Planetary Constants Kernel
PCK

March 2006

Navigation and Ancillary Information Facility

Topics

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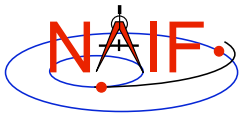

Overview - 1

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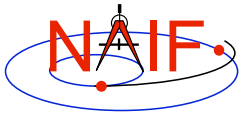
- The P_constants kernel (PCK or PcK) is logically part of the "planet kernel."
- SPICE PCK data consist of:
  - Orientation (also known as "rotation") models for extended, natural solar system bodies: sun, planets, natural satellites, a few asteroids
    - » Models yield the mapping from a specified inertial frame to a body-fixed frame as a function of time.
    - » The data also provide the time derivative of the inertial-frame-to-body-fixed mapping.
  - Physical and cartographic constants
    - » Sets of radii for triaxial shape models.
    - » Additional items could be included, such as:
      - prime meridian offset from principal axis
      - magnetic dipole location
      - gravity parameters: GM, J2, higher order gravity field terms
      - ring model parameters



Overview - 2

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- The SPICE PCK subsystem provides interface routines that enable SPICE-based applications to:
  - for a user-specified epoch, compute the transformation between any SPICE supported frame and a body-fixed frame specified within the PCK
    - » using a 3x3 rotation matrix for position transformations (PXFORM)
    - » using a 6x6 state transformation matrix for state transformations (SXFORM)
  - obtain available cartographic and physical constants associated with a specified body.

Body-Fixed Frames

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- **Body-fixed frames used in PCK files 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.**
- **High-precision earth-fixed frames have names of the form ITRFnn, for example ITRF93.**
  - **The International Earth Rotation Service (IERS) defines these frames.**

Shape Models

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- **Shape models are triaxial, having the form:**

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

- **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.**

IAU Rotation Models - 1

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- 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 now supported by SPICE.
  - 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 shape models
  - Nominally triaxial
  - 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.
- 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).

High Precision Rotation Models

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- SPICE high precision rotation data are currently available only for the earth, moon, and Eros.
  - The IERS provides the data for the earth.
    - » Much more accurate than the earth's IAU rotation model
    - » Very "perishable" data: the highest accuracy is obtainable only for past epochs.
  - Data for the moon come from JPL's DE405 planet/lunar ephemeris
    - » The binary lunar PCK represents the moon's so-called "principal axis" reference frame.
- SPICE binary PCK files are used to accommodate these high precision models.
  - Chebyshev polynomials represent Euler angles giving orientation as a function of time.
  - Data available from a loaded binary PCK always takes precedence over functionally equivalent data available in a loaded text kernel, independent of file loading order.

High Precision Earth Rotation Model

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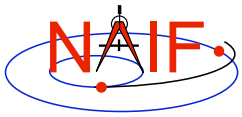
- The IERS high precision earth rotation model takes into account:
  - Precession: 1976 IAU model due to Lieske.
  - Nutation: 1980 IAU model
  - True sidereal time using accurate values of TAI-UT1
  - Polar motion *
  - Nutation corrections *

    * Polar motion and nutation corrections aren't used in implementing the "Earth true equator and equinox of date" frame.
- Update rate for rapidly changing components: several times per week.
  - NAIF has recently initiated an automatic script to capture these updates and produce a new high precision earth PCK
    - » File is placed on the NAIF server. Full path and file name:

      pub/naif/generic_kernels/pck/earth_000101_yymmdd_yymmdd.bpc
    - » SPICE users may capture file with wget:

      wget "ftp://naif.jpl.nasa.gov/pub/naif/generic_kernels/pck/earth_000101*.bpc"



Accurate Earth Surface Locations

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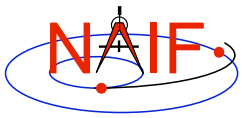
- High accuracy determination of surface locations relative to an inertial frame involves motions in addition to earth rotation, including:
  - tidal effects
  - ocean and atmospheric loading
  - tectonic plate motion
- Tectonic plate motion is now accounted for in NAIF's DSN station SPK file. It is not currently modeled in SPK files for non-DSN stations.
- The other non-rotational effects affecting surface locations are NOT modeled by a PCK, and in fact are not modeled by any SPICE component.



PCK Files - 1

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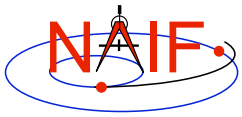
- The SPICE text kernel mechanism is used to implement generic PCK files.
  - Users may easily visually inspect data.
  - Users may (carefully!) modify kernels with a text editor.
    - » Data or comments may be added, deleted, or changed.
    - » Comments should be added to explain changes .
  - Kernel 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 creates and distributes text PCK files based on IAU/IAG reports, published in *ICARUS*.



PCK Files - 2

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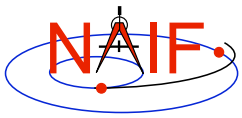
- The SPICE system stores high-precision models in binary PCKs.
  - They include a "comment area" to store metadata.
  - They support high-speed, direct access.
  - They support multiple data types.
    - » Chebyshev, position only. Polynomials represent Euler angles. Rates are obtained by differentiating polynomials. Coverage intervals have fixed length.
      - Used for the earth and moon
    - » Chebyshev, position and velocity. Separate sets of polynomials are used to represent Euler angles and their rates. Coverage intervals have variable length.



PCK Files - 3

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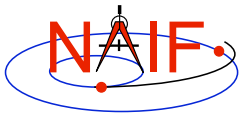
- SPICE Toolkit utilities enable reading and writing comments, summarizing, and porting binary PCKs.
  - Use the *commnt* utility to access a binary PCK comment area.
  - Use the *brief* or *spacit* utility to summarize a binary PCK.
  - Use the *toxfr* and *tobin* utilities, or the *spacit* utility, to port binary PCK files between computers with incompatible binary standards.
    - » If using NAIF Toolkit Version N0052 or later, you can read non-native binary format PCK files using SPICE Toolkit software: simply move the binary file between the two computers using binary mode of FTP. (Not including VAX or Alpha machines.)
  - See the "introduction_to_kernels" tutorial for details about porting a binary PCK and manipulating comments in a binary PCK.



Interface Routines - 1

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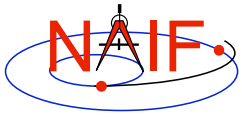
- Call FURNSH to load PCKs.
- Call SXFORM to return a state transformation.
  - Returns 6x6 matrix (position and angular rate)

```
CALL SXFORM ( FROM, TO, ET, XFORM )
sxform_c    ( from, to, et, xform );
cspice_sxform, from, to, et, xform
```

- Call PXFORM to return a position transformation.
  - Returns 3x3 matrix (position only)

```
CALL PXFORM ( FROM, TO, ET, ROTATE )
pxform_c    ( from, to, et, rotate );
cspice_pxform, from, to, et, rotate
```

- 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:

```
CALL BODVRD ( BODYNM,     ITEM,     MAXN, N,  VALUES )
CALL BODVRD ( 'SATURN',   'RADII', 3      N,  RADII  )
CALL BODVCD ( 699,        'RADII', 3      N,  RADII  )

bodvrd_c    ( bodynm,     item,     maxn, &n, values );
bodvrd_c    ( "SATURN",   "RADII", 3     &n, radii  );
bodvcd_c    ( 699,        "RADII", 3     &n, radii  );

cspice_bodvrd, bodynm, item, maxn, values
cspice_bodvrd, 'SATURN', item, 3, radii
cspice_bodvcd, 699,      item, 3, 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 also use general kernel pool fetch routines to fetch data assigned to non-standard names:
  - GCPOOL, GDPOOL, GIPOOL