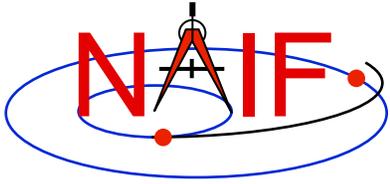


Navigation and Ancillary Information Facility

Digital Shape Kernel Subsystem (DSK)

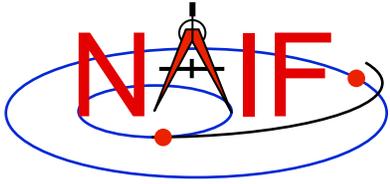
April 2016



Topics

Navigation and Ancillary Information Facility

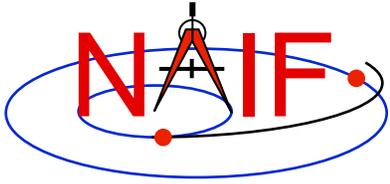
- **DSK subsystem overview**
- **DSK shape representations**
- **N66 version of DSK subsystem**
- **DSK concepts pertinent to N66**
- **DSK files**
- **Writing and using DSK files**
- **Post-N66 updates**
- **Development status and plans**



DSK Subsystem Overview

Navigation and Ancillary Information Facility

- **The DSK subsystem**
 - enables SPICE-based applications to conveniently make use of surface shape (topographic) data in geometry computations
 - serves as a format for transmission and archival of surface shape data
 - consists of SPICE software, DSK file format specifications, and documentation



DSK Shape Representations

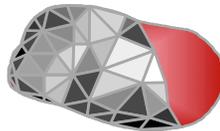
Navigation and Ancillary Information Facility

- **The DSK subsystem handles two representations of shape data**

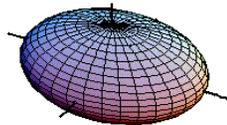
- Digital elevation model

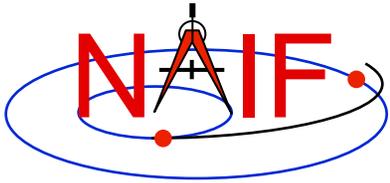


- Tessellated plate model



- **DSK supplements the tri-axial ellipsoid shape model**

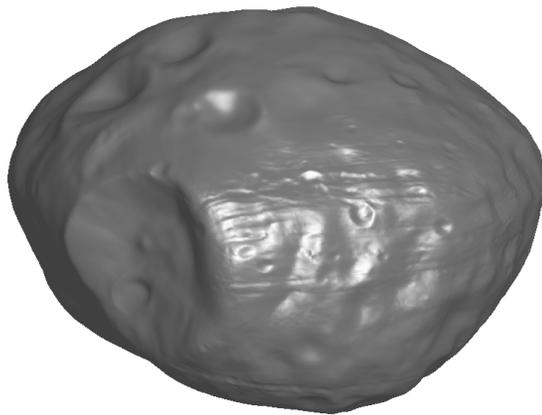




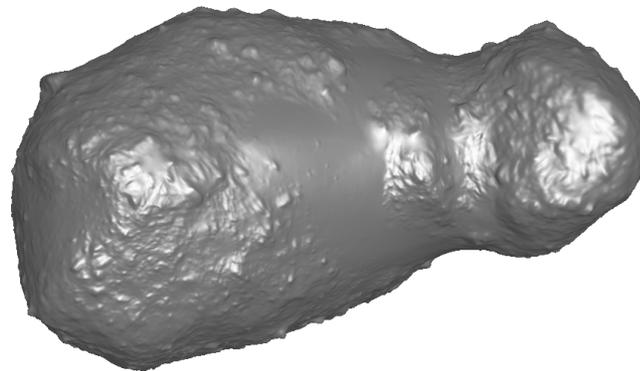
Tessellated Plate Model

Navigation and Ancillary Information Facility

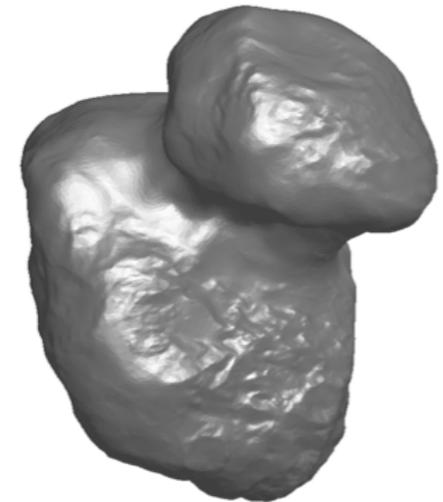
- The surface of the object is represented as a collection of triangular plates
- More flexible than digital elevation model: any arbitrary 3-D surface can be modeled
 - Surface could be a complicated shape with multiple surface points having the same latitude and longitude
 - » Examples: “dumbbell”-shaped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



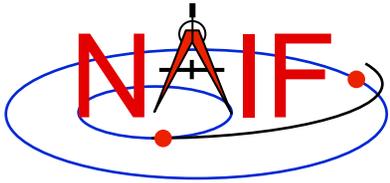
Phobos



Itokowa



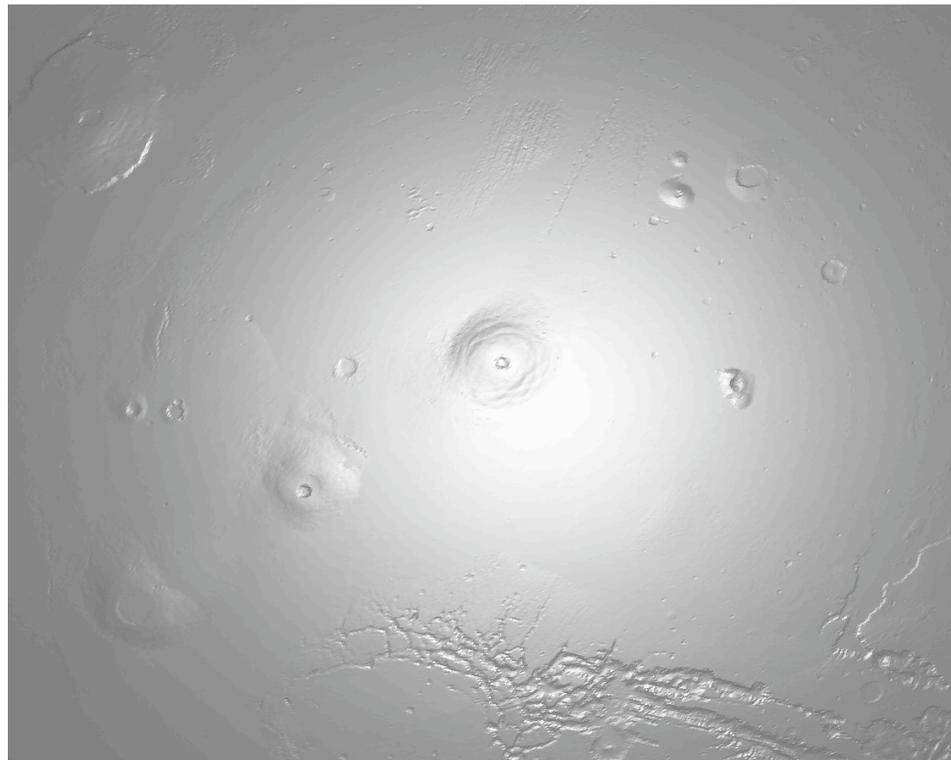
Churyumov-Gerasimenko

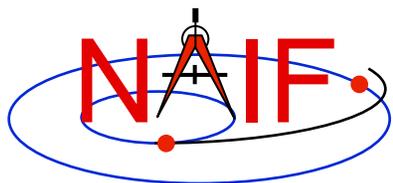


Digital Elevation Model

Navigation and Ancillary Information Facility

- **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**





Coming Soon: N66 Toolkit with DSK

Navigation and Ancillary Information Facility

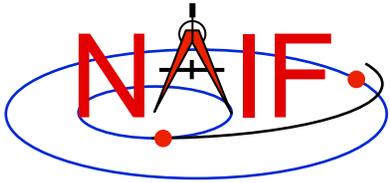
- **First version of the DSK subsystem to be included in the official SPICE Toolkit**
- **Will be fully supported in Fortran, C, IDL, and MATLAB**
- **Will support only the tessellated plate model data type (Type 2 DSK)**
 - **DEM support (Type 4) will be added in a future Toolkit version**



N66 DSK New Features

Navigation and Ancillary Information Facility

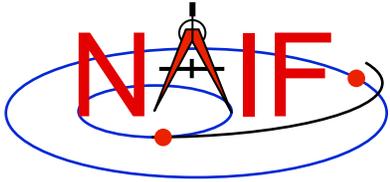
- **An alpha-test DSK Toolkit has been available for quite some time: used on Rosetta, DAWN and more**
- **Once the Type 2 DSK is added to an official Toolkit (version N66) some new features will be available**
 - **Supports multi-segment, multi-file DSK data sets**
 - » Up to 5K DSK files can be loaded simultaneously
 - **Supports run-time data translation: big-endian DSK files can be read on little-endian platforms, and vice versa**
 - **Existing standard SPICE Toolkit geometry APIs will support DSK shape data, where applicable**
 - » No longer necessary to access DSK data using segment-oriented APIs
 - **DSK utility programs will be included in the SPICE Toolkit**



N66 DSK APIs -1

Navigation and Ancillary Information Facility

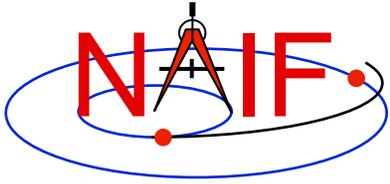
- **Kernel load/unload/info:**
 - FURNISH, UNLOAD, KCLEAR, KTOTAL, KINFO, KDATA
- **Geometry:**
 - Ray-surface intercept: SINCPT, DSKXV, DSKXSI
 - Sub-observer point: SUBPNT
 - Sub-solar point: SUBSLR
 - Illumination angles at surface point: ILLUMF, ILLUMG, ILUMIN
 - Longitude-latitude grid to surface points: LATSRF
 - Find occultation state at a given time: OCCULT
 - Find occultation or transit of point target behind/across DSK shape: GFOCLT
 - Generate limb points: LIMBPT
 - Generate terminator points: TERMPT
 - Compute outward normal vector at surface point: SRFNRM



N66 DSK APIs -2

Navigation and Ancillary Information Facility

- **Low-level access:**
 - DLA segment traversal: DLABFS, DLABBS, DLAFNA, DLAFPA
 - Fetch type 2 counts/plates/vertices/normals: DSKZ02, DSKP02, DSKV02, DSKN02
 - Fetch all type 2 data structure contents: DSKI02, DSKD02
 - Fetch DSK segment descriptor: DSKGD
- **Plate utilities:**
 - PLTVOL, PLTAR, PLTEXP, PLTNP, PLTNRM
- **Create DSK files:**
 - DSKOPN, DSKW02, DSKCLS, DSKMI2, DSKRB2
- **Summary routines:**
 - DSKOBJ, DSKSRF
- **Surface name-code translation:**
 - SRFS2C, SRFSCC, SRFC2S, SRFCSS



Graphic Depictions

Navigation and Ancillary Information Facility

- **In the next several charts we provide graphic depictions of the high-level APIs that should be of interest to many users**

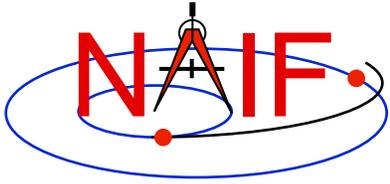
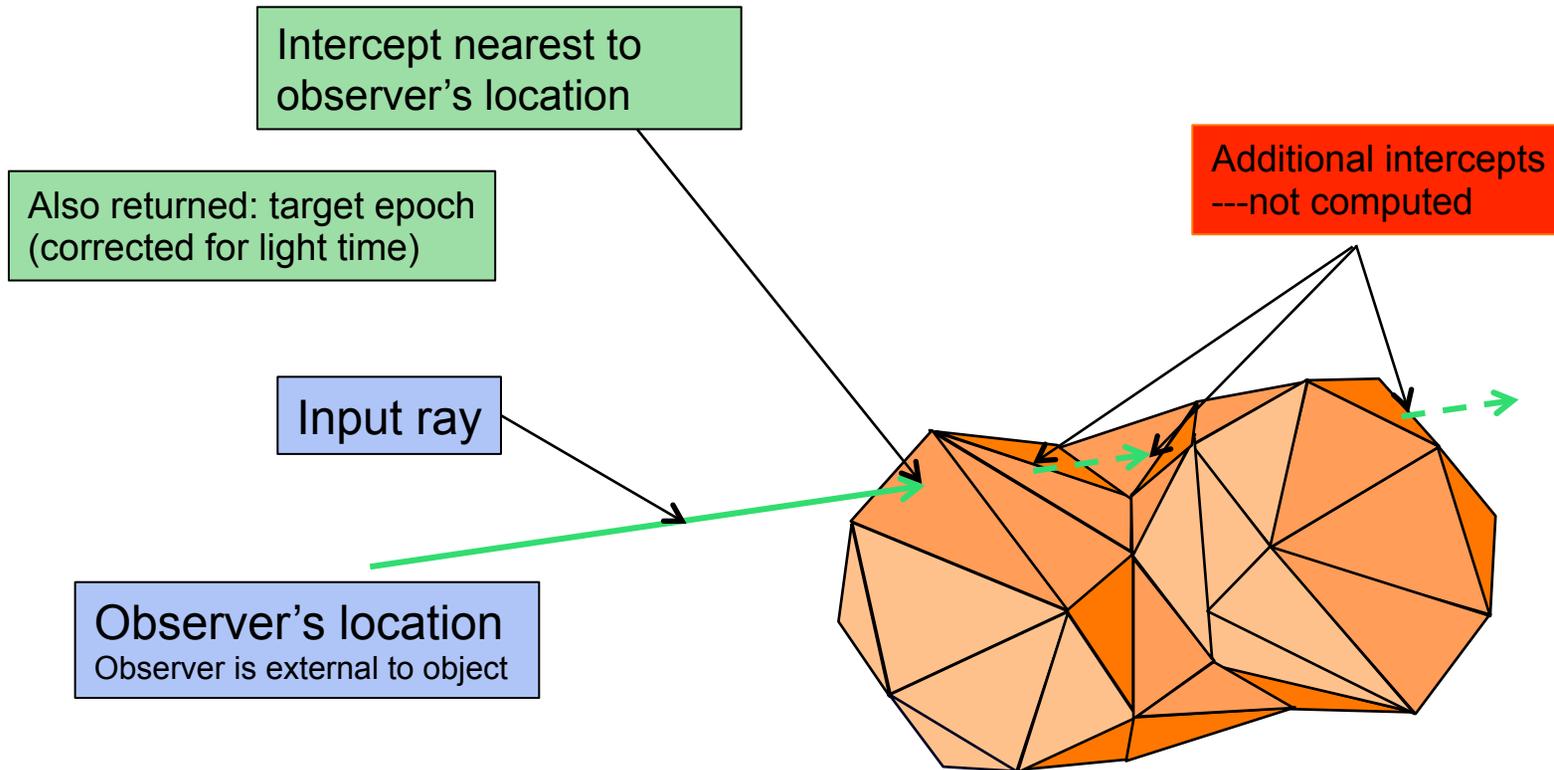


Plate Model Surface Intercept

Navigation and Ancillary Information Facility

API: SINCPT



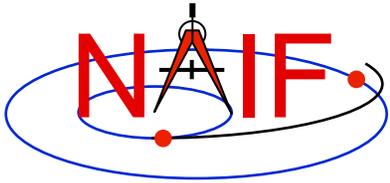
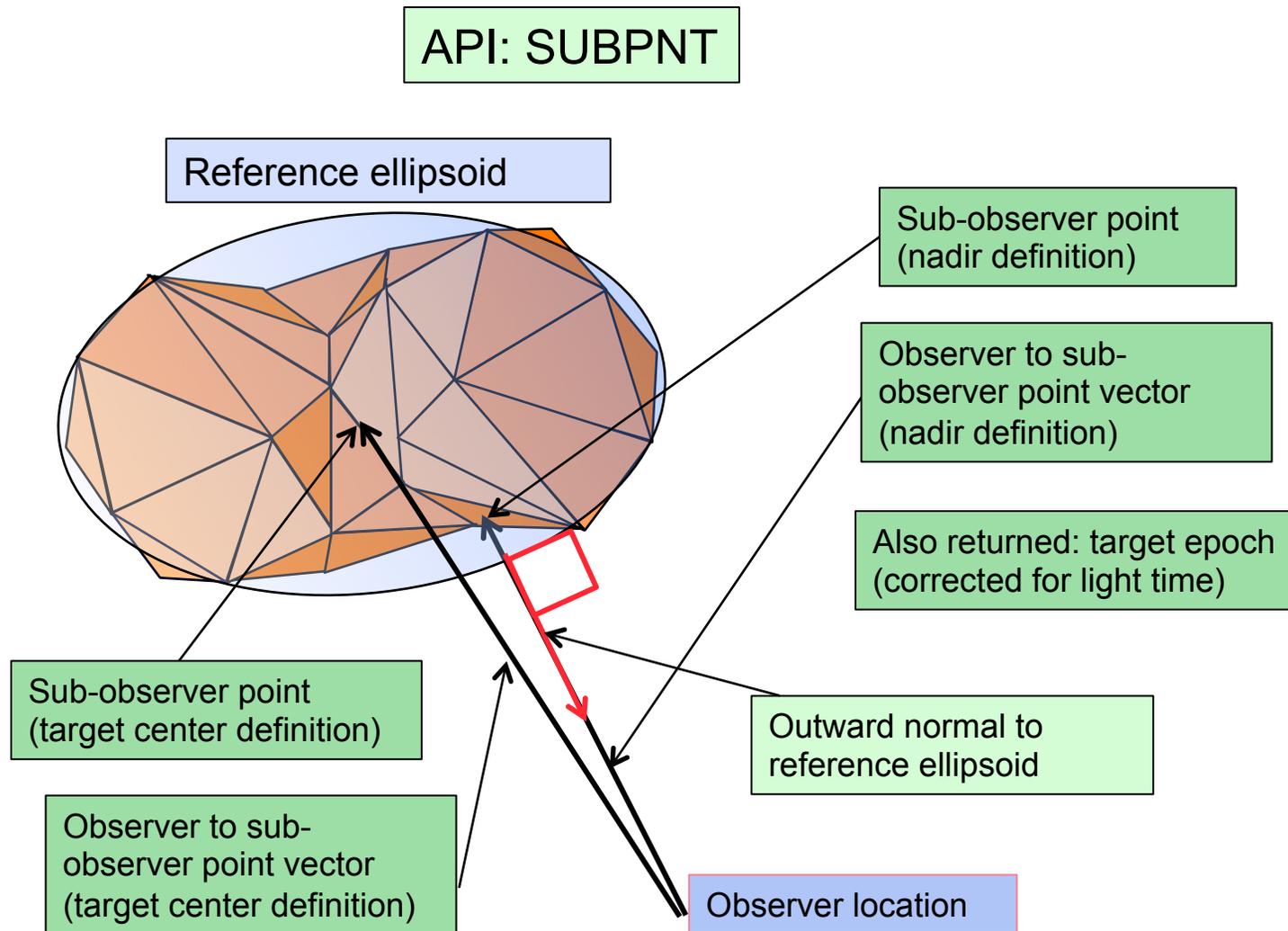


Plate Model Sub-observer Point

Navigation and Ancillary Information Facility

API: SUBPNT



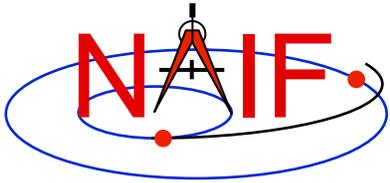


Plate Model Sub-solar Point

Navigation and Ancillary Information Facility

API: SUBSLR

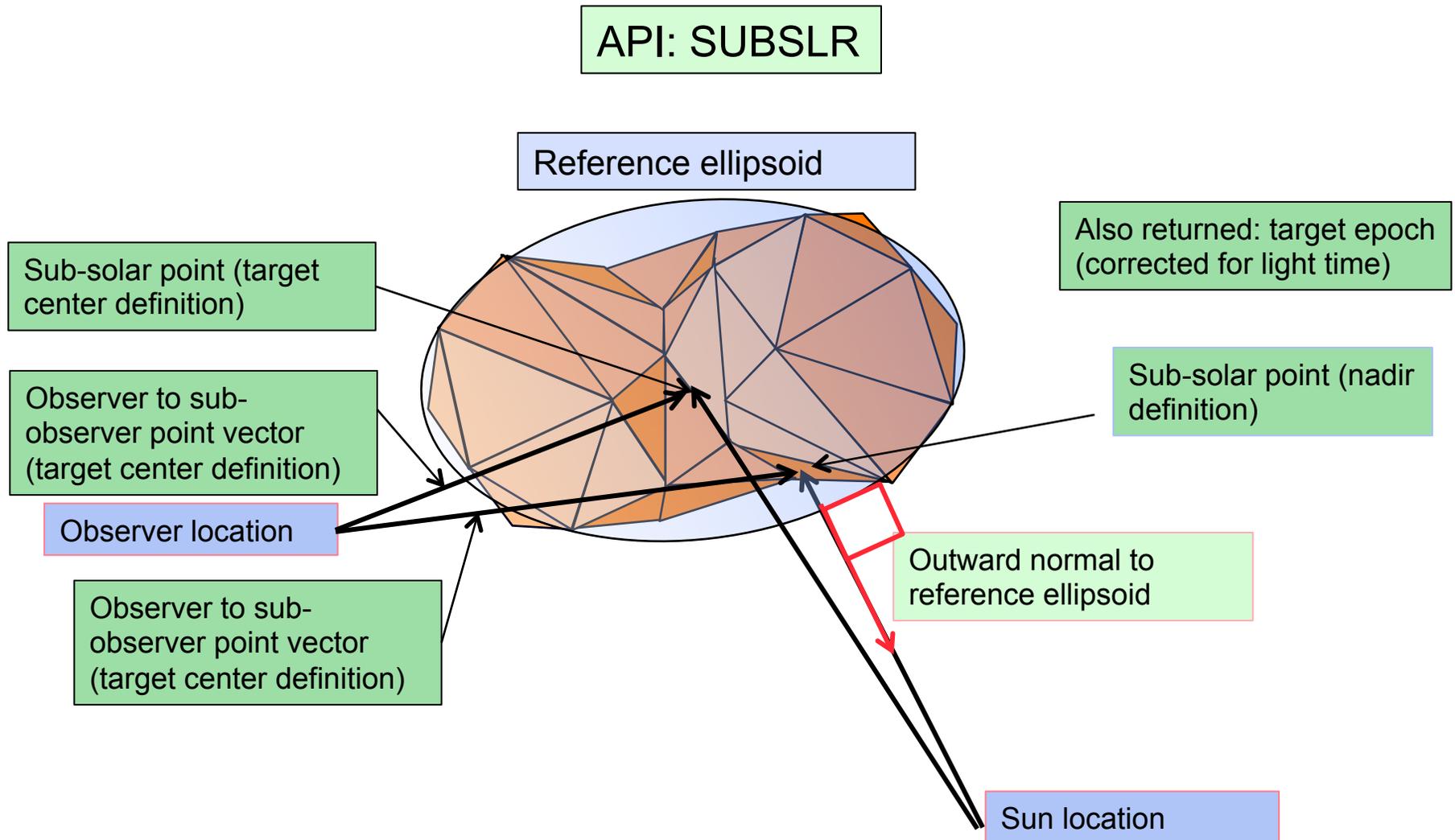
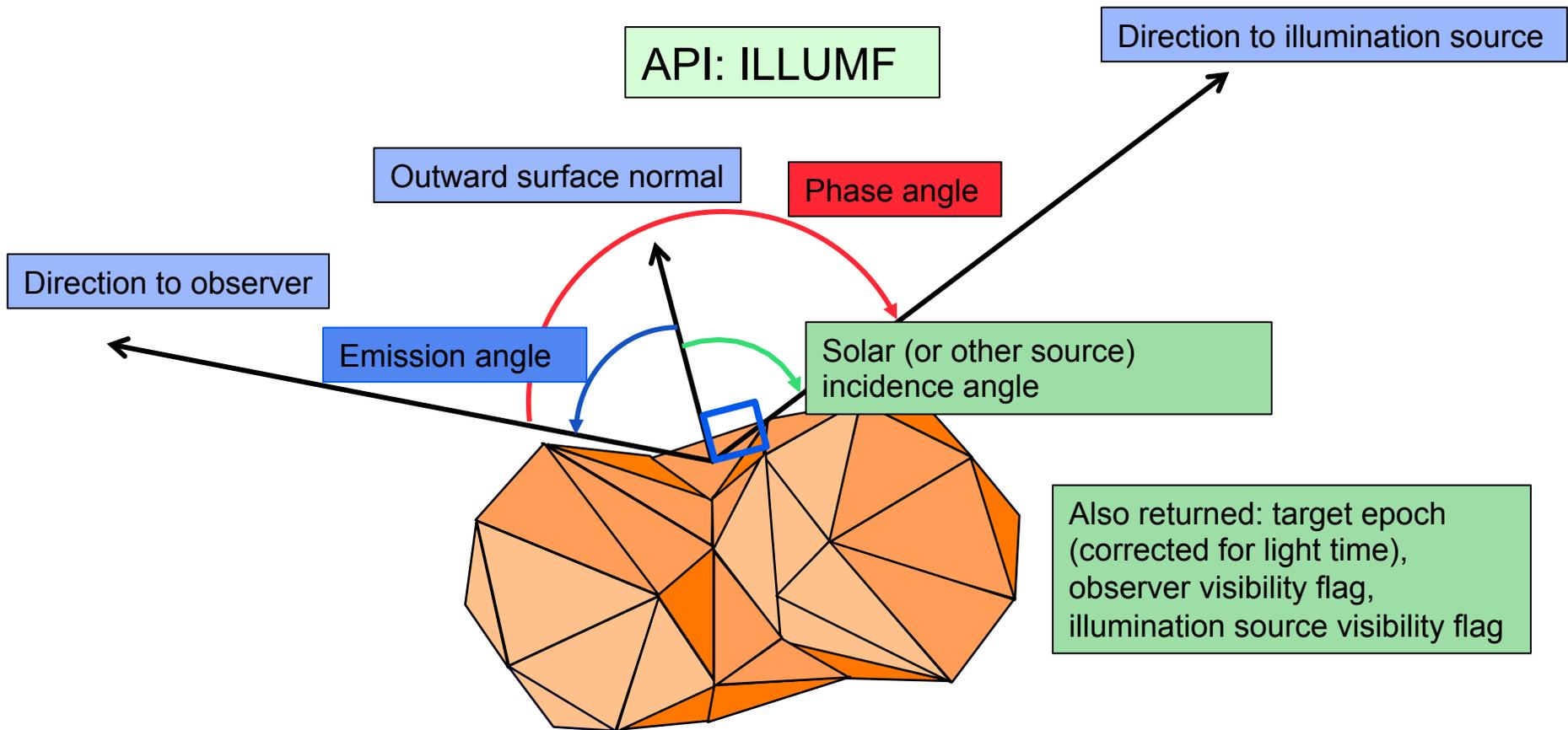




Plate model Illumination Angles

Navigation and Ancillary Information Facility



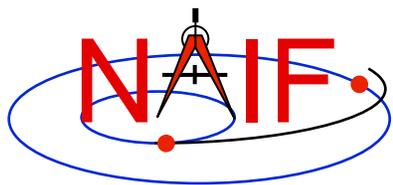


Plate Model Surface Point Grid

Navigation and Ancillary Information Facility

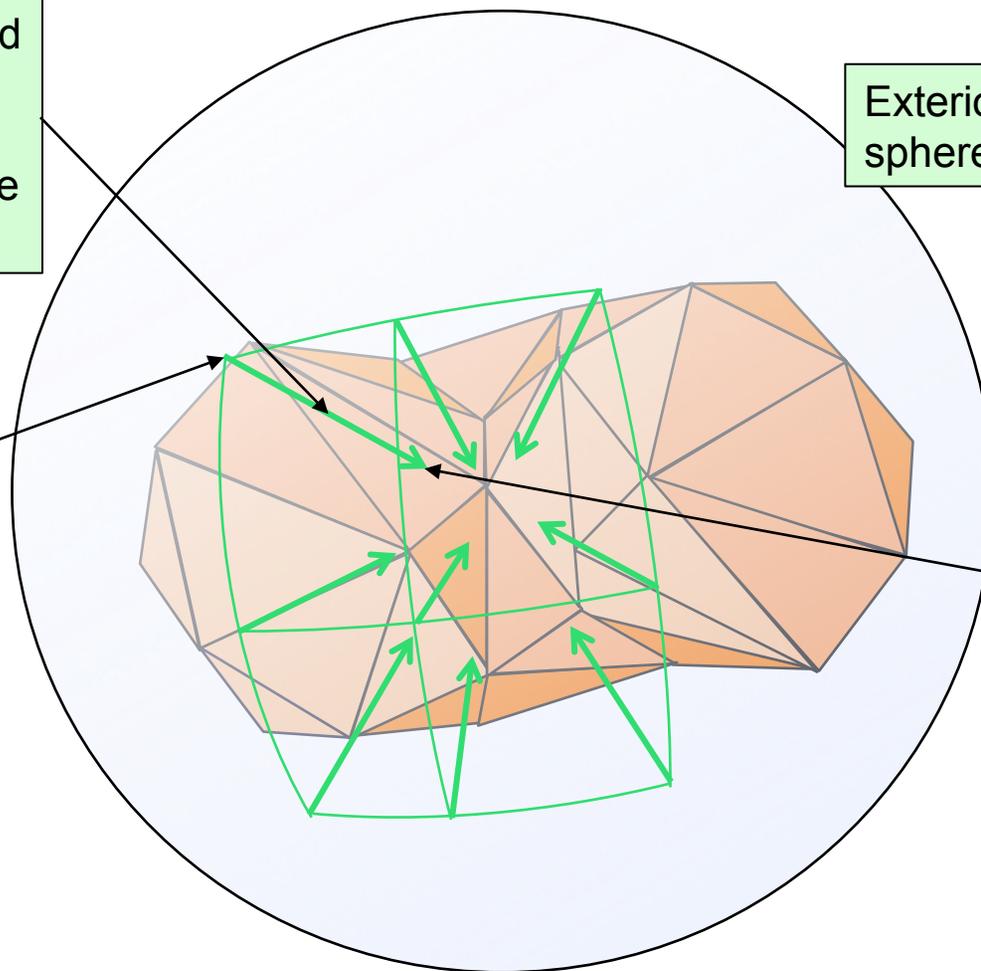
API: LATSRF

Ray emanating from grid point, pointing toward center of body-fixed, body-centered reference frame

Exterior bounding sphere for target object

Grid point---specified by planetocentric longitude and latitude, and by radius of exterior bounding sphere. This grid contains 9 points.

Surface intercept point corresponding to grid point: planetocentric longitude and latitude of intercept match those of the grid point. An intercept is computed for each input grid point.



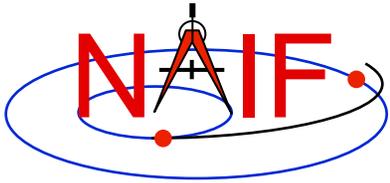


Plate Model Limb-1

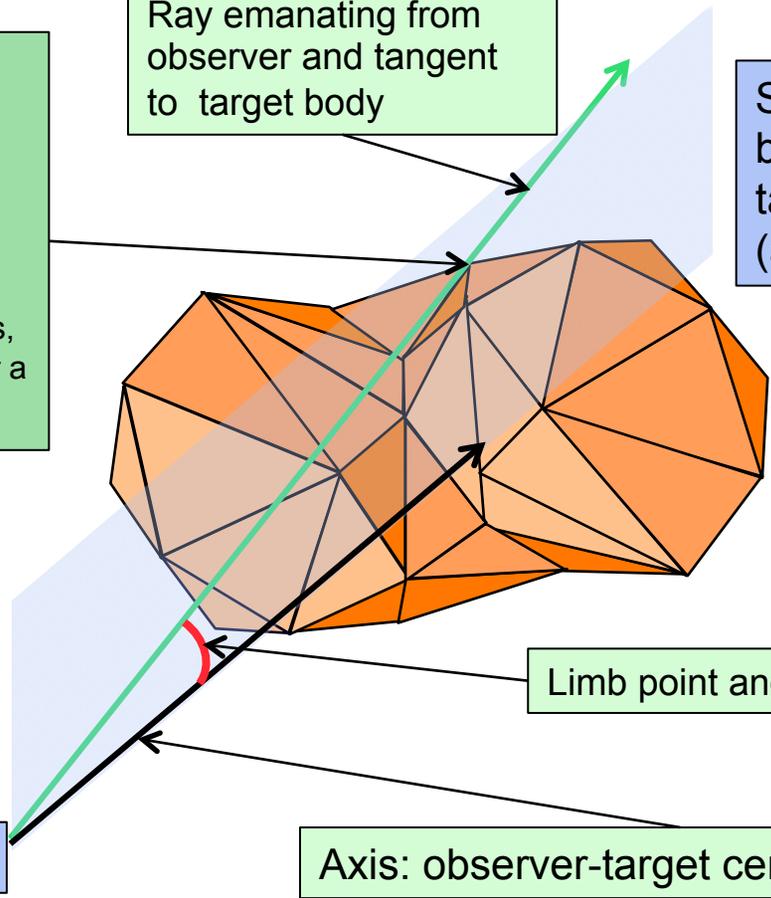
Navigation and Ancillary Information Facility

API: LIMBPT

Limb point---the tangent ray in the selected half plane at the **maximum** angle from the axis is selected (for some shapes, multiple tangents will exist for a given axis and half-plane).

Ray emanating from observer and tangent to target body

Specified half-plane bounded by observer-target center line (axis): contains ray



Limb point angle relative to axis

Observer location

Axis: observer-target center vector

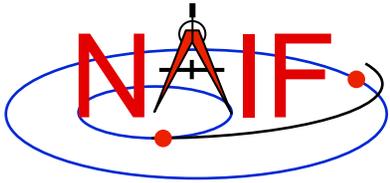


Plate Model Limb-2

Navigation and Ancillary Information Facility

API: LIMBPT

Rays emanating from observer, lying in half-plane, and tangent to target body

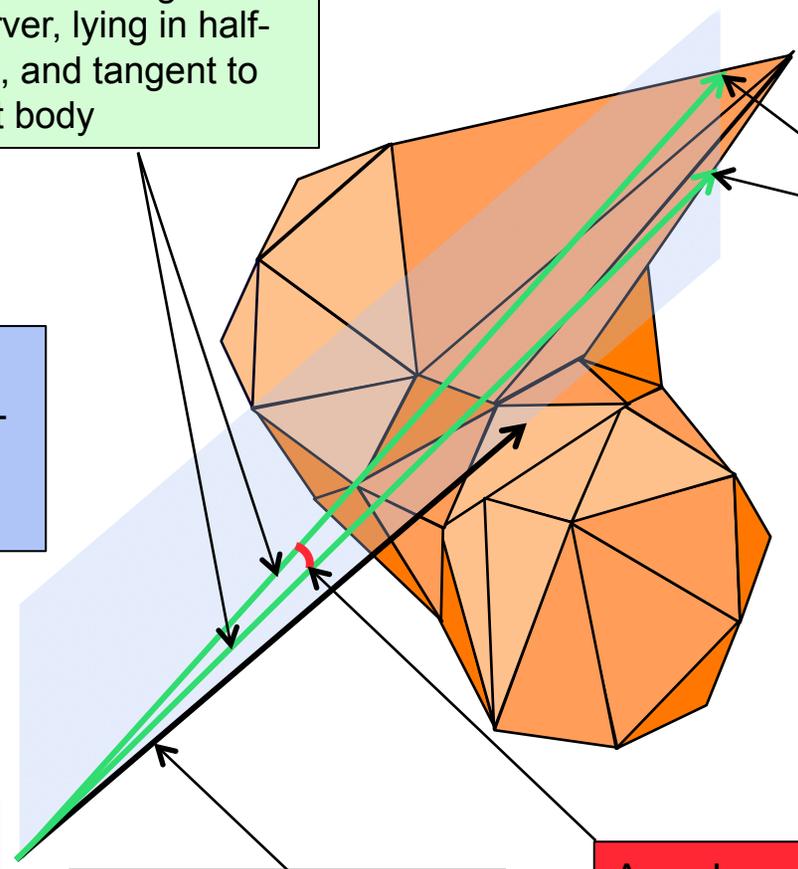
Limb points---each is tangent point of a ray in the selected half plane

Specified half-plane bounded by observer-target center line (axis): contains ray

Observer location

Axis: observer-target center vector

Angular search step must be < this angle



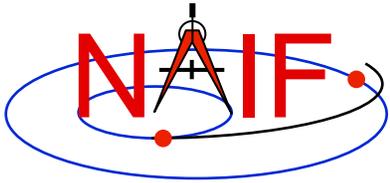
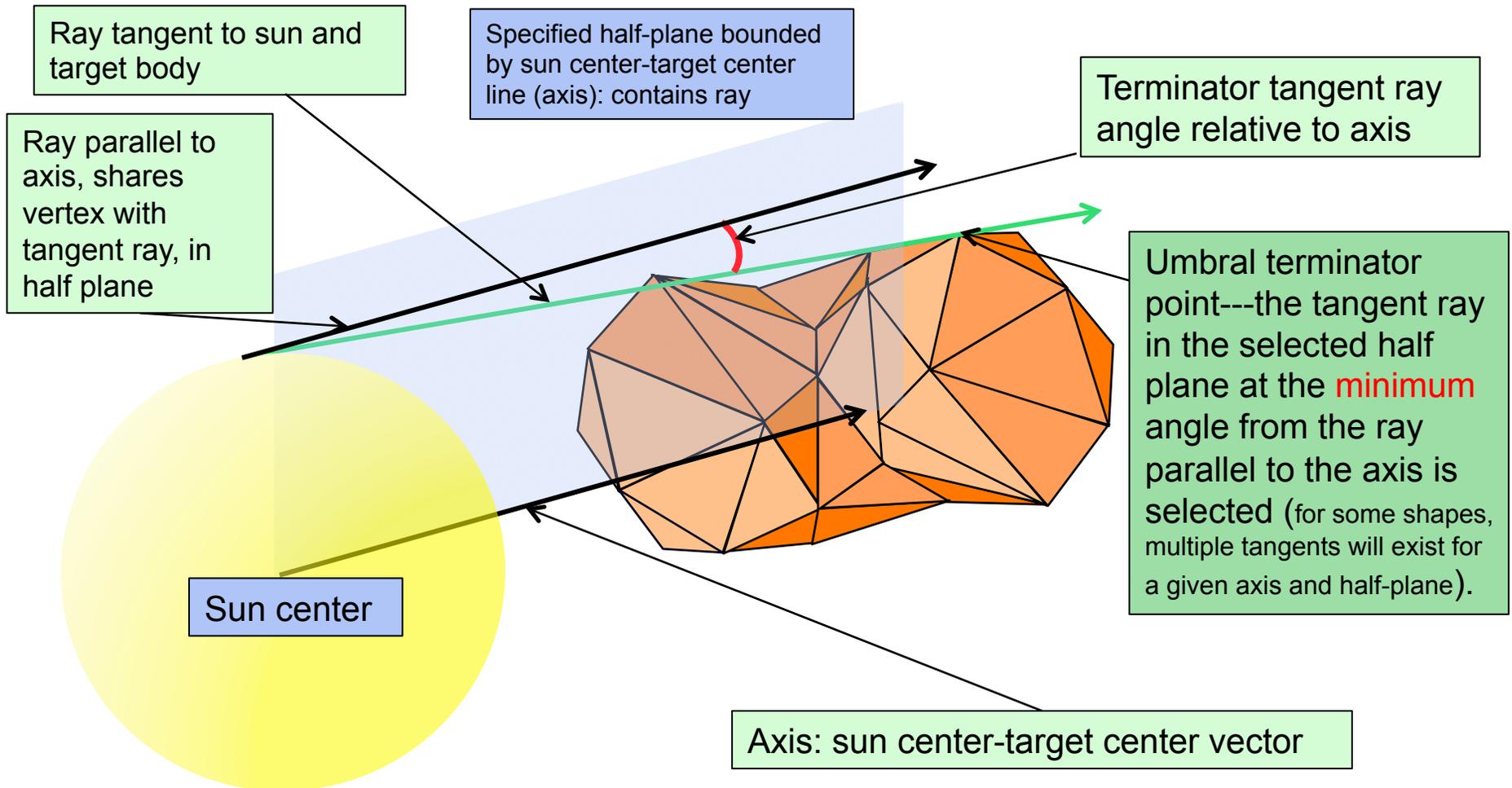


Plate Model Terminator-Umbral

Navigation and Ancillary Information Facility

API: TERMPT



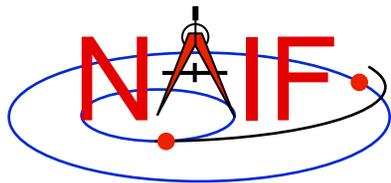
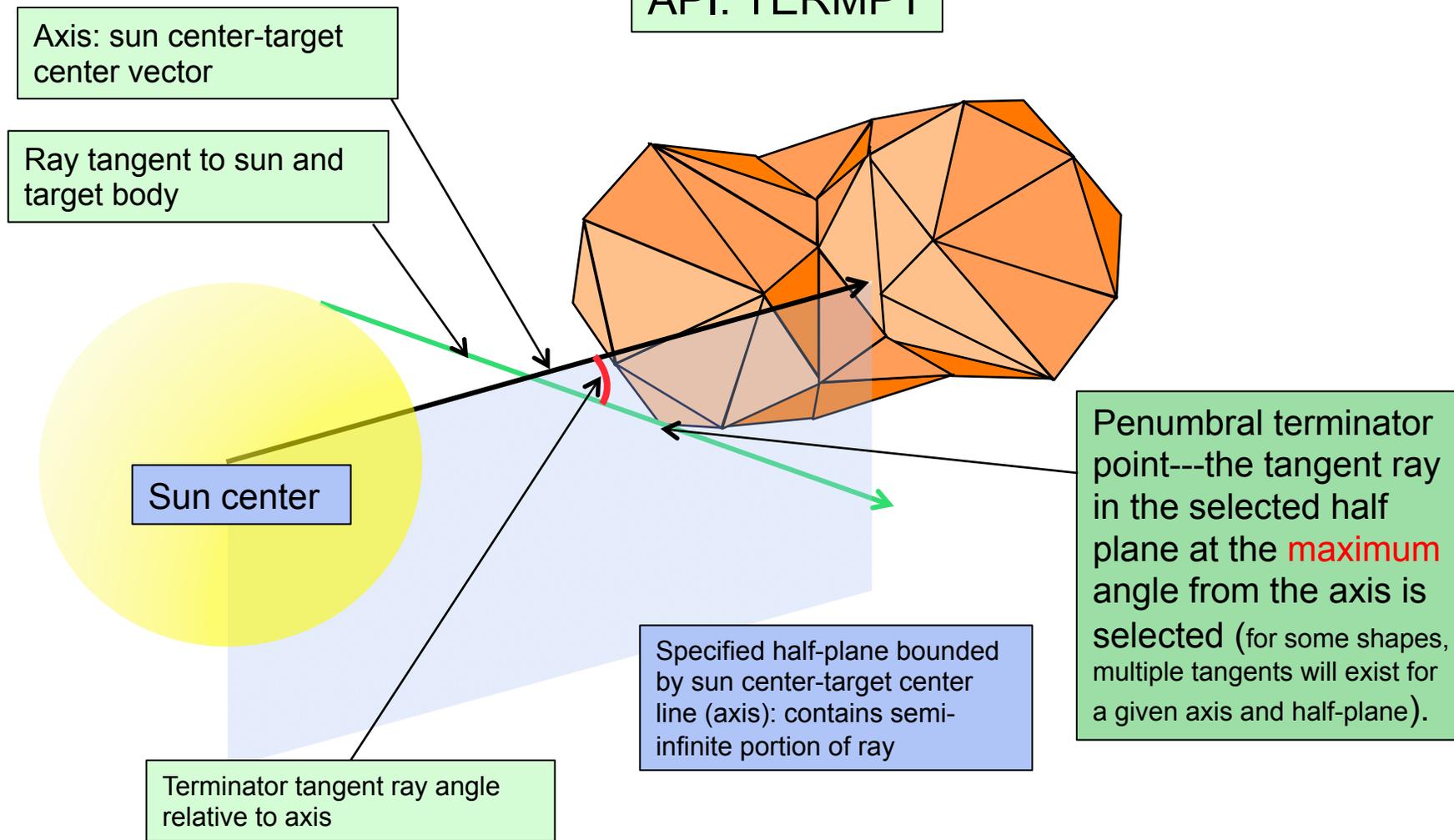
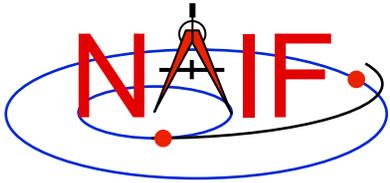


Plate Model Terminator-Penumbral

Navigation and Ancillary Information Facility

API: TERMPT

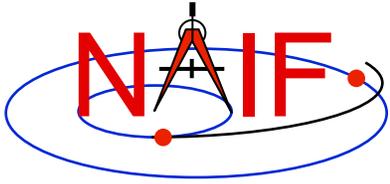




DSK API Example: SINCPPT-1

Navigation and Ancillary Information Facility

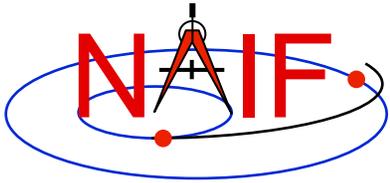
- Find ray intercept point on target surface:
 - CALL SINCPPT (**METHOD, TARGET, ET, FIXREF, ABCORR,**
OBSRVR, DREF, DVEC, SPOINT, TRGEP,
SRFVEC, FOUND)
 - » SINCPPT is a high-level SPICE API present in the (current) N0065 SPICE Toolkit.
 - » The input string argument METHOD indicates the surface model to use.
 - » To model the target body shape using its reference ellipsoid, set METHOD to 'ellipsoid'
 - » To model the target body shape using DSK data, set METHOD to one of the forms
 - '**DSK/UNPRIORITIZED**'
 - If all DSK segments for the body designated by TARGET are applicable
 - '**DSK/UNPRIORITIZED/SURFACES = <surface name or ID 1>, ...**'
 - If only DSK segments for the specified surfaces associated with the body designated by TARGET are applicable
 - » For the DSK case, the keyword UNPRIORITIZED is currently required. This keyword indicates that no applicable segment can mask another.



DSK API Example: SINCP2 -2

Navigation and Ancillary Information Facility

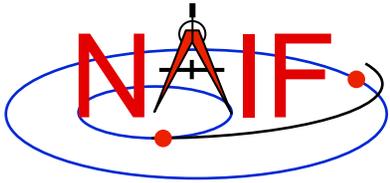
- » **Other inputs:** target body name, epoch, body-fixed reference frame, aberration correction, observer name, reference frame for direction vector, direction vector.
- » **Outputs:** ray-surface intercept in Cartesian coordinates, expressed in the body-fixed frame associated with the target---evaluated at the optionally light-time corrected epoch TRGEPC, TRGEPC itself, observer-to-intercept vector expressed in body-fixed frame, and found flag indicating whether intercept exists.



DSK Utility Programs

Navigation and Ancillary Information Facility

- **Create DSK files: MKDSK**
 - Creates a DSK file containing a single type 2 segment
- **Export DSK data to text format files: DSKEXP**
 - Writes data from type 2 DSK segments to one or more text files
 - Supports simple output formats such as obj
- **Summarize DSK files: DSKBRIEF**
- **Merge DSK files: DLACAT**
 - Concatenates segments from multiple DSK files into a single DSK file
- **Transform binary architecture of DSK file: TOXFR, TOBIN, BINGO (BINGO not part of standard SPICE Toolkit)**
- **Read/write comment area: COMMNT**



DSK Concepts-1

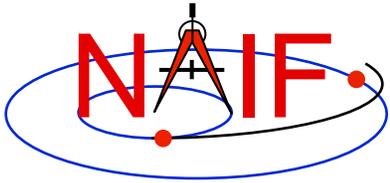
Navigation and Ancillary Information Facility

- **Surface**

- A second identifier, in addition to the central body
 - » A “surface” has name and an integer ID code
 - Surfaces occupy a name space distinct from that of bodies
 - APIs are provided for surface name/ID conversion
- Used to distinguish different versions of data for a given body
 - » Allows use of different versions without loading and unloading kernels
 - High-frequency kernel loading and unloading is too inefficient for DSK applications

- **Data class**

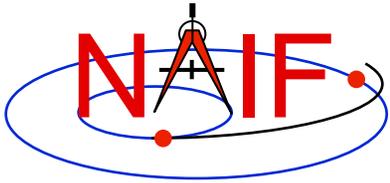
- A “hook” to differentiate kinds of data for different applications
 - » Distinct from concept of “data type”
- Currently used to indicate geometric characteristics of surface data
 - » **Class 1: shape is single-valued function of domain coordinates. Example, for latitudinal coordinates:**
 - Every ray emanating from the origin of the body-fixed reference frame associated with the body passes through the surface once
 - Such surfaces cannot have features such as cliffs or caves
 - DEMs can represent class 1 surfaces
 - » **Class 2: arbitrary shape**
 - Not required to be convex, closed, or connected
 - Plate models are only DSK data type that can be used for class 2 surfaces



DSK Concepts-2

Navigation and Ancillary Information Facility

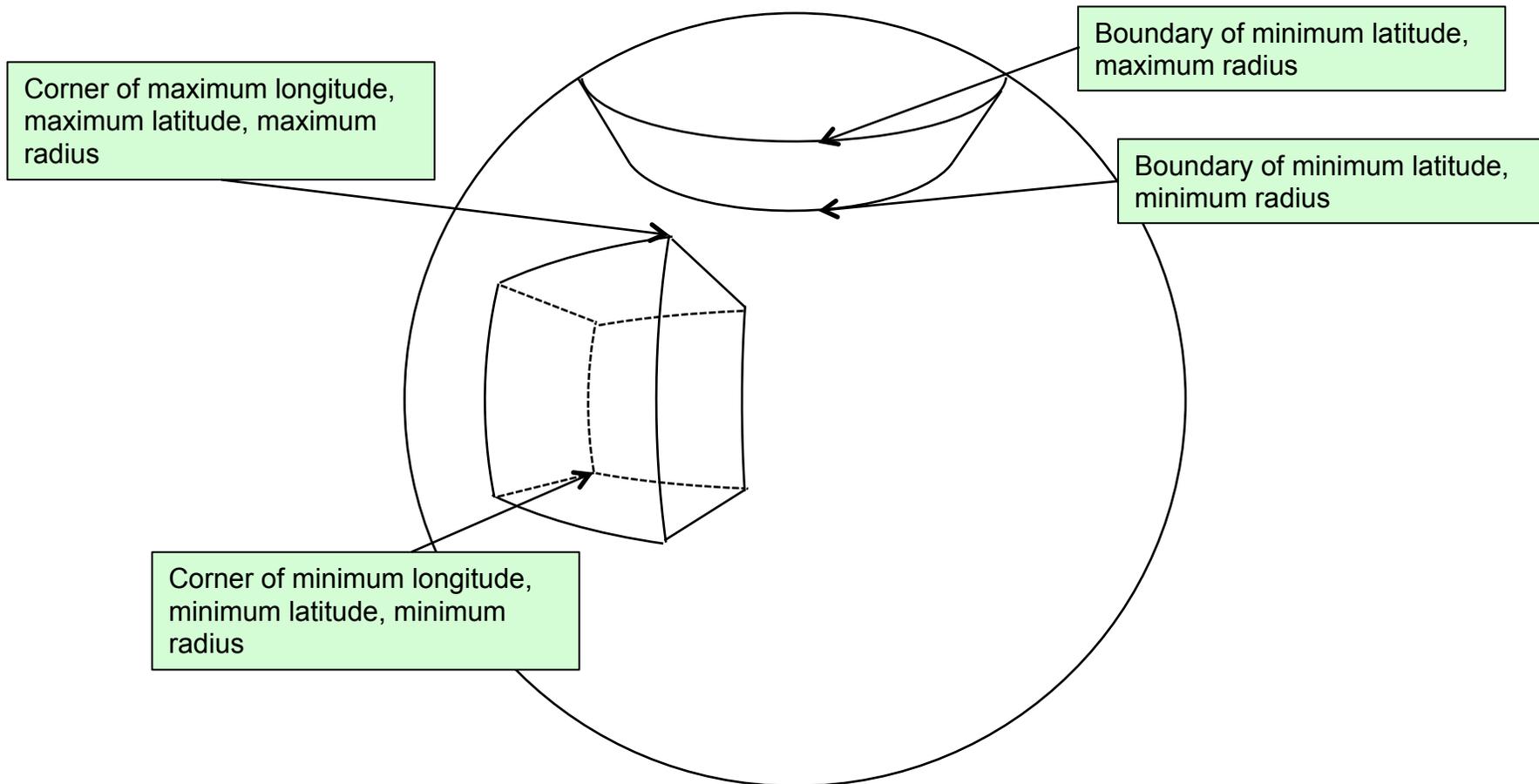
- **Kernel priority**
 - Unlike SPK, CK, and binary PCK files, the concept of segment “priority” does not apply to all DSK applications
 - » Not applicable to data sets including segments of class 2
 - Concept simply doesn’t make sense when multiple heights can correspond to a single longitude/latitude coordinate pair
 - » Can apply to data sets containing only class 1 segments
- **Coordinate systems**
 - Associated with segments
 - » Segment coverage is described in terms of a coordinate system associated with that segment
 - Can be any of
 - » Planetocentric latitudinal
 - » Planetodetic
 - » Cartesian
- **Segment coverage**
 - The spatial “coverage” of a segment is a region of space within which the segment provides valid surface data
 - » Characterized by three coordinate ranges
 - For example: min, max longitude; min, max latitude; min, max radius
 - » “Padding” data may be provided outside of a segment’s coverage region

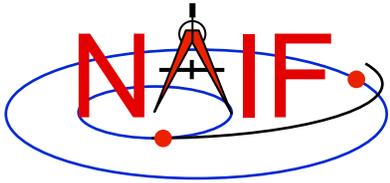


DSK Concepts -3

Navigation and Ancillary Information Facility

DSK segment spatial coverage examples---
planetocentric coordinate system

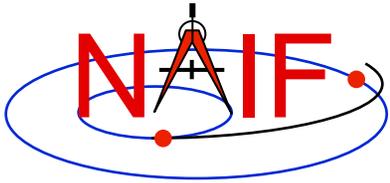




DSK Files -1

Navigation and Ancillary Information Facility

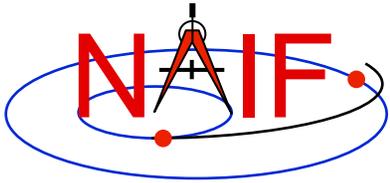
- **High-level view of the DSK file format:**
 - Binary, direct access format
 - Contains a comment area (like SPK files)
 - Contains a list of one or more data structures called “segments.”
- **A DSK segment provides topography (surface shape) data**
 - For a single extended object (such as a planet or asteroid)
 - For a specified coordinate range, in a specified coordinate system
 - In a specified reference frame
 - For a specified time range
 - Using a specified mathematical representation of the surface (data type)
- **Each DSK segment contains data, plus additional information:**
 - A data structure called a DSK Descriptor
 - » Contains the attribute information listed above, plus
 - The segment’s surface ID code
 - The segment’s data class
 - Data type-dependent information
 - » For type 2 (triangular plate model), spatial indexing data structures are included
 - » For type 4 (DEM), algorithm descriptors are included



DSK Files -2

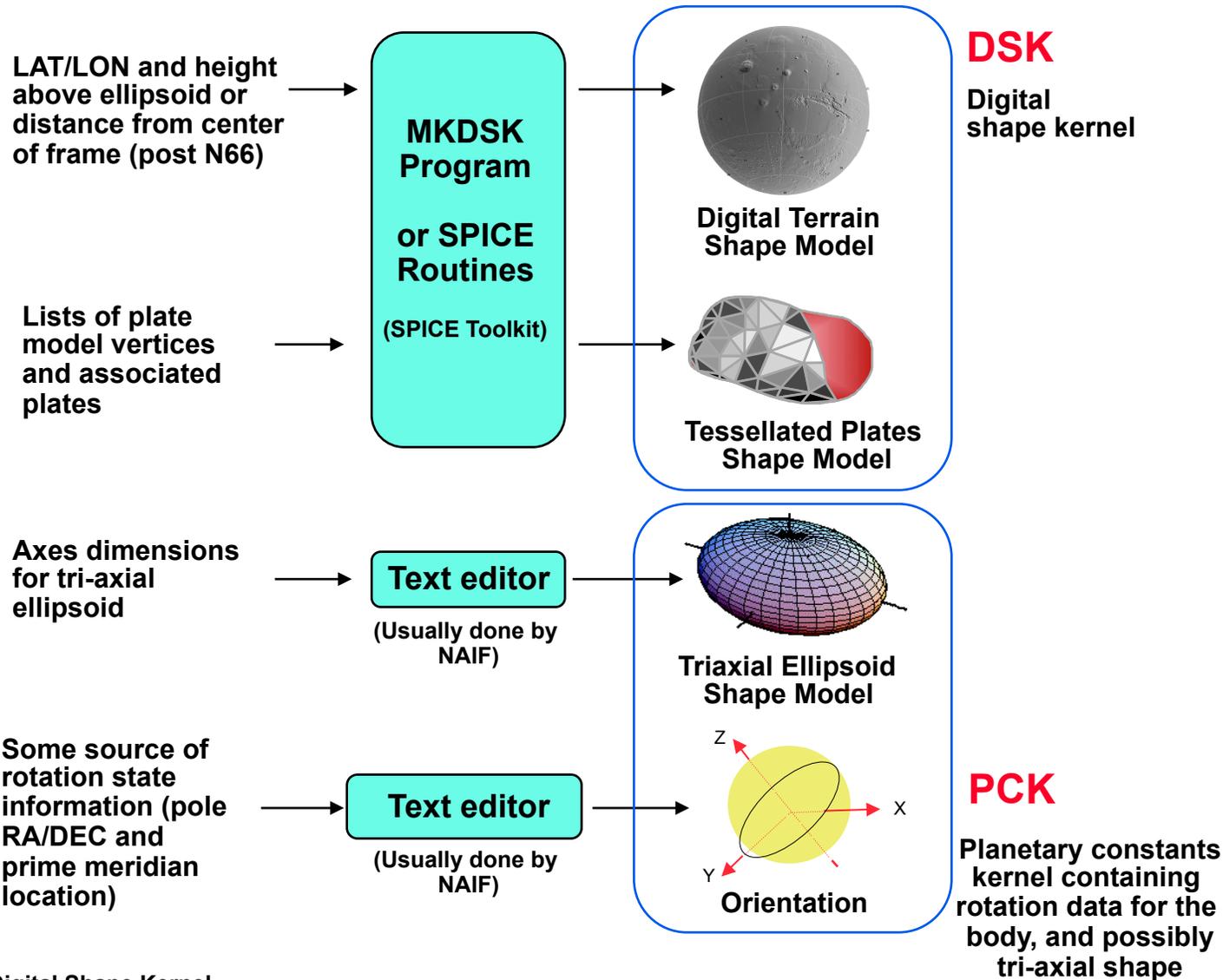
Navigation and Ancillary Information Facility

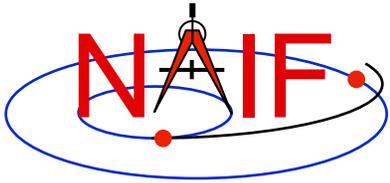
- **DSK files are based on the SPICE “DAS” (direct access, segregated) file format.**
 - Binary, random access format
 - Supports storage of integer, double precision, and character data
 - DAS software has buffering system independent of the host computer’s operating system
 - Provides comment area
 - Supports porting across incompatible binary architectures (big- and little-endian)
- **Another low-level SPICE format called “DLA” (DAS linked array) is built upon the DAS format.**
 - Allows grouping of data into segments
 - Provides view of segments as a doubly linked list
 - File structure is similar to DAF, but DLA data can be character or integer as well as double precision.
- **The DSK format is built upon the DLA format.**



Writing Shape and Orientation Kernels

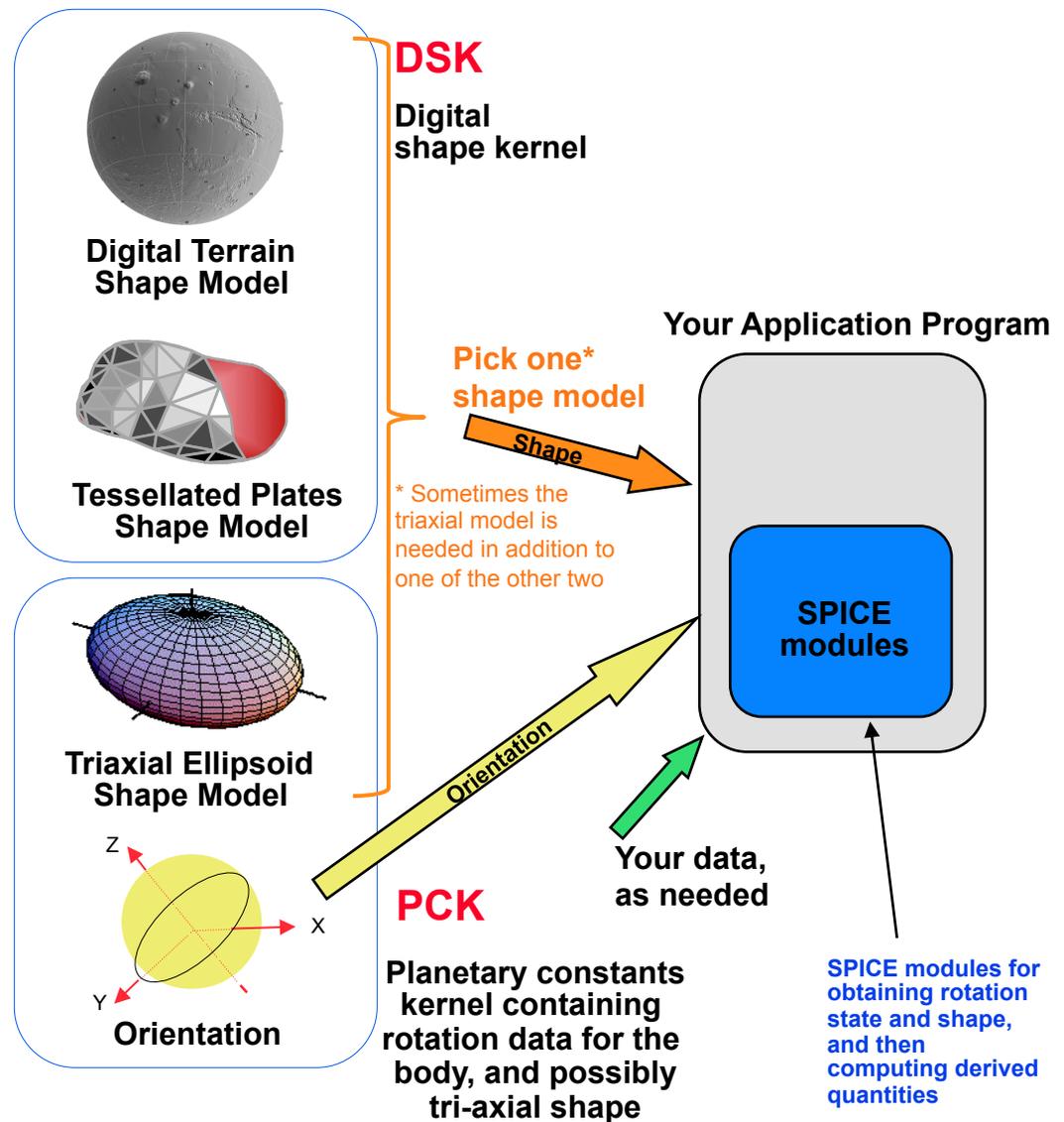
Navigation and Ancillary Information Facility

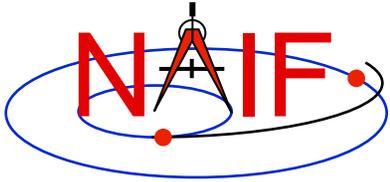




Using Shape and Orientation Kernels

Navigation and Ancillary Information Facility





DSK Development Status

Navigation and Ancillary Information Facility

- **History**

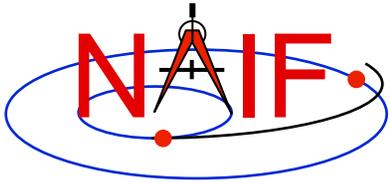
- A partial alpha-test DSK Toolkit was released in July, 2010
 - » Contains support only for the tessellated plate model data type (Type 2)
 - » Available in Fortran, C, IDL, MATLAB and JNI
 - » Some bug fixes and improvements released Feb. 25, 2015
 - These need be overlaid on the alpha-test DSK toolkits
- A special DSK Toolkit containing some of the digital elevation model (DEM) capability has been provided to the SMAP mission (earth science)

- **Progress**

- All N66 DSK geometry APIs shown here exist in final form, except for corrections that may result from ongoing tests.
- All N66 DSK APIs (Fortran and C) have complete documentation, including working example programs. MATLAB and IDL development is slightly behind.
- Utility programs are complete, with the exception of DSKBRIEF.

- **Plans**

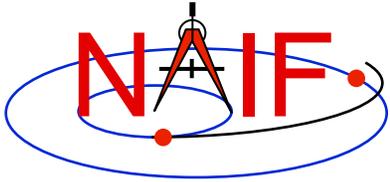
- Further work on the tessellated plate capability is ongoing now
 - » Release date of an official N66 Toolkit containing the DSK tessellated plate capability likely in May-June 2016
 - Functionality will be greatly enhanced relative to Alpha DSK Toolkit
 - » Release date of official Toolkits containing the digital elevation model capability is TBD



Post-N66 DSK Updates-1

Navigation and Ancillary Information Facility

- **Principal addition to the DSK subsystem will be support for type 4 DSK segments. Type 4 contains digital elevation model (DEM) data.**
- **Properties of DSK type 4 segments:**
 - **Built-in algorithms**
 - » Much as interpolation methods are built into SPK and CK segments, DSK type 4 segments will contain descriptors for algorithms to be used for
 - Interpolating height data
 - Performing ray-surface intercept computations
 - Ray-surface intercept acceleration techniques
 - Surface normal computation
 - **Non-raster data organization**
 - » Raster data can optionally be re-organized to greatly increase average file read efficiency
 - **Support for multiple primitive numeric data types**
 - » 16-bit packed integer
 - » 32-bit integer
 - » 32-bit real
 - **Support for multiple map projections**
 - » Equirectangular
 - » Stereographic



Post-N66 DSK Updates-2

Navigation and Ancillary Information Facility

- **Possible additional DSK utility programs**
 - DSK comparison program—compare height or radius data over specified region
 - DSK validation program
 - DSK sub-setter
 - DSK data type converter: DEM to plate model and vice versa
 - DSK parameter editor (analogous to DAFMOD or BSPIDMOD): change ID codes or other parameters in a DSK file instead of having to re-create the file.
 - DSK re-sampler: replace large DSK type 2 segments with multiple, smaller type 2 segments having the combined coverage of the original segment.
 - » In some cases, such re-sampled type 2 DSK segments allow DSK software to operate much more efficiently.