The SPICE Concept
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The Navigation Ancillary Information Facility (NAIF), acting under the directions of NASA's Office of Space Science, has built a data system–named SPICE–to assist scientists in planning and interpreting scientific observations from space-borne instruments. The principal objective of this information system is that it will provide geometric and other ancillary information used to plan space science missions and subsequently recover the full value of science instrument data returned from missions, including correlation of individual instrument data sets with data from other instruments on the same or other spacecraft.

The primary SPICE data sets are often called “kernels” or “kernel files.” SPICE kernels are composed of navigation and other ancillary information that has been structured and formatted for easy access and correct use by the space science and engineering communities. SPICE kernels are produced by the most knowledgeable sources of such information, usually located at a mission operations center. They must include or be accompanied by metadata--consistent with flight project data system standards--that provide pedigree and other descriptive information needed by prospective users.

SPICE kernel file contents are summarized below.

S- Spacecraft ephemeris, or more generally, location of an observer, given as a function of time.

P- Planet, satellite, comet, or asteroid ephemerides, or more generally, location of a target body, given as a function of time.

The ephemeris data for spacecraft and target bodies are normally combined in a single file called the SPICE SPK file. (But just target ephemerides, or just a spacecraft ephemeris, can be held in an SPK file; it is not necessary that both types be present.)

The P kernel also logically includes certain physical, dynamical and cartographic constants for target bodies, such as size and shape specifications, and orientation of the spin axis and prime meridian. These target body physical and cartographic constants are found in the SPICE PCK file.

I- Instrument description kernel, containing descriptive and operational data peculiar to a particular scientific instrument, such as mounting alignment, internal timing relative to the spacecraft clock, and field-of-view model parameters. This instrument information is contained in the SPICE IK file.

C- Pointing kernel, containing a transformation traditionally called the C-matrix that provides time-tagged pointing (orientation) angles for a spacecraft structure upon which science instruments are mounted. Attitude data are contained in the SPICE CK file.

E- Events kernel, summarizing mission activities–both planned and unanticipated. Events data are contained in the SPICE EK file set which consists of three components: Science Plans, Sequences, and Notes.

Several miscellaneous kernel files--spacecraft clock (SCLK file) and leapseconds (LSK file)--are also part of SPICE; these are used in converting time tags between various time measurement systems.

Also available is the SPICE Database Kernel (DBK file). This provides a simple, portable relational database functionality used for several purposes, such as the Sequence component of the E-kernel, star catalogs, image catalogs and SPICE kernel file management. The DBK can also be used by customers in place of a commercial product whenever wide portability and low cost are key requirements.

Perhaps the "SPICE" acronym should have been "SPICES," with the final "S" standing for "Software." The SPICE system includes the NAIF Toolkit, a large collection of allied software. The principal component of this Toolkit is a library of portable subroutines needed to read the kernel files and calculate most common observation

geometry parameters. Users integrate these SPICE "Toolkit" subroutines into their own application programs to compute observation geometry parameters and related information where and as needed. The NAIF Toolkit was originally implemented in ANSI FORTRAN 77, but is now becoming available in the C language as well. (A C++ version is planned for the future.)

NAIF has designed the kernel file and software Toolkit architectures with portability and multimission application as principal goals. In addition, because extensive software documentation and examples are provided with the Toolkit, with a reasonable learning effort the software can be confidently used by the full spectrum of the NASA-supported space science community.

A flight project's mission operations center concentrates on producing, cataloging and distributing complete and accurate kernels on a timely basis. Kernel updates should be made promptly if/as improved data sources become available.

Users may order those kernels of interest--using them in application programs hosted at their home sites to compute needed geometric and related ancillary information. Users can even update some kernels and produce their own versions of other kernels to support their own analyses or to provide their colleagues with any improvements in ancillary information resulting from their work.

Each flight project delivers well documented copies of all SPICE kernels and Toolkit software to the appropriate permanent archive facility, assuring ready availability of this data for future users. Ideally this archive is open to the international community of scientists and engineers. User-produced kernels may also be similarly archived. (For NASA planetary missions, the NAIF node of NASA’s Planetary Data System is the archive site.)

Because generic ephemerides for most solar system target bodies are available at the NAIF, SPICE is frequently used for mission design and for planning observations. In these cases the observer could be a "predict" spacecraf ephemeris produced by a mission design organization, a terrestrial telescope or a user-provided instrument location. In some cases "predict" versions of other SPICE kernels are also made to help simulate a full data processing system. With this flexibility scientists may use SPICE throughout the experiment life cycle—from mission planning to detailed observation design to instrument data analysis and finally to correlation of results with those from other missions.

A large set of core SPICE components is in place. Extension and adaptation of this core system to encompass broader functionality and to meet specific needs of new projects will be an ongoing endeavor. This work will include provision of some broadly useful application programs and development of additional kernel types. Examples of new applications are: adaptation of SPICE for landers and rovers, and, use of SPICE to point and tune NASA's Deep Space Network antennas to track all customer spacecraft.

The SPICE system is, or soon will be, used on numerous national and international space missions, such as Galileo, Mars Global Surveyor , Near Earth Asteroid Rendezvous , Mars Surveyor 98, Stardust and Cassini. Limited data from some older missions such as Voyager, Viking and Pioneer have been "restored" into SPICE format. While the principle use of SPICE has been in the planetary science discipline, astrophysics, space physic and even Earth science projects are also using this technology.

In addition to providing SPICE technology to NASA and international space missions the NAIF Group serves as the Ancillary Data Node of NASA's Planetary Data System. In this role NAIF provides a permanent archive, and distribution and consultation functions for planetary project ancillary data sets.

For further information contact the NAIF Group located in the Navigation and Flight Mechanics Section of Caltech's Jet Propulsion Laboratory in Pasadena California.

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