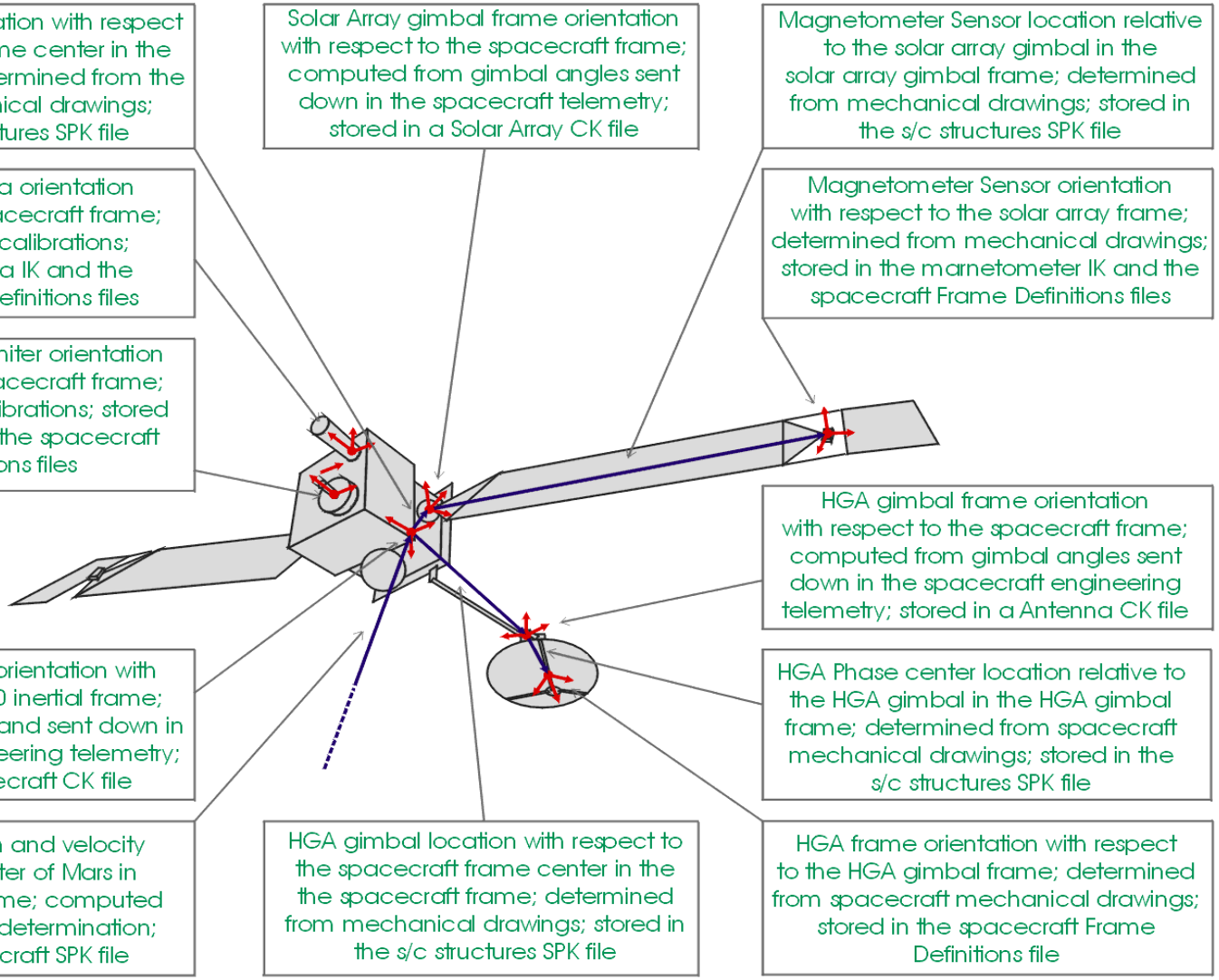
Navigation and Ancillary Information Facility



Applying SPICE to a Full Planetary Investigation: Orbiter, Lander, Rover

Orbiter Geometry

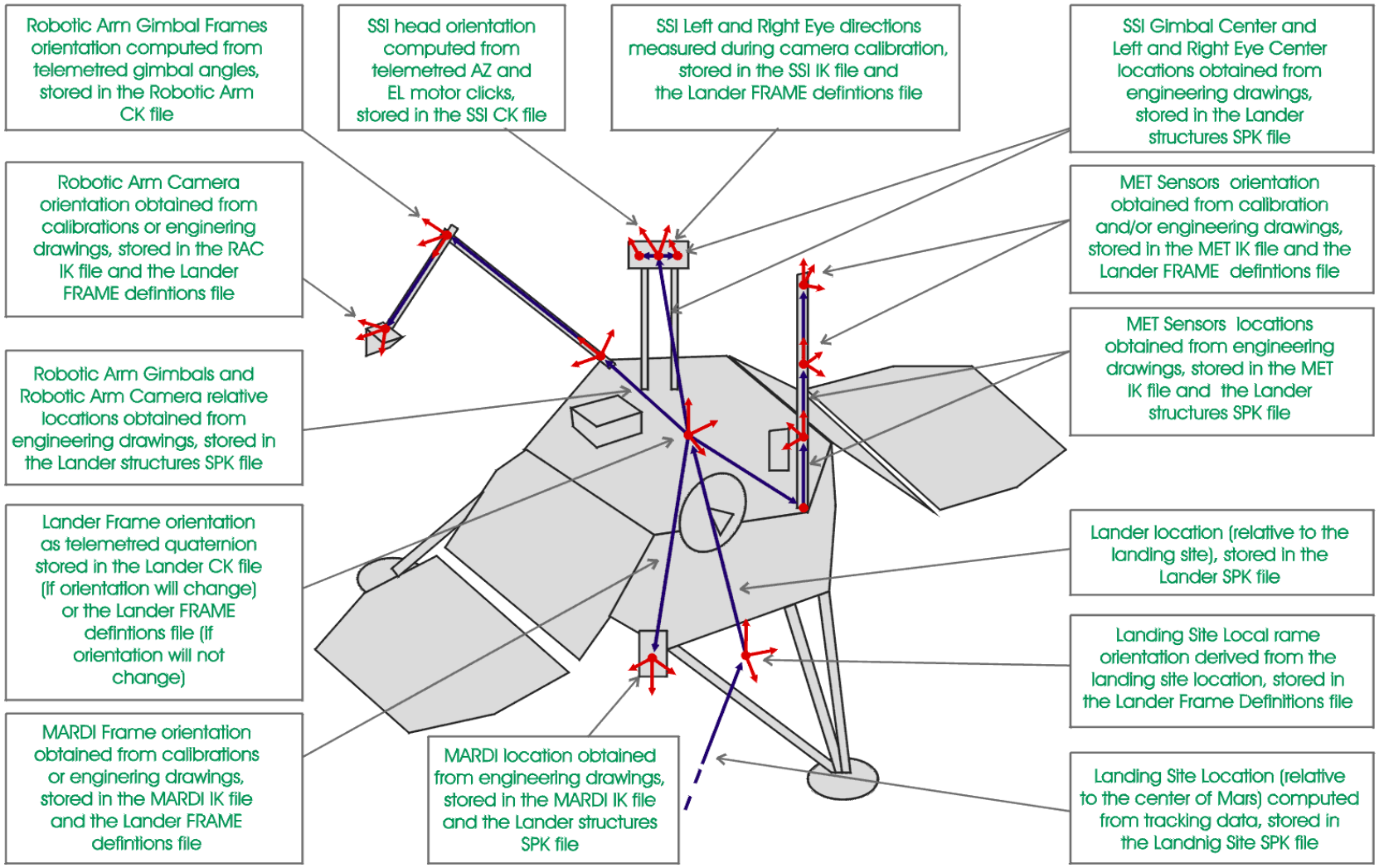
Navigation and Ancillary Information Facility



Applying SPICE to an Orbiter (MGS)

Lander Geometry

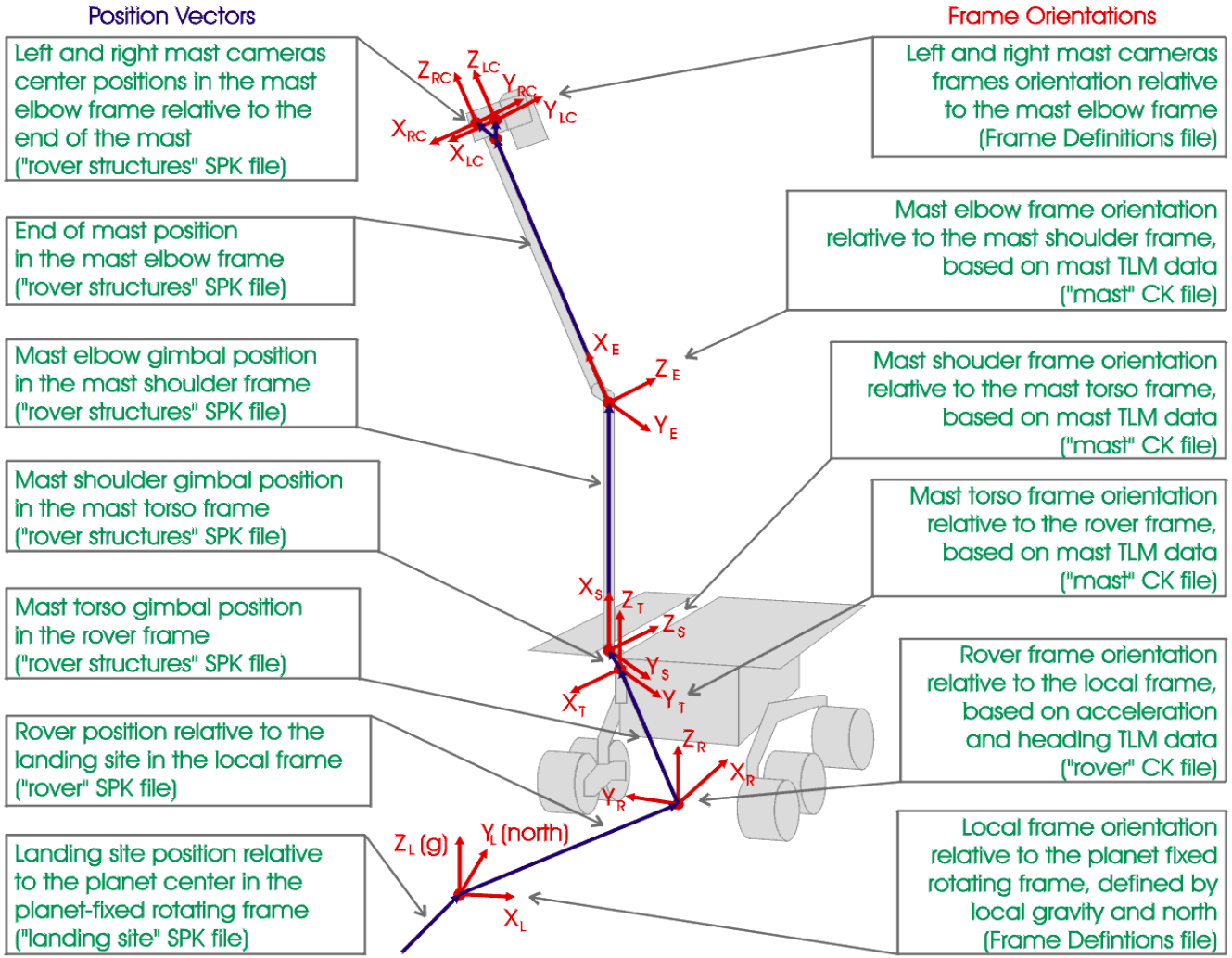
Navigation and Ancillary Information Facility



Applying SPICE to a Lander (M98)

Rover Geometry

Navigation and Ancillary Information Facility



Applying SPICE to a Surface Rover (Rocky-7)

Major SPICE Customers

Navigation and Ancillary Information Facility

Restorations	Past Customers	Current Customers	Pending
Apollo 15, 16 [P]	Magellan [P]	Galileo	Messenger
Mariner 9 [P]	Clementine (NRL)	Mars Global Surveyor	New Horizons (Pluto)
Mariner 10 [P]	Mars Observer	Stardust	Mars Science Lab
Viking Orbiters [P]	Mars 96 (Russia)	Cassini/Huygens	Phoenix
Pioner 10/11 [P]	Hubble Telescope [S]	Mars Odyssey	
Haley armada [P]	ISO [S]	Mars Exploration Rover	Future Possibilities
Phobos 2 [P] (Russia)	MSTI-3 (by ACT Corp.)	SIRTF [P]	NASA Mars Program
Ulysses [P]	OTD (by MSFC)	Genesis	Discovery Program
Voyagers [P]	Mars Pathfinder	Mars Express (ESA)	Explorers Program
	Mars Climate Orbiter	Deep Impact	Space Interferometry
	Mars Polar Lander	Mars Recon. Orbiter	
	NEAR	DSN Metric Predicts [S]	Not Likely
	Deep Space 1	Planetary Data System	Muses-C (Japan)
	CONTOUR		Rosetta (ESA)
	Space VLBI [P]		Venus Express (ESA)

[P] = partial use of SPICE

[S] = special tools or services provided by NAIF

Building Blocks for Your Applications

Navigation and Ancillary Information Facility

NAIF offers its "SPICE" ancillary information system as a model and core set of blocks for building tools that can help execute a multimission, international space exploration program