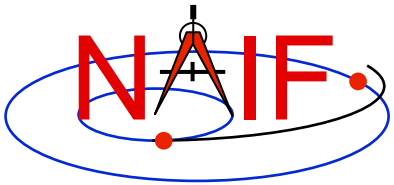
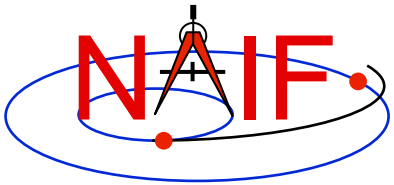


Navigation and Ancillary Information Facility

Shape Model Subsystem Preview (DSK)

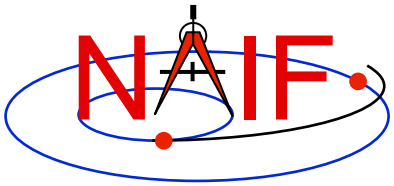
January 2012



SPICE DSK Topics

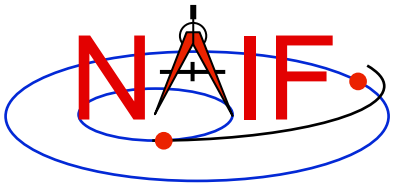
Navigation and Ancillary Information Facility

- Overview
- Requirements
- DSK Data Representations
- DSK System Components
- DSK Software Components
- DSK API Examples
- Using Shape with Orientation Data
- DSK Development Status



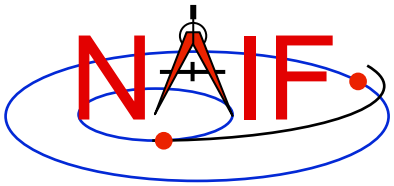
Overview

- **NAIF is developing a new SPICE kernel type**
  - **DSK: Digital Shape Kernel**
- **The DSK subsystem deals with data sets describing topography of solar system objects, or more generally, shapes of 3-dimensional objects. Examples:**
  - **Digital elevation models (DEM) for the surfaces of Mars or the Moon**
  - **Tessellated plate model for the surface of a natural satellite, asteroid or comet nucleus**
- **The DSK system facilitates high-accuracy, SPICE-based geometric computations using "complex" shape data**
  - **Currently SPICE uses only triaxial ellipsoid shape models.**



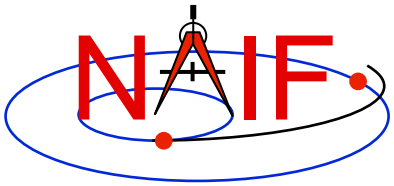
Requirements -1

- All “requirements” listed here are of an informal nature
  - Derived from customer interaction and NAIF team members’ experience using SPICE
- Overall requirement: facilitate high-accuracy geometry computations involving realistic models of surfaces of extended bodies.
- Examples of computations that should be supported:
  - » Location of “sub-observer point” and height of observer above surface
  - » Ray-surface intercept point
  - » Occultation/transit state of a point target
  - » Limb and terminator location
  - » Illumination angles at a specified surface point
  - » Determine if a target is in an instrument’s field of view (FOV)



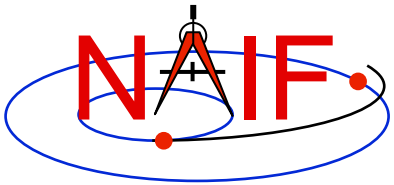
Requirements -2

- System should support efficient random access data search
  - For example: for a given (LONGITUDE, LATITUDE) coordinate pair, return radius (distance from body center) of the corresponding surface point
- System should support rapid, high volume data extraction ("bulk read")
  - Required for efficient use by graphics applications
- System should be able to use data sets spread across multiple files
  - Some current data sets exceed 2Gbytes in size
  - Larger data sets should be expected in the future
  - Impractical to store all needed data in one file
- System should be able to work with models for different bodies simultaneously.
  - For example: support simultaneous use of data sets for Mars and Phobos.



Requirements -3

- System should be able to work with multiple models for different parts of the surface of a specified body simultaneously.
  - Support simultaneous use of multiple data sets having different resolutions, or even different mathematical representations, for different regions of the surface.
- DSK files should be portable
- DSK files should support inclusion of metadata
- Tools should be provided for:
  - summarizing contents of DSK files
  - accessing metadata in DSK files
  - merging or subsetting DSK files
  - ingesting data from other types of files. Examples:
    - » Dr. Robert Gaskell's ASCII plate model files
    - » Dr. Peter Thomas' ASCII format used for Vesta model
    - » DLR ASCII formats used for Phobos

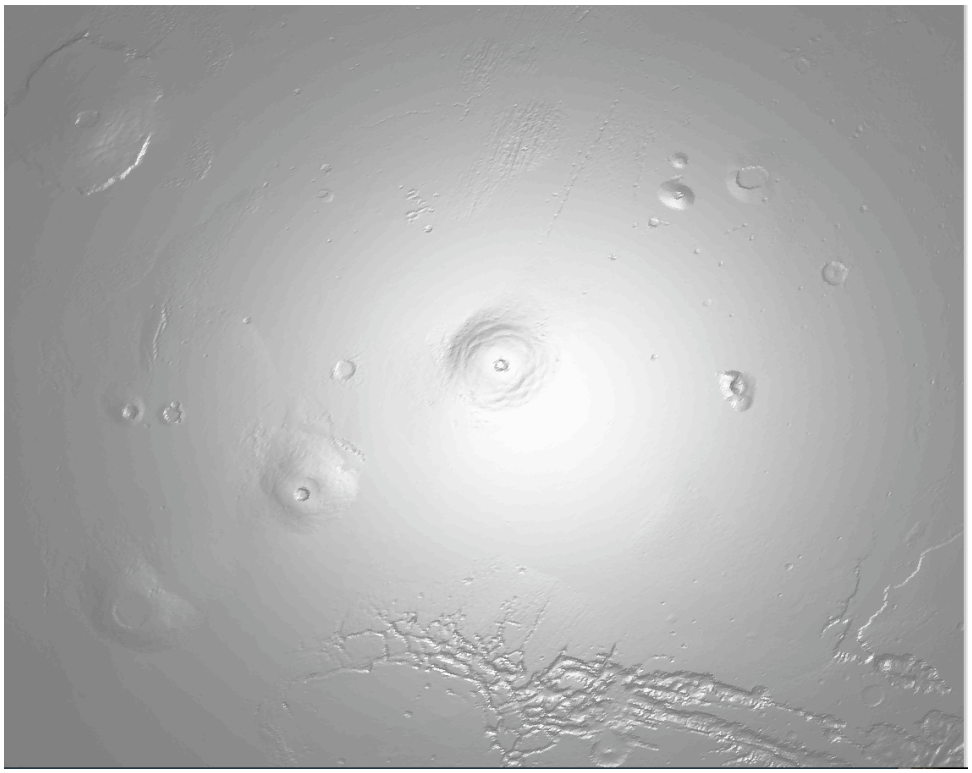


DSK Shape Representations

- **The DSK subsystem will handle two representations of shape data**
  - **Digital elevation model**
  - **Tessellated plate model**
- **DSK supplements the only existing SPICE shape model: tri-axial ellipsoid**

DSK Data Representations -1

- **Digital elevation model (DEM)**
  - **Maps longitude/latitude to "elevation"**
    - » **Elevation of a surface point can be defined as distance from the origin of a body-fixed reference frame**
    - » **Elevation can be defined as height above a reference ellipsoid**
  - **Example: image created from MGS laser altimeter (MOLA) Mars DEM**



DSK Data Representations -2

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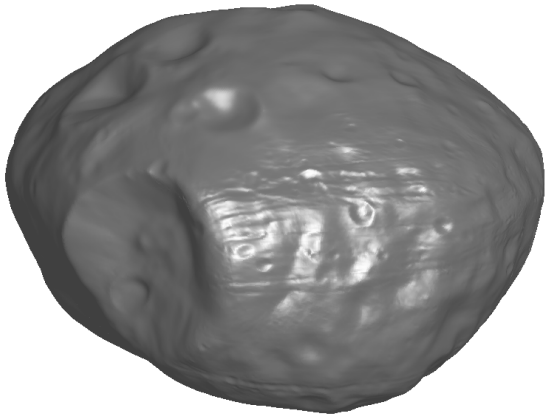
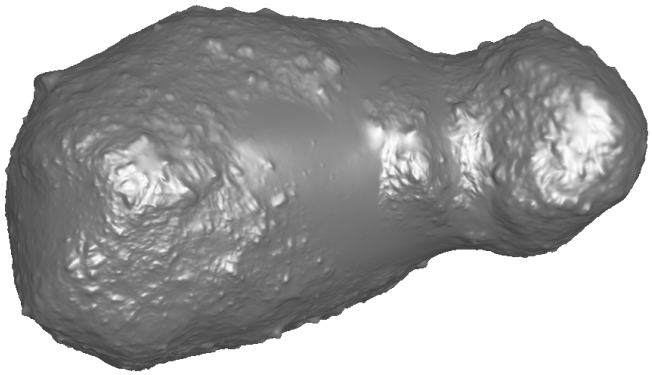
- **Tessellated plate model**
  - **Surface of object is represented as a collection of triangular plates**
  - **More flexible than digital elevation model: arbitrary 3-D surface can be modeled**
    - » **Surface could be a complicated shape with multiple surface points having the same latitude and longitude**
      - **Examples: "dumbbell"-shaped asteroid, caves, arches**
  - **Less efficient than digital elevation model of similar resolution in terms of storage and computational speed**



Phobos



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DSK Data Representations -3

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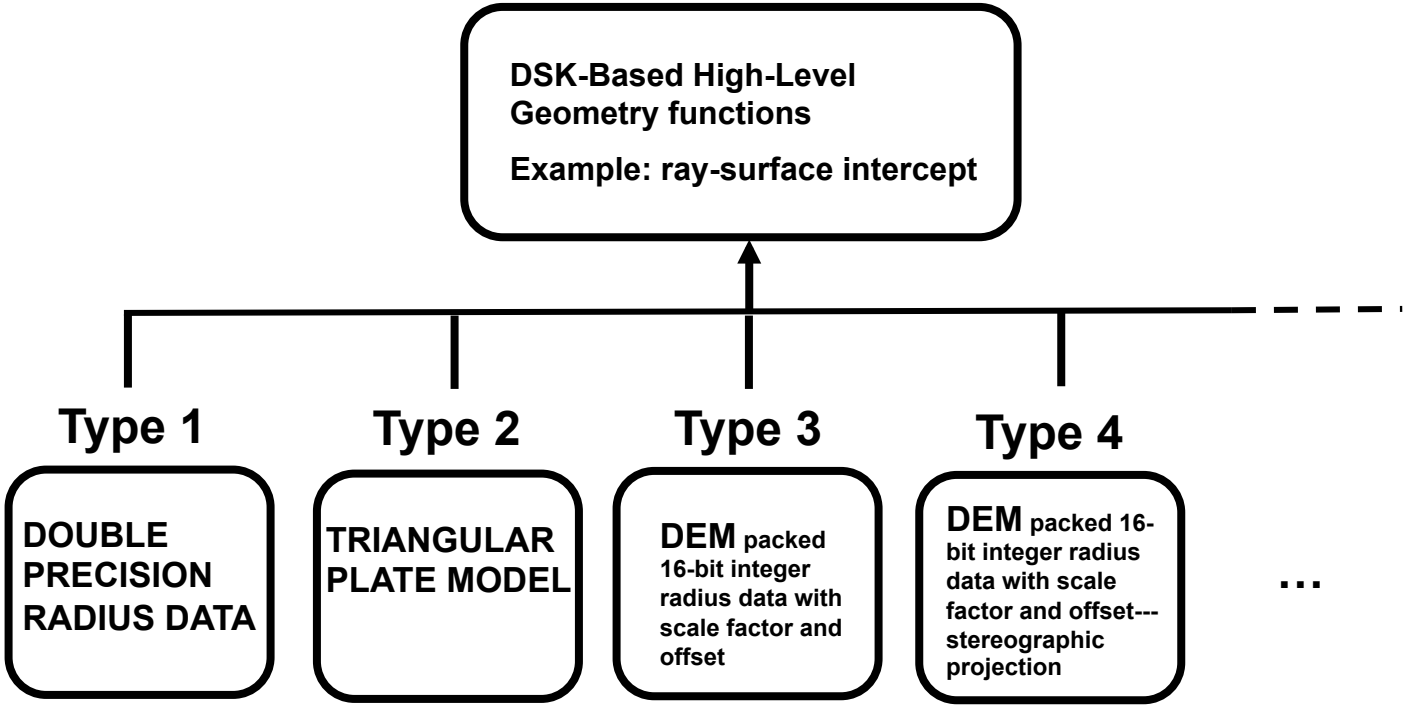
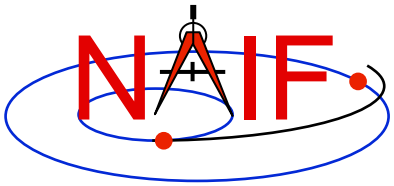
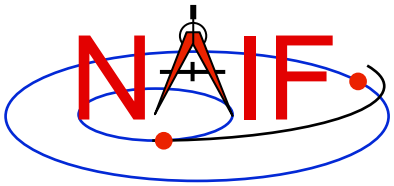
- **DSK shape representations are polymorphic:**
  - DSK shape representations are called "Data Types."
  - Each data type has its own mathematical representation of a surface
  - Each data type has associated software that implements common functionality, such as the ability to return a radius (distance of surface point from body center) value for a specified latitude and longitude.
  - Each data type may have additional, unique functionality.
    - » For example, type 2 has accessor routines that return plate and vertex data. These functions are not applicable to other data types.





DSK System Components

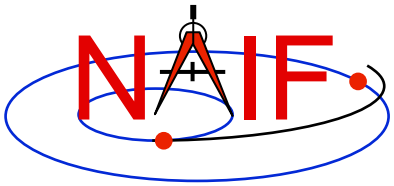
- **DSK Files**
  - Built upon the SPICE DAS file architecture
    - » Binary, direct access
    - » System-independent buffering built in
    - » Comment area built in
- **DSK Software**
  - SPICE software which enables users to create and use DSK kernels
    - » Writer routines
    - » Reader routines
    - » High-level API routines
      - For example: routines dealing with observer-target geometry
    - » Supporting utility programs



DSK Software Components -1

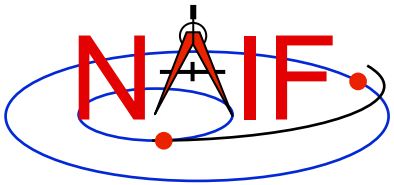
Navigation and Ancillary Information Facility

- **Writers**
  - Routines that enable a SPICE-based application to create a DSK kernel
    - » Open new DSK kernel for write access
    - » Open existing DSK kernel for write access
    - » Start new DSK segment ("segments" are partial DSK data sets containing data for a given region on a specified object)
    - » Add data to DSK segment
- **Readers**
  - Routines that extract data from a DSK file
    - » Return elevation of surface at given longitude/latitude
    - » Return specified attributes, for example the surface normal vector, for a specified longitude and latitude
    - » Rapidly obtain data for large portion of surface ("bulk read")
    - » Return DSK attributes such as number of plates, pixel size, min/max elevation, etc.
- **High-level functions (including, but not limited to, the following):**
  - Compute sub-observer point on surface and height of observer above surface
  - Compute intercept of ray with surface
  - Determine whether a portion of a target body's surface is within the FOV of specified instrument at specified time.
  - Determine occultation/transit state of a point target
  - Compute limb and terminator location
  - Compute Illumination angles at a specified surface point



DSK Software Components -2

- **Utility programs that**
  - **Create DSK files: import other surface shape data sets into SPICE DSK format**
  - **Port DSK files**
  - **Provide comment area access**
  - **Summarize DSK file contents**
  - **Subset or merge DSK files**
  - **Downsample DSK files**
  - **Convert one DSK data type to another**
    - » **Example: create type 2 DSK file from type 1**



DSK API Examples

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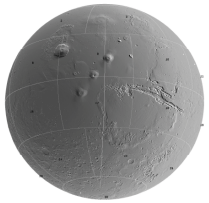
- Get radius at surface point (inputs are in red, outputs in blue):
  - CALL DSKRAD (TARGET, LON, LAT, RADIUS)
    - » Inputs: target body name, longitude and latitude of point of interest
    - » Output: radius (distance from target center) at surface point
- Find sub-observer point on target:
  - CALL SUBPT (METHOD, TARGET, ET, ABCORR, OBSRVR, SPOINT, ALT)
    - » SUBPT is a generic, high-level API. SUBPT doesn't assume the surface is modeled by a DSK.
    - » Input "METHOD" indicates surface model and sub-point definition
      - For ellipsoids, METHOD may be set to 'near point' or 'intercept'
      - For DSKs, set METHOD to 'DSK intercept', indicating that the sub-point is defined as the closest intersection to the observer of the observer-target center ray with the surface, and a DSK shape model is to be used.
      - Note that SPICE should not assume DSK is to be used just because a DSK for the target body is loaded; may be too inefficient for some applications. Caller must say which model is to be used.
    - » Other inputs: target body name, epoch, aberration correction, observer name.
    - » Outputs: sub-observer point in Cartesian coordinates, expressed in the body-fixed frame associated with the target, and altitude of the observer above the sub-point.

Writing Shape and Orientation Kernels

Navigation and Ancillary Information Facility

LAT/LON and height above ellipsoid or distance from center of frame

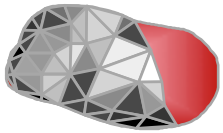
→ **MKDSK Program** (SPICE Toolkit) →



Digital Terrain Shape Model

Lists of plate model vertices and associated plates, and optionally, albedo data for each plate

→ **MKDSK Program** (SPICE Toolkit) →



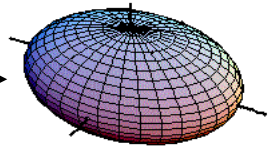
Tessellated Plates Shape Model

DSK

Digital shape kernel

Axes dimensions for tri-axial ellipsoid

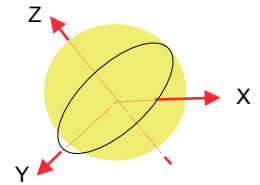
→ **Text editor** (Usually done by NAIF) →



Triaxial Ellipsoid Shape Model

Some source of rotation state information (pole RA/DEC and prime meridian location)

→ **Text editor** (Usually done by NAIF) →



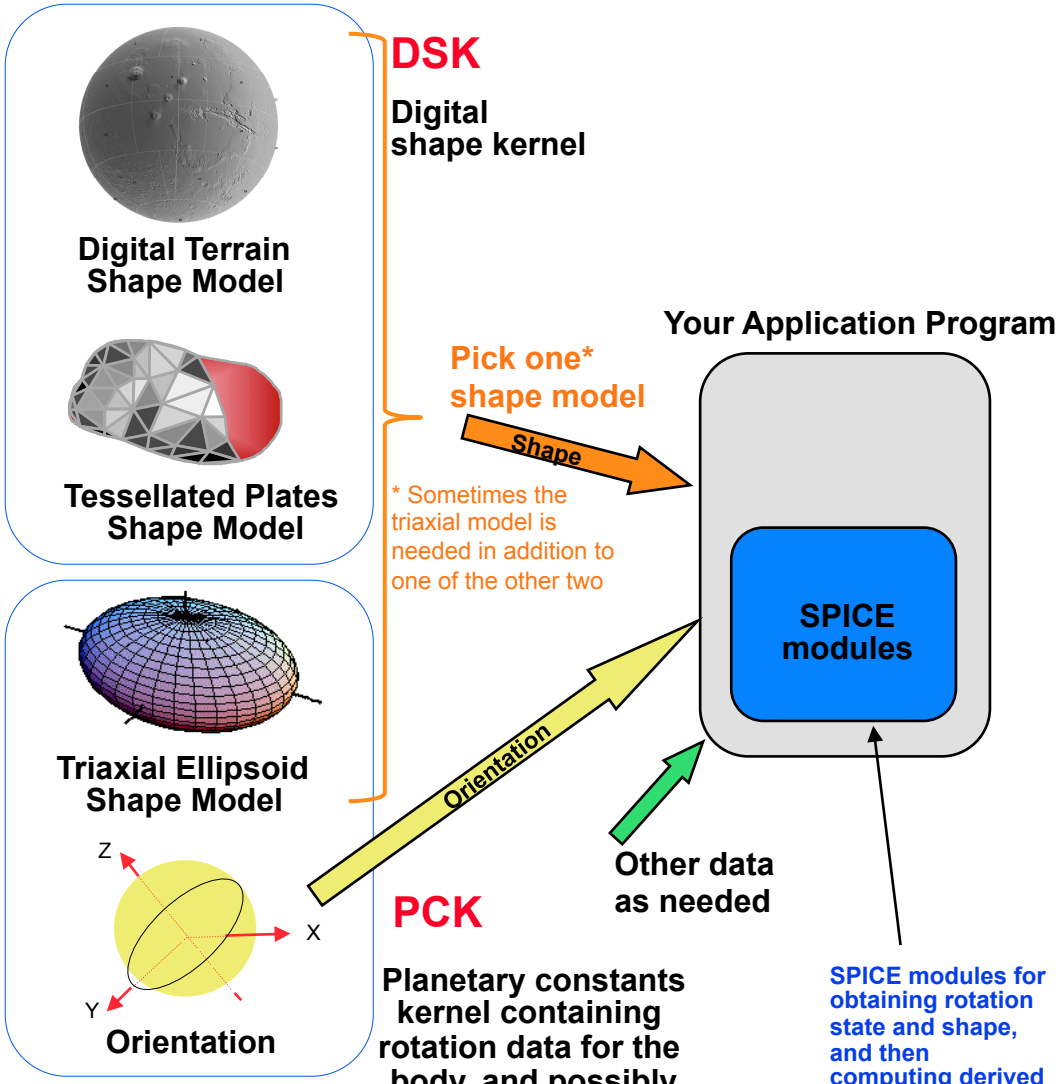
Orientation

PCK

Planetary constants kernel containing rotation data for the body, and possibly tri-axial shape

Using Shape and Orientation Kernels

Navigation and Ancillary Information Facility



DSK Development Status

Navigation and Ancillary Information Facility

- **History**
  - Alpha Test DSK Toolkit was released in July, 2010.
    - » Available in Fortran, C, and IDL.
    - » Contains support only for plate model data type
    - » The DSK File format used in this prototype has been finalized; the format will be supported by the official SPICE Toolkit.
- **Plans**
  - Release date of a first official version of the DSK system is TBD.