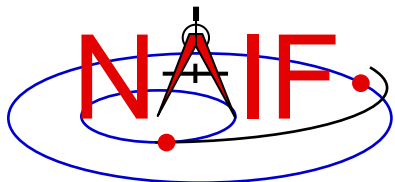


Navigation and Ancillary Information Facility

Planetary Constants Kernel PCK

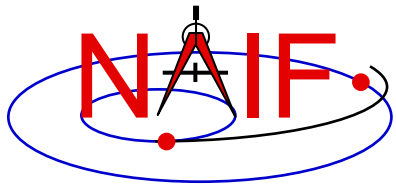
January 2020



Topics

Navigation and Ancillary Information Facility

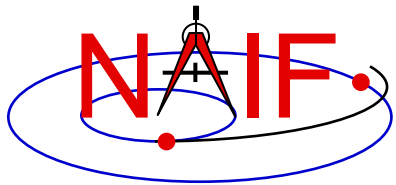
- **Overview**
- **Text PCK Orientation Models**
- **Binary PCK Orientation Models**
- **PCK reference frames**
- **PCK Shape Models**
- **Using PCKs**
- **Interface Routines**
- **PCK Precedence Rules**
- **PCK Utility Programs**



Overview

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- **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 and comets.**
 - **Binary PCKs are used only when very high accuracy orientation data are available.**
 - » **Currently available only for the earth and the moon**
 - » **One still needs to use a text-style PCK to get shape data**

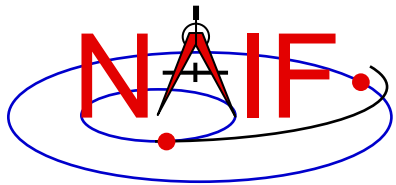


Text PCKs - 1

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- **Text PCK files contain size, shape and orientation data associated with natural solar system bodies: planets, satellites, and a few comets and asteroids.**
 - Some additional kinds of data might also be included.
- **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, body-centered 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*

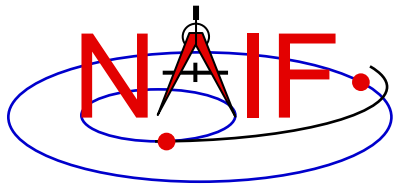


Text PCKs - 2

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- **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_POLE_RA = ( 40.589  -0.036  0. )  
BODY699_POLE_DEC = ( 83.537  -0.004  0. )  
BODY699_PM = ( 38.90  810.7939024  0. )  
BODY699_RADII = ( 60268  60268  54364 )
```
 - **Users may easily inspect data in text PCKs.**
 - **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

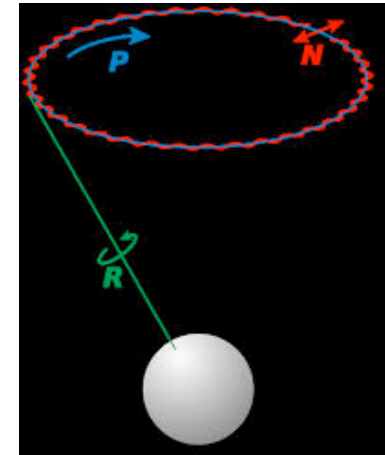
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- **For the sun, planets and a few major asteroids:**
 - PCK models use low-degree (typically linear) polynomials to represent RA and DEC of the pole (body-fixed +Z-axis) as a function of time.
 - The prime meridian is also represented by a low-degree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

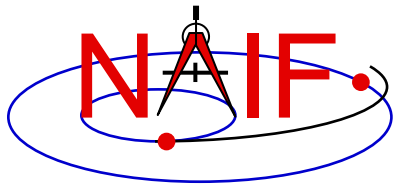
P = precession of the bodies' rotational axis

N = nutation of the bodies' rotational axis



- **For natural satellites:**

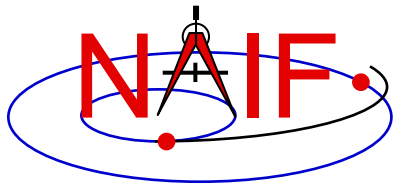
- In addition to low-degree polynomials for the spin axis and prime meridian, trigonometric polynomial terms are used to more accurately represent precession and nutation.
- A few satellites have chaotic rotation and so are not modeled.



Text PCK Orientation Models - 2

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- **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 name “J2000” as a synonym 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.)**

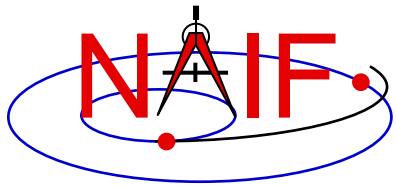


Text PCK Orientation Models - 3

Navigation and Ancillary Information Facility

- **Body-fixed frames provided in text PCKs have +Z axes consistent with planetocentric coordinate systems. The +X axes of these frames coincide with planetocentric longitude 0.**
- **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.

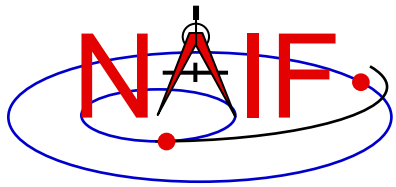
*The dwarf planets are: Ceres, Pluto, Haumea, Makemake, Eris



Binary PCK Orientation Models

Navigation and Ancillary Information Facility

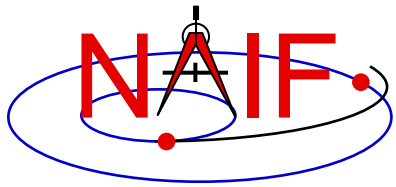
- **When available, the SPICE system can store high-accuracy orientation model data in binary PCKs.**
- **Binary PCKs are limited to storing orientation data.**
 - Applications that require shape data must also load a text PCK.
- **Orientation data from a binary PCK always supersede orientation data 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 the NAIF server.**
 - The accuracy of these is much better than what is provided in the generic text PCK.
 - See the tutorial "lunar-earth_pck-fk" for details.



Location of Text PCK Reference Frame Specifications

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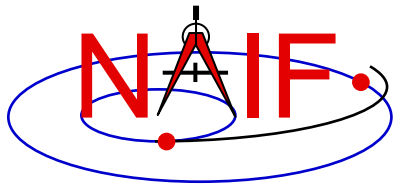
- **Many PCK reference frame specifications are built into SPICE. Examples are IAU_SATURN and IAU_TITAN.**
 - To use these, load a text PCK file containing orientation data for the body of interest.
 - » Typically this is the current generic text PCK
 - Be very cautious about using IAU_EARTH and IAU_MOON; the binary PCKs for these two bodies offer much more accuracy.
 - Data for a small number of comets and asteroids are included.
- **Other PCK frames are not built-in and must be defined in a frames kernel that is loaded by your program. Examples are 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.



Location of Binary PCK Reference Frame Specifications

Navigation and Ancillary Information Facility

- **Special high-accuracy earth and lunar body-fixed frames are realized using binary PCKs.**
 - These frames are named:
 - » For the earth: ITRF93
 - » For the moon: MOON_PA and MOON_ME
- **To use high-accuracy earth or moon orientation, load the appropriate binary PCK and allied FK.**
 - See the special tutorial “lunar-earth_pck-fk” for details on these.

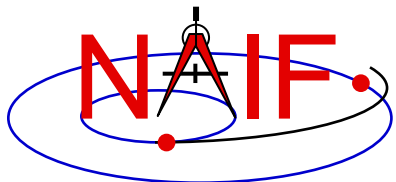


PCK Shape Models

Navigation and Ancillary Information Facility

- **PCK shape models are nominally triaxial ellipsoids**
 - For many bodies, the two equatorial axes have the same value; these bodies have a spheroidal shape.
 - For some bodies, one or more radii have not been determined.
 - See the DSK tutorial for information about other kinds of shape models available within SPICE.

- **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, DRDGEO and XFMSTA are the modules performing these transformations.
 - **Exception: SPICE supports planetographic coordinate transformations only for bodies modeled as spheres or spheroids.**
 - » PGRREC, RECPGR, DPGRDR, DRDPGR and XFMSTA are the modules supporting these transformations.

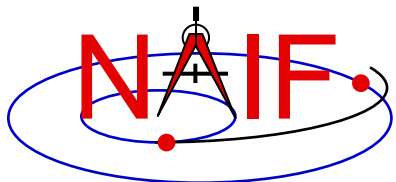


Using PCK Data

Navigation and Ancillary Information Facility

- **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 the 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.**

*Fortran
examples*

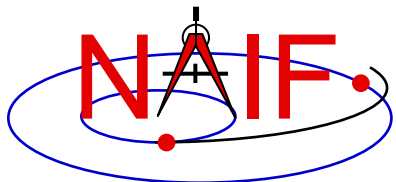


Interface Routines - 1

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)
- 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 requested output reference frame is inertial.
 - That's because, in the course of its work, this call must convert the position of the DSN station relative to the Earth's center from an Earth-fixed, earth-centered frame to the J2000 frame.

Fortran
examples

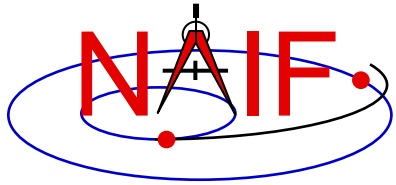


Interface Routines - 2

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Fortran
examples

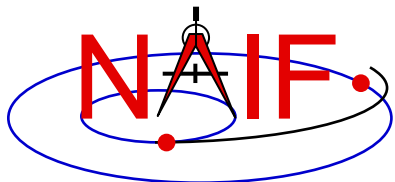
- Call **BODVRD** or **BODVCD** to retrieve constants associated with a body. For example:
 - `CALL BODVRD ('SATURN' , 'RADII' , 3 , N , RADII)`
 - `CALL BODVCD (699 , 'RADII' , 3 , N , RADII)`
 - These calls retrieve values associated with the variable `BODY699_RADII`.
 - The variable name is **case-sensitive**, 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

Navigation and Ancillary Information Facility

- **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.
- **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 have been loaded.**



PCK Utility Programs

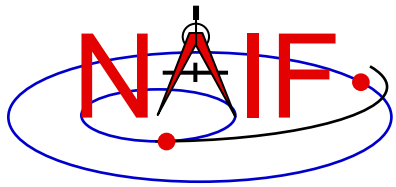
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- **These utilities are included in the Toolkit.**

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

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

BFF	displays <u>binary</u> file format of a binary PCK file
BINGO	converts <u>binary</u> PCK files between big-endian and little-endian formats



Additional Information on PCK

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- **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