



Navigation and Ancillary Information Facility

Planetary Constants Kernel PCK

October 2007



Topics

Navigation and Ancillary Information Facility

- Overview
- Using PCKs
- Text PCKs
- IAU Models
- Binary PCKs
- Interface Routines
- PCK Reference Frames



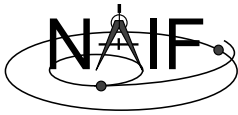
Overview

Navigation and Ancillary Information Facility

- The **P_constants** kernel (PCK or Pck) is logically a part of the “planet kernel.”
- **SPICE PCK data consist of:**
 - Orientation (also known as “rotation”) models for extended, natural solar system bodies: sun, planets, natural satellites, a few asteroids
 - » Location of the pole and prime meridian
 - » Axis directions of a body-fixed, body-centered reference frame
 - » Spin rate
 - Physical and cartographic constants
 - » Sets of radii for triaxial shape models.
 - » Additional items could be included, such as
 - prime meridian offset from the principal axis
 - magnetic dipole location
 - gravity parameters: GM, J2, higher order gravity field terms
 - ring model parameters
- **PCK data files are called “PCK kernels,” “PCKs” or “PCK files.”**
- **The PCK subsystem supports text and binary PCK file formats.**
 - Text PCKs may contain orientation, shape, and other cartographic or physical data.
 - Binary PCKs are used for high-accuracy orientation data.
 - » Binary PCKs are available only for the earth and the moon.

Pck Subsystem

3



Using PCKs

Navigation and Ancillary Information Facility

- **Load PCKs using FURNISH**
 - Orientation data from a binary PCK always supersedes orientation data (for the same object) obtained from a text PCK, no matter the order in which the kernels are loaded
- **PCK orientation data are usually accessed via Frame system or SPK calls**
 - Example: Get the IAU_SATURN body-fixed reference frame to J2000 position or state transformation matrix at ET:
 - » CALL PXFORM ('IAU_SATURN', 'J2000', ET, RMAT)
 - » CALL SXFORM ('IAU_SATURN', 'J2000', ET, XFORM)
 - Example: Get state of Saturn relative to Cassini in the IAU_Saturn body-fixed reference frame:
 - » CALL SPKEZR ('SATURN', ET, 'IAU_SATURN', 'LT+S', CASSINI, STATE, LT)
 - Example: Get state of Cassini relative to the DSN station DSS-13 in the J2000 inertial reference frame:
 - » CALL SPKEZR ('CASSINI', ET, 'J2000', 'LT+S', 'DSS-13', STATE, LT)
 - An Earth PCK must be loaded in order for this call to work.
 - Even though the specified reference frame is inertial
 - This call, in the course of its work, converts the position of the DSN station relative to the Earth's center from an Earth-fixed, earth-centered frame to the J2000 frame.
- **Access to PCK shape and other data is discussed in the section titled “Interface Routines”**

Pck Subsystem

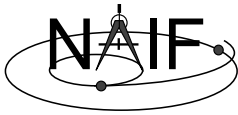
4



Text PCK Files - 1

Navigation and Ancillary Information Facility

- Text PCK files may contain orientation, shape and other data associated with natural solar system bodies.
- NAIF creates and distributes “generic” text PCK files based on IAU/IAG reports, published in *ICARUS*.
 - These PCKs contain orientation and shape data provided by the reports.
 - SPICE PCK software is designed to use these data to compute orientation of body-fixed frames.
- NAIF provides a “masses” PCK containing GM values for the Sun and planetary systems.
 - Values from this file may be used with SPICE osculating element routines
- Text PCKs are sometimes produced by NASA flight projects and others; not only by NAIF.



Text PCK Files - 2

Navigation and Ancillary Information Facility

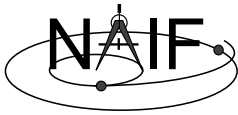
- The SPICE text kernel mechanism is used to implement generic PCK files.
 - Users may easily visually inspect data.
 - Users may (carefully!) modify text PCKs with a text editor.
 - » Data or comments may be added, deleted, or changed.
 - » Comments should be added to explain changes .
 - Kernel variables contain the mathematical terms appearing in rotation or shape models.
 - » `BODY699_RADII = (60268 60268 54364)`
 - » `BODY699_POLE_RA = (40.58 -0.036 0.)`
 - The user may include additional kernel variables to change the base frame or reference epoch.
 - Kernel variable names are case-sensitive.
 - » NAIF uses only upper case for variable names; we suggest you do the same.



IAU Rotation Models - 1

Navigation and Ancillary Information Facility

- **SPICE shape models use data from the IAU/IAG (formerly IAU/IAG/COSPAR) Working Group Report, as published in *ICARUS*.**
 - Latest full report used by NAIF was issued in 2000.
- **IAU rotation models are provided:**
 - for the sun and planets:
 - » IAU models use low-degree (typically linear) polynomials to represent RA and DEC of the pole (body-fixed +Z-axis) as a function of time.
 - » The prime meridian is also represented by a low-degree polynomial.
 - » Trigonometric polynomial terms are supported by SPICE
 - but are rarely used in IAU models for planet orientation
 - for natural satellites:
 - » Additional trigonometric polynomial terms are used to more accurately represent precession and nutation.
 - » A few satellites exhibit chaotic rotation and so are not modeled.
 - for some major asteroids (e.g. Ida, Eros, Gaspra, Vesta)



IAU Rotation Models - 2

Navigation and Ancillary Information Facility

- **IAU body-fixed frames are planetocentric.**
 - Z-axis is aligned with +/- spin axis. The positive Z-axis points toward the north side of the invariable plane of the solar system.
 - The invariable plane is normal to the solar system's angular momentum vector. It is
 - » approximately the same as Jupiter's orbital plane.
 - » roughly parallel to the ecliptic plane.
 - X-axis defines the prime meridian.
 - Y-axis completes the right-handed frame.
- **The IAU base frame is the IERS-defined International Celestial Reference Frame (ICRF).**
 - SPICE treats the ICRF as equivalent to J2000 (EME2000).
- **The IAU reference epoch is J2000 (2000 Jan 1 12:00:00 TDB).**



IAU Shape Models

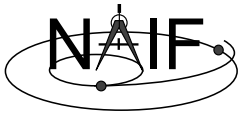
Navigation and Ancillary Information Facility

- **IAU shape models are nominally triaxial ellipsoids**

- Triaxial ellipsoid shape models have the form:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

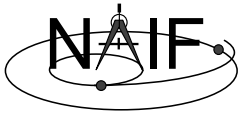
- For many bodies, two of the axes (equatorial axes) have the same value (spheroidal)
 - For some bodies, one or more radii have not been determined.
- **Although many bodies are in fact modeled by spheroids or oblate spheroids, SPICE deals with the general, triaxial case.**
 - Exception: SPICE supports geodetic coordinate transformations only for bodies modeled as spheroids or oblate spheroids.
 - » RECGEO and GEOREC are the modules performing these transformations.
 - Exception: SPICE supports planetographic coordinate transformations only for bodies modeled as spheroids or oblate spheroids.
 - » PGRREC, RECPGR, DPGRDR and DRDPGR are the modules supporting these transformations.



Binary PCK Files

Navigation and Ancillary Information Facility

- **The SPICE system stores high-accuracy orientation models in binary PCKs.**
 - Binary PCKs are implemented using the DAF file architecture (as are SPK files)
 - » Binary PCKs are not human-readable.
 - » SPICE API routines enable applications to create binary PCKs.
 - » SPICE Toolkit utilities enable reading and writing comments, summarizing, and porting binary PCKs.
 - Like SPK files, binary PCKs support multiple data representations (“data types”).
 - » Type 2: Chebyshev polynomials for Euler angles, angular velocity obtained by differentiation, constant interval length.
 - » Type 3: Separate Chebyshev polynomials for Euler angles and their derivatives, variable interval length.
- **Binary PCKs are limited to storing orientation data.**
 - Applications that require shape data must also load a text PCK.
- **Binary PCKs are available for the Earth and Moon.**
 - The orientation data provided by these kernels are much more accurate than those provided by generic text PCKs based on the IAU/IAG reports.
 - These kernels are the topic of the tutorial on high-accuracy orientation data and associated frames for the Earth and Moon.



Interface Routines - 1

Navigation and Ancillary Information Facility

- Call FURNISH to load PCKs.
 - CALL UNLOAD or KCLEAR to unload them.
- Call SXFORM to return a state transformation.
 - Returns 6x6 matrix (attitude and angular velocity)

```
CALL SXFORM ( FROM, TO, ET, XFORM )
sxform_c    ( from, to, et, xform );
cspice_sxform, from, to, et, xform
xform = cspice_sxform ( from, to, et )
```
- Call PXFORM to return a position transformation.
 - Returns 3x3 matrix (attitude only)

```
CALL PXFORM ( FROM, TO, ET, RMAT )
pxform_c    ( from, to, et, rmat );
cspice_pxform, from, to, et, rmat
rmat = cspice_pxform ( from, to, et )
```
- The older routines TISBOD, TIPBOD, and BODMAT are still supported, but NAIF recommends users not call them directly.



Interface Routines - 2

Navigation and Ancillary Information Facility

- Call BODVRD or BODVCD to retrieve constants associated with a body. For example:

```
CALL BODVRD ( 'SATURN', 'RADII', 3      N, RADII )
CALL BODVCD ( 699,      'RADII', 3      N, RADII )

bodvrd_c    ( "SATURN", "RADII", 3      &n, radii );
bodvcd_c    ( 699,      "RADII", 3      &n, radii );

cspice_bodvrd, 'SATURN', item, 3, radii
cspice_bodvcd, 699,      item, 3, radii

radii = cspice_bodvrd ( 'SATURN', item, 3 )
radii = cspice_bodvcd ( 699,      item, 3 )
```

 - These calls retrieve values associated with the variable BODY699_RADII.
 - The variable name is case-sensitive, so the string "RADII" above must be in upper case.
- You can also use general kernel pool fetch routines to fetch data assigned to non-standard names:
 - GCPOOL, GDPOOL, GIPOOL



PCK Reference Frames -1

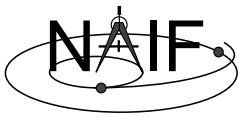
Navigation and Ancillary Information Facility

- **Many PCK reference frame specifications are built-in to SPICE.**
 - “Just add orientation data” (load PCK files) to use these frames. Examples:
 - » IAU frames: IAU_SATURN, IAU_TITAN, IAU_EARTH, IAU_MOON, etc.
 - » IERS frames: ITRF93
- **Other PCK frames are not built in and must be specified at run time by loading frame kernels, for example:**
 - Body fixed frames for asteroids or “newer” natural satellites
 - » See the Frames Required Reading for information on creating frame kernels that specify PCK reference frames.
 - Lunar body-fixed frames: MOON_ME, MOON_PA
 - » See the tutorial on “high-accuracy orientation data and associated frames for the Earth and Moon” for details.
- **SPICE makes default associations between bodies and built-in PCK frames**
 - For example, the default PCK frames for the planets are IAU_MERCURY, IAU_VENUS, IAU_EARTH, etc.

continued on next page

Pck Subsystem

13



PCK Reference Frames - 2

Navigation and Ancillary Information Facility

(continued)

- You can look up the default PCK frame associated with a body by calling CNMFRM or CIDFRM.
 - » In Icy, only CNMFRM is currently available.
 - » Neither is yet available in beta version of Mice.
- **Some SPICE routines use the default PCK frames:**
 - SUBPT, SUBSOL, ILLUM, SRFXT, ET2LST
 - implicitly used in some dynamic frames
- **You can change the default PCK frame associated with a body by loading a frame kernel that assigns a new default frame to that body.**
 - For the Earth or Moon, you can load a “frame association kernel” provided by NAIF.
 - For any body, you can load a frame kernel containing the assignment
`OBJECT_<body name>_FRAME = '<new default frame name>'`
 - » Example: `OBJECT_MOON_FRAME = 'MOON_ME'`
- **For high-accuracy work involving the Earth or Moon and any SPICE routines that use the default PCK frames, you normally would override the SPICE default frames by loading frame association kernels .**
 - See the tutorial on “high-accuracy orientation data and associated frames for the Earth and Moon” for details.

Pck Subsystem

14