

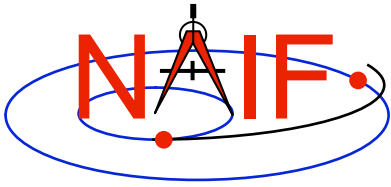


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Navigation and Ancillary Information Facility

# **Planetary Constants Kernel PCK**

**September 2009**



# Topics

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



# Overview

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- 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.



# Using PCKs

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- **Load PCKs using FURNISH**
  - Orientation data from a binary PCK always supersede 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”**



# Text PCKs - 1

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- **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 flight projects and others—not only by NAIF.**



## Text PCKs - 2

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- 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

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- **SPICE PCK shape models use data from the IAU/IAG (formerly IAU/IAG/COSPAR) Working Group Report, as published in *ICARUS*.**
  - The latest IAU 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

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- **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

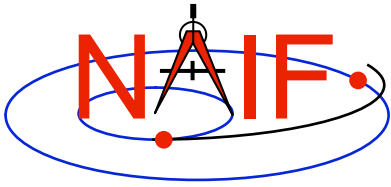
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- **IAU shape models are nominally triaxial ellipsoids**

- 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 PCKs

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- **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

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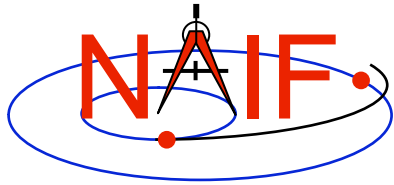
- **Call FURNISH to load PCKs.**
  - CALL UNLOAD or KCLEAR to unload them.
- **Call SXFORM to return a state transformation.**
  - Returns 6x6 matrix (attitude and angular velocity)

```
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

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

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

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

```
IDL      cspice_bodvrd, 'SATURN', 'RADII', 3, radii
          cspice_bodvcd, 699, 'RADII', 3, radii
```

```
MATLAB   radii = cspice_bodvrd ('SATURN', 'RADII', 3 )
          radii = cspice_bodvcd ( 699, 'RADII', 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 use general kernel pool fetch routines to fetch data assigned to any non-standard names
  - GCPOOL, GDPOOL, GIPOOL



# PCK Reference Frames - 1

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- **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.
  - You can look up the default PCK frame associated with a body by calling CNMFRM or CIDFRM.
    - » Neither is yet available in Mice.



## PCK Reference Frames - 2

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- **Some (mostly deprecated) SPICE routines implicitly use the default PCK frames (IAU\_<body name>).**
- **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.**
  - Reference the tutorial on “high-accuracy” orientation data and associated frames for the Earth and Moon for details.



# PCK Utility Programs

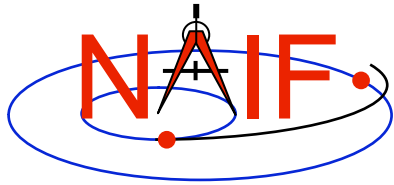
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- **The following PCK utility programs are included in the Toolkit:**

<b>BRIEF</b>	summarizes coverage for one or more binary PCK files
<b>SPACIT</b>	generates segment-by-segment summary of a binary PCK file
<b>COMMNT</b>	reads, appends, or deletes comments in a binary PCK file
<b>FRMDIFF</b>	samples or compares orientation of a PCK-based frame
- **These additional PCK utility programs are provided on the NAIF Web site (<http://naif.jpl.nasa.gov/naif/utilities.html>)**

<b>DAFMOD</b>	alters frame IDs in a binary PCK file
<b>DAFCAT</b>	concatenates together binary PCK files
<b>BFF</b>	displays binary file format of an binary PCK file
<b>BINGO</b>	converts binary PCK files between IEEE and PC binary formats



# Additional Information on PCK

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- **For more information about PCK, look at the following:**
  - Most Useful Routines document
  - PCK Required Reading document
  - Headers of the routines mentioned
  - Lunar/Earth High-Precision PCK/FK tutorial
  - BRIEF and FRMDIFF User's Guides
- **Related documents:**
  - Frames Required Reading
  - Kernel Required Reading
  - NAIF\_IDS Required Reading
  - Time Required Reading