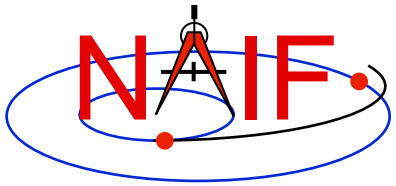
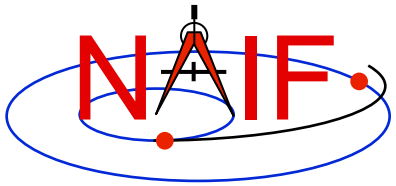


Navigation and Ancillary Information Facility

Planetary Constants Kernel
PCK

April 2016



Topics

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- Using PCKs
- Interface Routines
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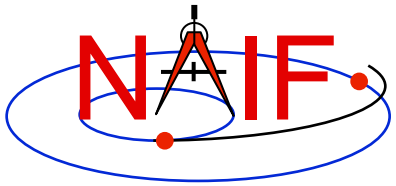
- PCK Utility Programs



Overview

- **The Planetary Constants Kernel (PCK) subsystem comprises both text and binary kernels**
  - **Text PCKs provide orientation and shape models for the sun, planets, natural satellites and a few asteroids**
  - **Binary PCKs are used only when very high accuracy orientation data are available**
    - » **Available only for the earth and the moon**

Text PCKs - 1

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- **Text PCK files contain orientation, shape and other data associated with natural solar system bodies.**
- **NAIF creates and distributes a "generic" text PCK based on the latest IAU/IAG Report.***
  - **The reports are issued about once every three years, and so might not contain the very latest available results.**
  - **SPICE PCK software is designed to use these data to compute orientation of body-fixed frames.**
  - **These frames have a name style of "IAU_*body-name*"**
- **NAIF also provides a "masses" PCK, containing GM values for the Sun and planetary systems.**
  - **Values from this file are typically used with SPICE osculating element routines, and in using the MKSPK application to make a Type 5 SPK file.**
- **Text PCKs are sometimes produced by flight projects and others–not only by NAIF.**

* "Report of the IAU/IAG Working Group on cartographic coordinates and rotational elements: <year issued>"; published in *Celestial Mechanics and Dynamical Astronomy*

Text PCKs - 2

- **The SPICE text kernel mechanism is used to implement PCK files.**
  - **Kernel variables contain the mathematical terms appearing in rotation or shape models. For example:**

```
BODY699_RADII   =  ( 60268   60268   54364  )
BODY699_POLE_RA =  ( 40.589  -0.036     0.  )
BODY699_POLE_DEC = ( 83.537  -0.004     0.  )
```

  - **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.**
  - **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.**

Text PCK Orientation Models - 1

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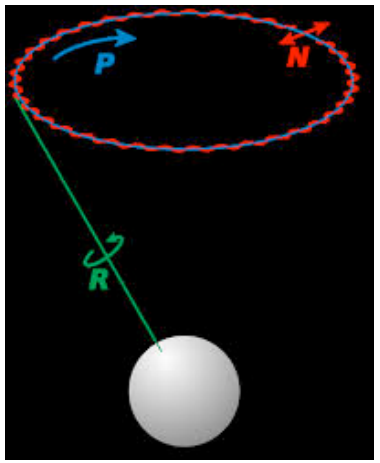
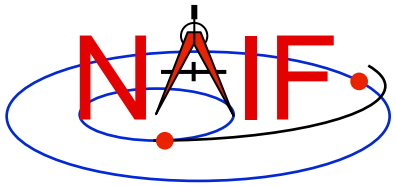
- **For the sun, planets and a few major asteroids:**
  - PCK models use low-degree (typically linear) polynomials to represent RA and DEC of the pole (body-fixed +Z-axis) as a function of time.
  - The prime meridian is also represented by a low-degree polynomial.
  - For a few planets trigonometric polynomial terms are used to more accurately represent precession and nutation of the pole.

R = rotation of the body about its rotational axis
P = precession of the bodies' rotational axis
N = nutation of the bodies' rotational axis



- **For natural satellites:**
  - In addition to low-degree polynomials for the spin axis and prime meridian, trigonometric polynomial terms are used to more accurately represent precession and nutation.
  - A few satellites have chaotic rotation and so are not modeled.



Text PCK Orientation Models - 2

- **The base frame for PCK orientation models is the International Celestial Reference Frame (ICRF), as defined by the International Earth Rotation Service (IERS).**
  - **For historical and backwards compatibility reasons SPICE uses the names "J2000" and "EME2000" as synonyms for the ICRF inertial reference frame, even though J2000 and ICRF are, in fact, not identical. (The difference is "well under 0.1 arc second.")**

Text PCK Orientation Models - 3

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- **Body-fixed frames provided in text PCKs are planetocentric.**

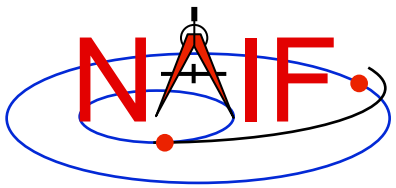
- **For planets and satellites the +Z axis (+90 LAT) always points to the north side of the invariable plane (the plane whose normal vector is the angular momentum vector of the solar system)**
  - » **Planetocentric longitude increases positively eastward**
  - » **Planetocentric latitude increases positively northward**

- **Dwarf planets*, asteroids and comets spin in the right hand sense about their "positive pole."**
  - **What the IAU now calls the "positive pole" is still referred to as the "north pole" in SPICE documentation.**
  - **The "positive pole" may point above or below the invariable plane of the solar system (see above).**
  - **This revision by the IAU Working Group (2006) inverts what had been the direction of the north pole for Pluto, Charon and Ida.**

*The dwarf planets are: Ceres, Eris, Haumea, Makemake, Pluto

Binary PCK Orientation Models

- The SPICE system stores high-accuracy orientation models in binary PCKs
- Binary PCKs are limited to storing orientation data
  - Applications that require shape data must also load a text PCK.
- 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
- Binary PCKs for the earth and the moon are available from NAIF
  - The accuracy of these is MUCH better than what is provided in the generic text PCK



Location of PCK Reference Frame Specifications

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- **Many PCK reference frame specifications are built-in to SPICE.**
  - **Load a text PCK file to use IAU frames. Examples:**
    - » **IAU_SATURN, IAU_TITAN, IAU_MARS, etc.**
      - **Be very cautious in using IAU_EARTH and IAU_MOON; the binary PCKs for these two bodies offer *much* more accuracy**
  - **Load the appropriate binary PCK for either the earth or the moon**
    - » **For the earth IERS frame: ITRF93**
    - » **For a lunar frame based on JPL ephemeris: DExxx**
    - » **See the special tutorial "lunar-earth_pck-fk" for details on these**

- **Other PCK frames are not built-in and must be specified at run time by loading a frames kernel, for example:**
  - **Body fixed frames for asteroids or "newer" natural satellites**
    - » **See the Frames Required Reading technical reference for information on creating frame kernels that specify PCK reference frames.**

PCK Shape Models

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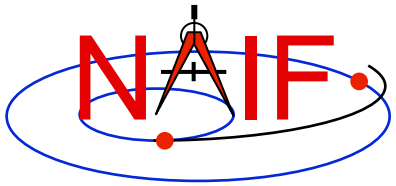
- **PCK shape models are nominally triaxial ellipsoids**
  - **For many bodies, two of the axes (equatorial axes) have the same value (spheroidal)**
  - **For some bodies, one or more radii have not been determined.**

- **Although many bodies are in fact modeled as spheres or spheroids, SPICE usually deals with the general, triaxial case.**
  - **Exception: SPICE supports geodetic coordinate transformations only for bodies modeled as spheres or spheroids.**
    - » **RECGEO, GEOREC, DGEODR and DRDGEO are the modules performing these transformations.**
  - **Exception: SPICE supports planetographic coordinate transformations only for bodies modeled as spheres or spheroids.**
    - » **PGRREC, RECPGR, DPGRDR and DRDPGR are the modules supporting these transformations.**



Using PCK Data

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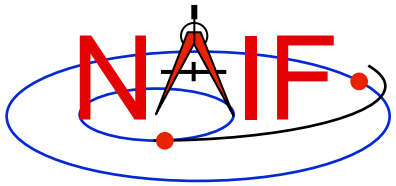
- **PCK orientation data are usually accessed using frame subsystem or ephemeris subsystem APIs**
  - **Example: Get the IAU_SATURN body-fixed reference frame to J2000 position or state transformation matrix at ET:**
    - **CALL PXFORM ('IAU_SATURN', 'J2000', ET, RMAT)**
    - **CALL SXFORM ('IAU_SATURN', '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)**
- **PCK shape data are usually accessed using APIs needing size and shape data such as SUBPT, SUBSLR, ILUMIN, etc.**



Interface Routines - 1

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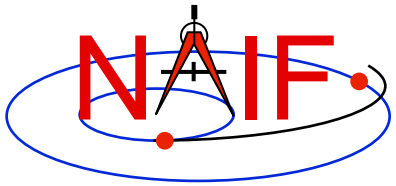
- Call FURNSH to load PCKs.
  - CALL UNLOAD or KCLEAR to unload them.
- Call SXFORM to return a state transformation.
  - Returns 6x6 matrix (attitude and angular velocity)
    - » `CALL SXFORM ( FROM, TO, ET, XFORM )`
- Call PXFORM to return a position transformation.
  - Returns 3x3 matrix (attitude only)
    - » `CALL PXFORM ( FROM, TO, ET, RMAT )`
- 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 )`
- 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.

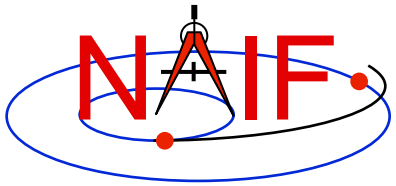


Interface Routines - 2

- **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 )`

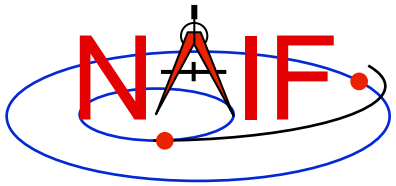
  - **These calls retrieve values associated with the variable BODY699_RADII.**
  - **The variable name is case-sensitive, so the string "RADII" above must be in upper case.**

- **You can use general kernel pool fetch routines to fetch data assigned to any non-standard names**
  - **GCPOOL, for character data**
  - **GDPOOL, for double precision data**
  - **GIPOOL, for integer data**



PCK Precedence Rules

- 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
- In text PCKs, assignments are of two types:
  - » "Direct": variable name = value(s)
  - » "Incremental": variable name += value(s)
  - – The last direct assignment made to a given variable replaces any/all previous assignments for that variable
  - – Incremental assignments simply add additional values to an existing variable
    - » The variable will be newly created if it didn't already exist



PCK Utility Programs

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- **These utilities are included in the Toolkit**

BRIEF	summarizes coverage for one or more binary PCK files
SPACIT	generates segment-by-segment summary of a binary PCK file
COMMNT	reads, appends, or deletes comments in a binary PCK file
FRMDIFF	samples a PCK-based frame or compares orientation of two PCK-based frames

- **These additional utilities are provided on the NAIF Web site (http://naif.jpl.nasa.gov/naif/utilities.html)**

BFF	displays binary file format of an binary PCK file
BINGO	converts binary PCK files between big-endian and little-endian formats

Additional Information on PCK

- **For more information about PCKs, 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**