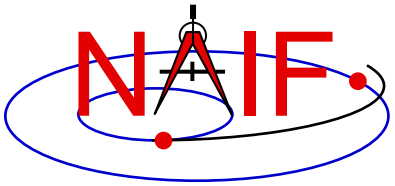
Digital Shape Kernel Subsystem (DSK)

January 2017



Topics

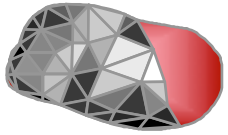
- DSK subsystem overview
- DSK shape representations
- N66 version of DSK subsystem
- DSK APIs and graphical depictions
- DSK API example
- DSK utility programs
- DSK concepts
- DSK files
- Writing and using DSK files
- Post-N66 updates

DSK Subsystem Overview

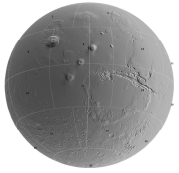
- **The DSK subsystem**
  - **Enables SPICE-based applications to conveniently make use of surface shape (topographic) data in geometry computations**
  - **Serves as a format for transmission and archival of surface shape data**
  - **Consists of SPICE software, DSK file format specifications, and documentation**

DSK Shape Representations

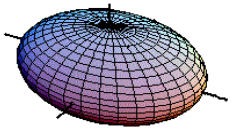
- **The DSK subsystem handles two representations of shape data**
  - **Tessellated plate model**



  - **Digital elevation model (development not yet finished)**



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



Tessellated Plate Model

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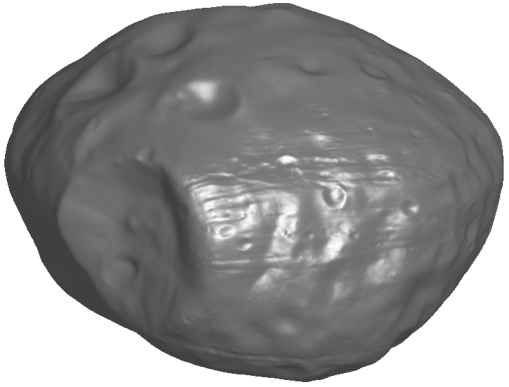
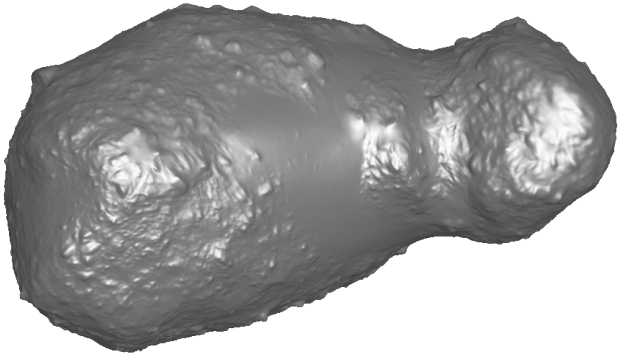
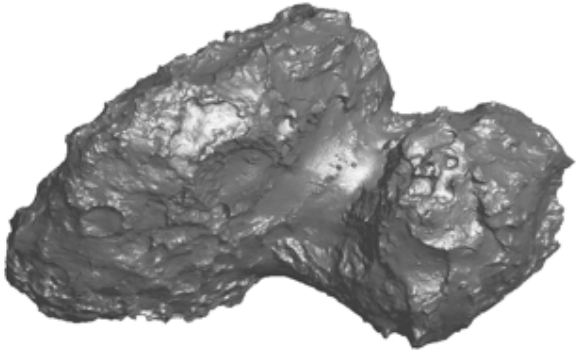
- The surface of the object is represented as a collection of triangular plates
- More flexible than digital elevation model: any arbitrary 3-D surface can be modeled
  - Surface could be a complicated shape with multiple surface points having the same latitude and longitude
    - » Examples: "dumbbell"-shaped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



Phobos



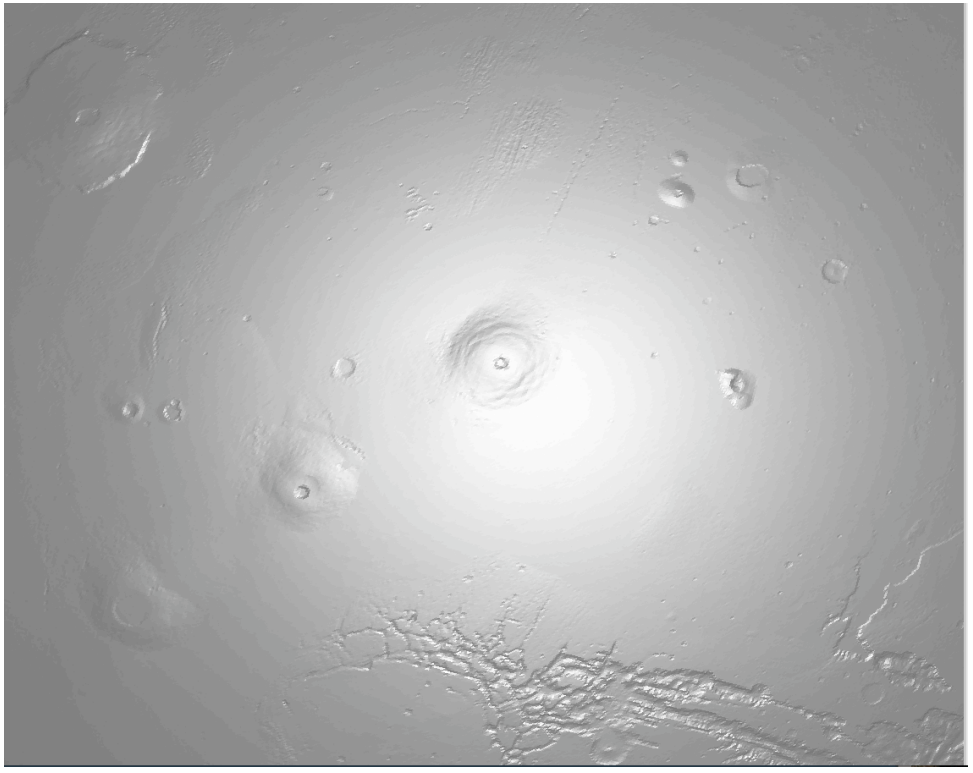
Itokowa



Churyumov-Gerasimenko

Digital Elevation Model

- **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**



N66 Toolkit with DSK

- **Supports only the tessellated plate model data type (Type 2 DSK)**

- **DEM support (Type 4) will be added in a future Toolkit version**

Some DSK Features

- **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**
- **Pre-DSK era SPICE Toolkit geometry APIs will support DSK shape data, where applicable**

N66 DSK APIs -1

- **Kernel load/unload/info:**
  - FURNSH, 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

- **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

- 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

API: SINCPT

Intercept nearest to observer's location

Also returned: target epoch (corrected for light time)

Additional intercepts ---not computed

Input ray

Observer's location
Observer is external to object

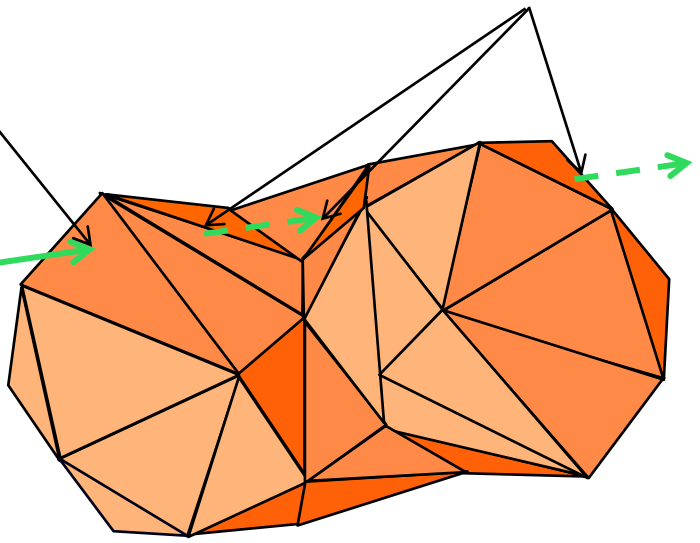


Plate Model Sub-observer Point

API: SUBPNT

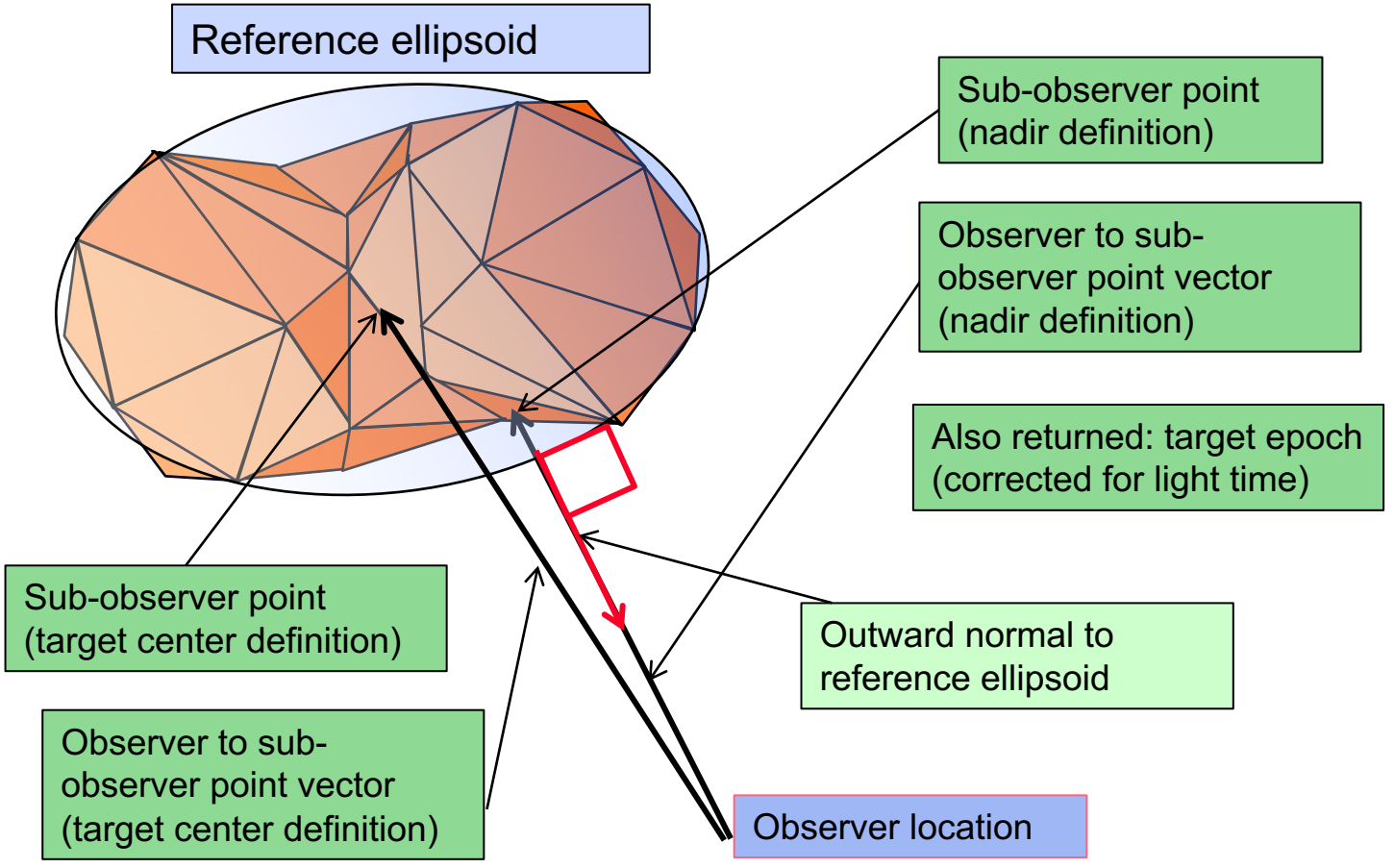


Plate Model Sub-solar Point

API: SUBSLR

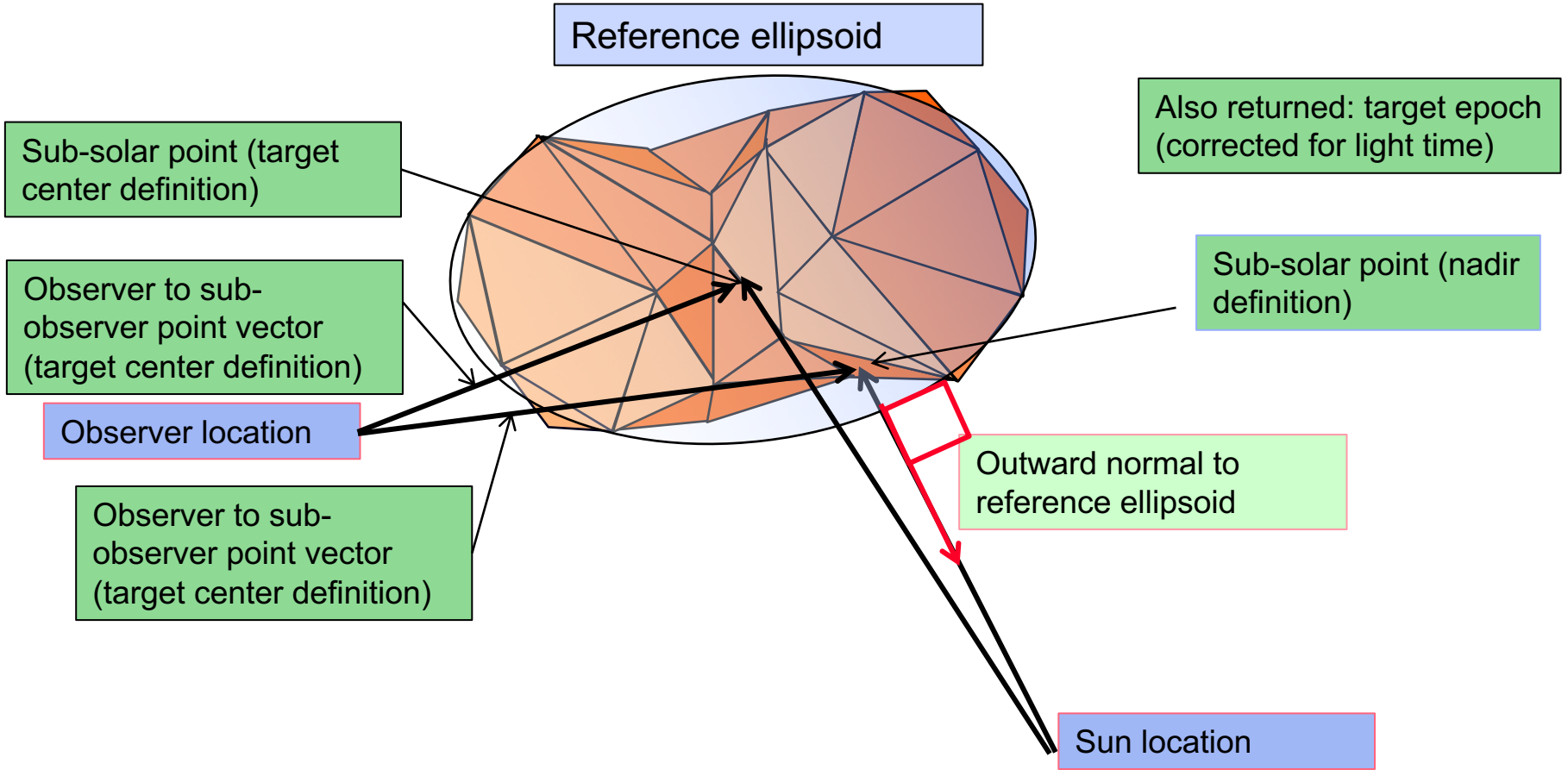


Plate model Illumination Angles

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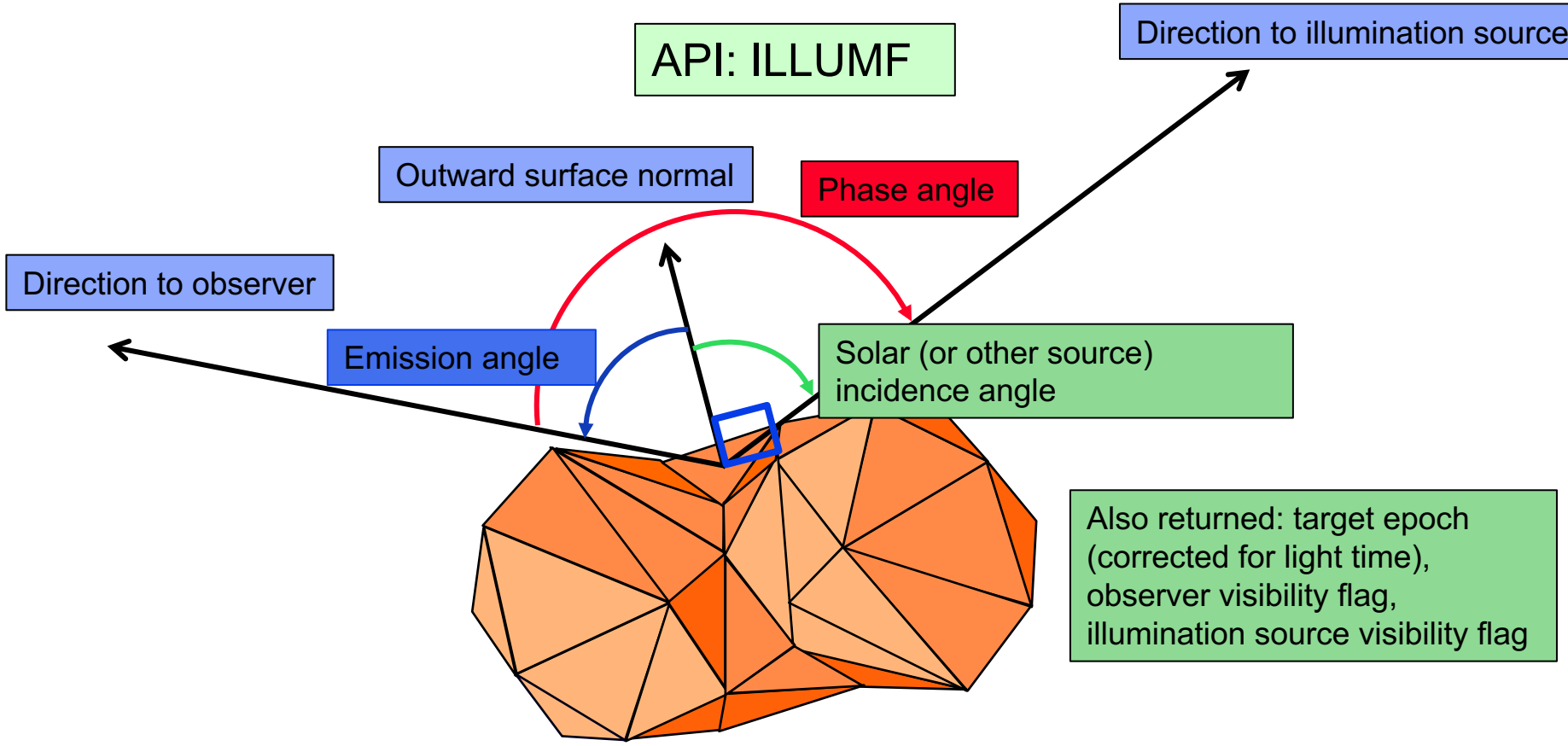

Plate Model Surface Point Grid

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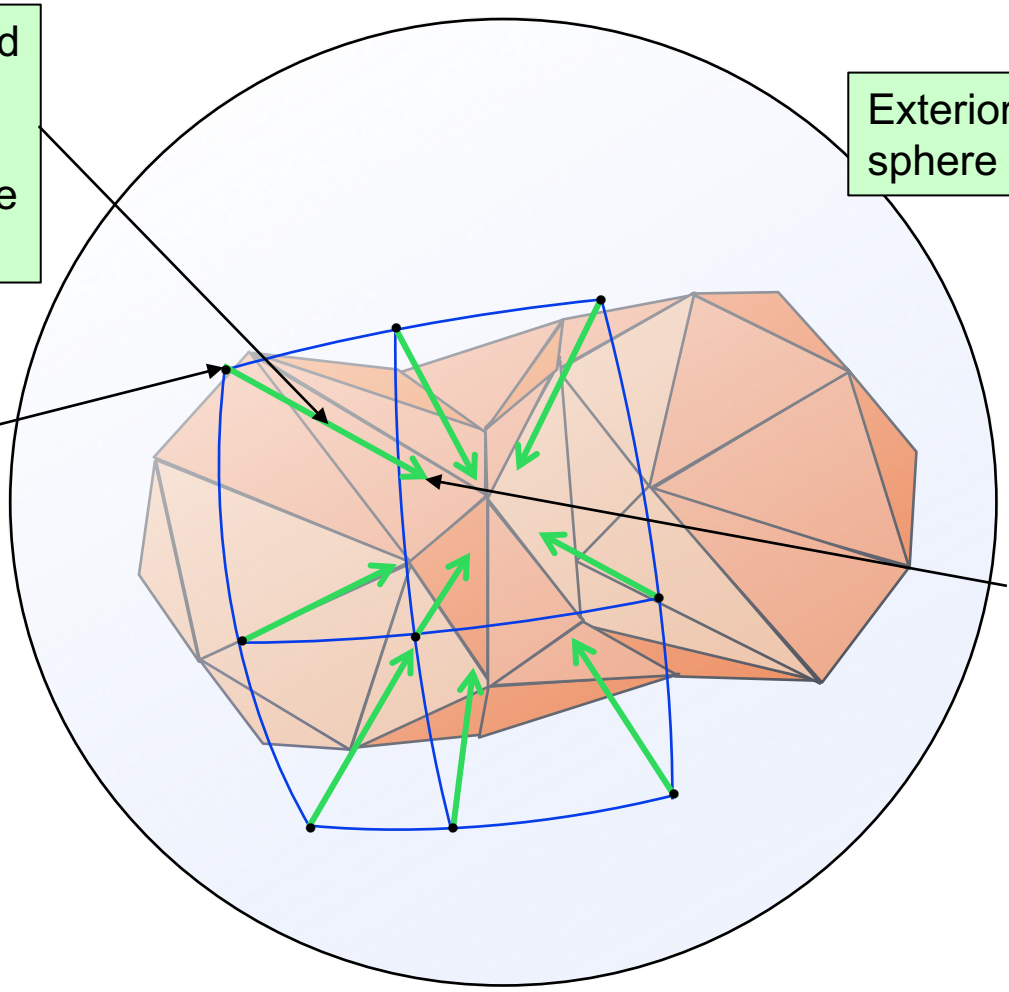
API: LATSRF

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

Exterior bounding sphere for target object



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

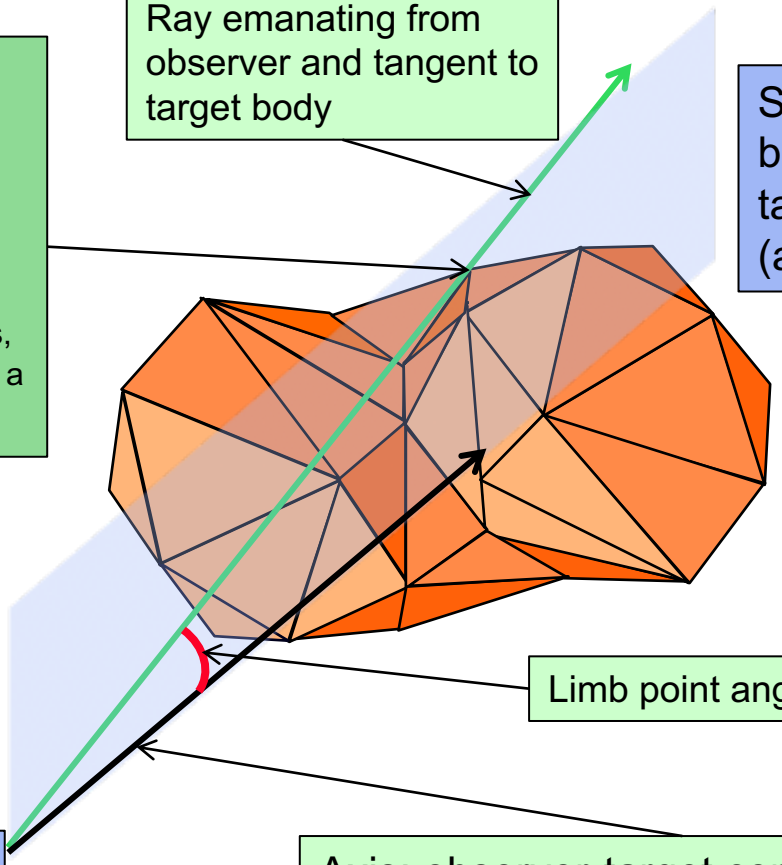
Navigation and Ancillary Information Facility

API: LIMBPT

Ray emanating from observer and tangent to target body

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).

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

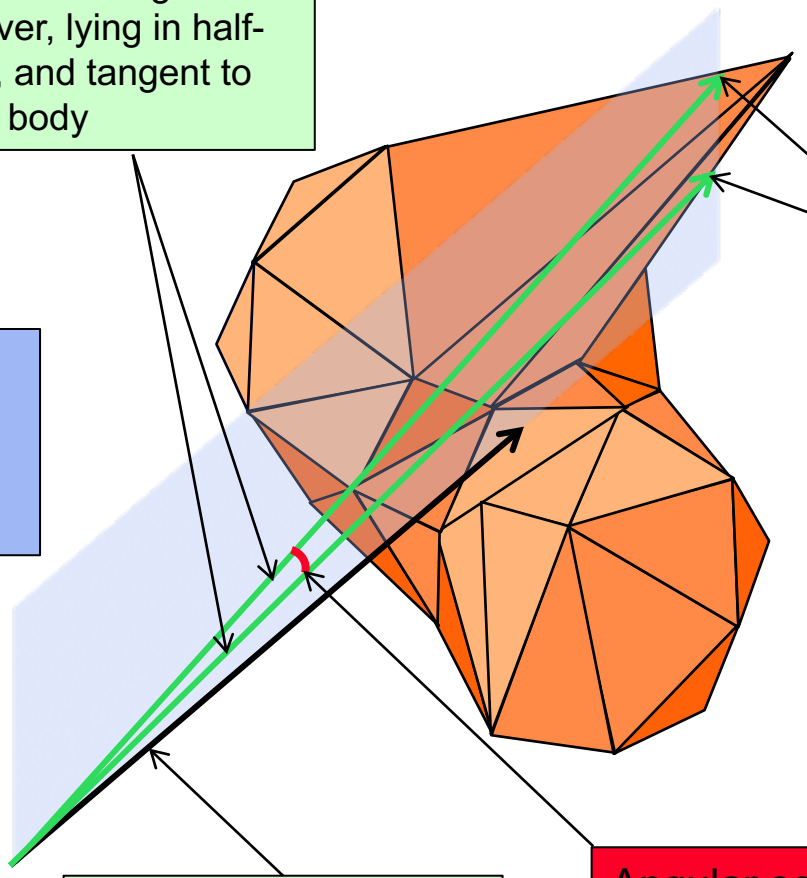
Plate Model Limb-2

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 greater than this angle

Plate Model Terminator-Umbral

Navigation and Ancillary Information Facility

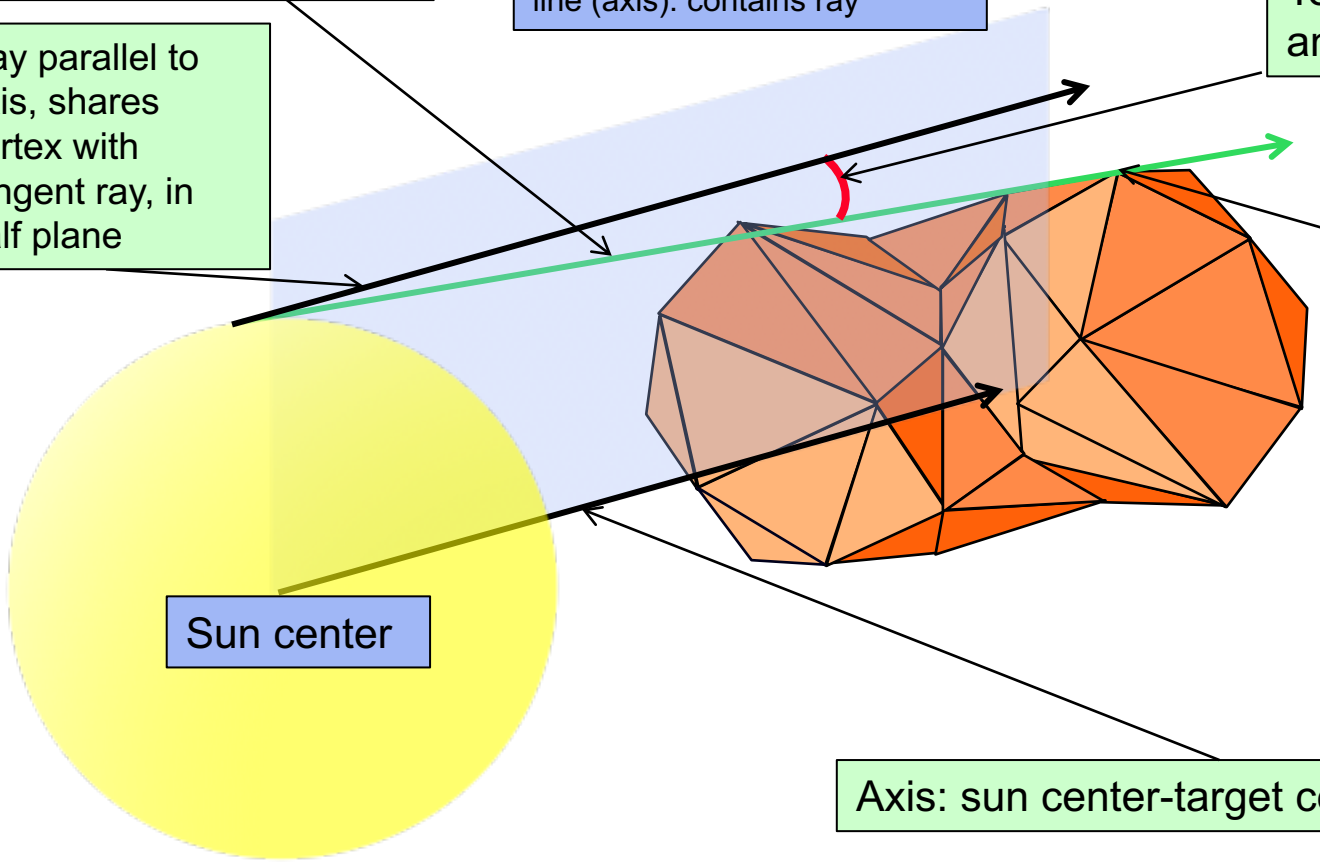
API: TERMPT

Ray tangent to sun and target body

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

Terminator tangent ray angle relative to axis

Ray parallel to axis, shares vertex with tangent ray, in half plane



Umbral terminator point---the tangent ray in the selected half plane at the minimum angle from the ray parallel to the sun-target axis is selected (for some shapes, multiple tangents will exist for a given axis and half- plane).

Sun center

Axis: sun center-target center vector

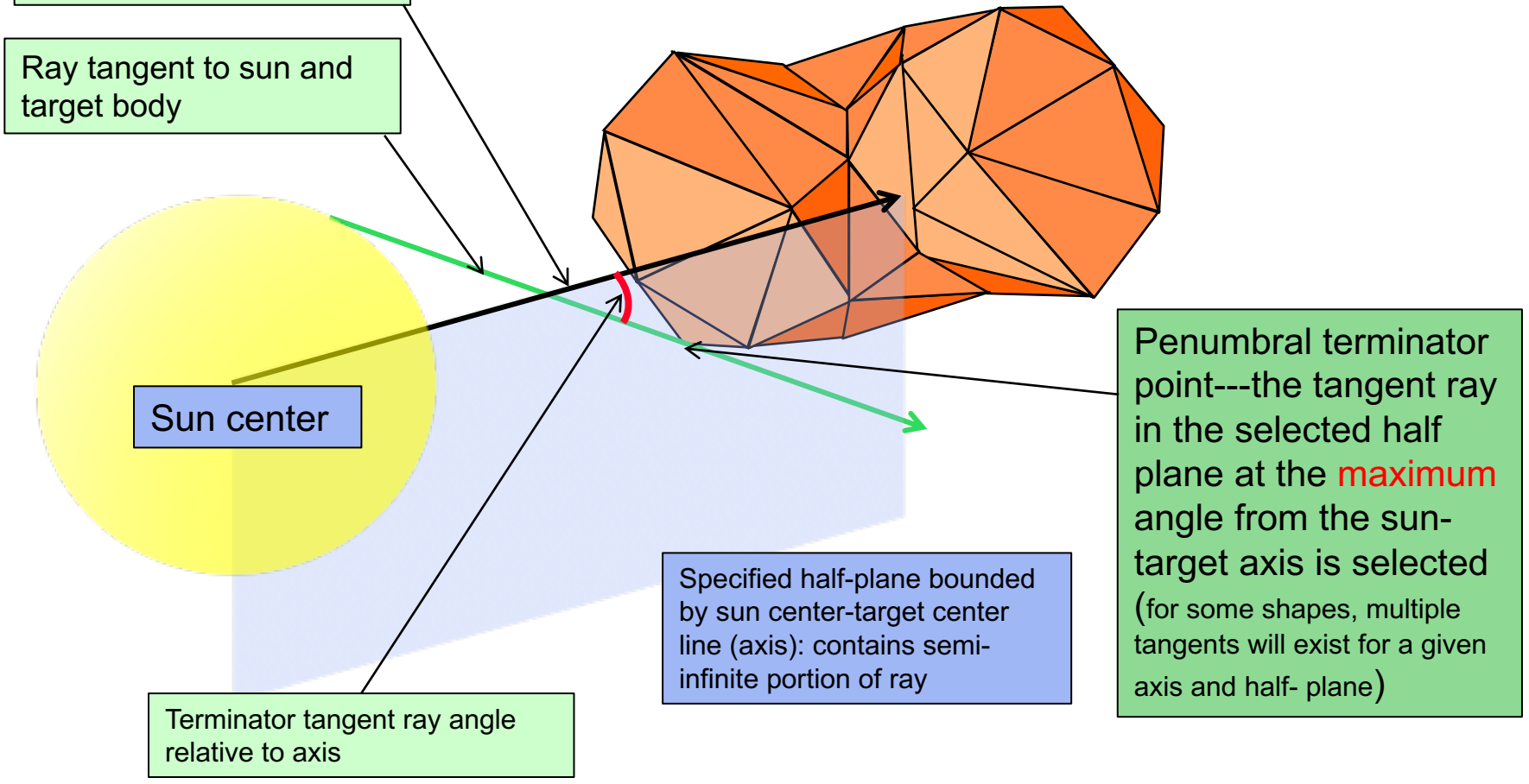
Plate Model Terminator-Penumbral

Navigation and Ancillary Information Facility

API: TERMPT

Axis: sun center-target center vector

Ray tangent to sun and target body



Sun center

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

Specified half-plane bounded by sun center-target center line (axis): contains semi-infinite portion of ray

Terminator tangent ray angle relative to axis

DSK API Example: SINCPT-1

- **Find ray intercept point on target surface:**
  - **CALL SINCPT (METHOD, TARGET, ET, FIXREF, ABCORR, OBSRVR, DREF, DVEC, SPOINT, TRGEPC, SRFVEC, FOUND)**
    - » **SINCPT 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: SINCPT -2

- 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

- Surface
  - A second identifier, in addition to the central body
    - » A "surface" has a 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

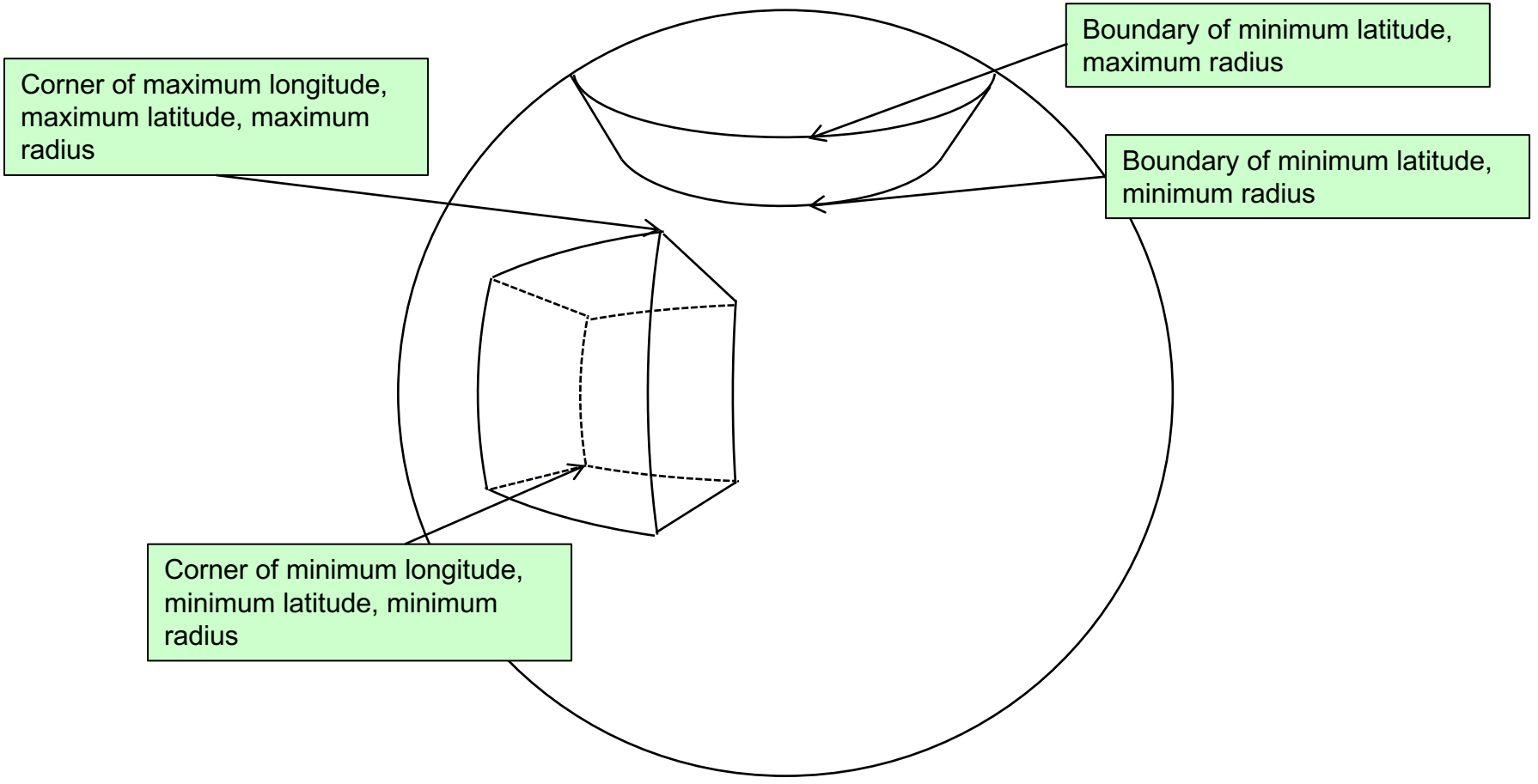
DSK Concepts-2

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

DSK segment spatial coverage examples---planetocentric coordinate system



DSK Files -1

- **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

- **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

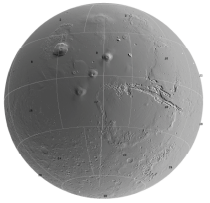
LAT/LON and height above ellipsoid or distance from center of frame (post N66)

Lists of plate model vertices and associated plates

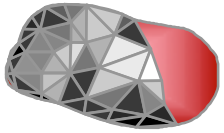
MKDSK Program

or SPICE Routines

(SPICE Toolkit)



Digital Terrain Shape Model



Tessellated Plates Shape Model

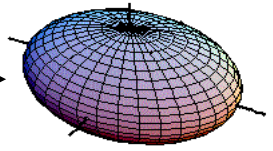
DSK

Digital shape kernel

Axes dimensions for tri-axial ellipsoid

Text editor

(Usually done by NAIF)

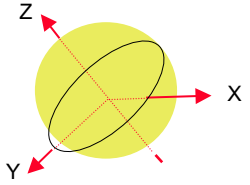


Triaxial Ellipsoid Shape Model

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

Text editor

(Usually done by NAIF)



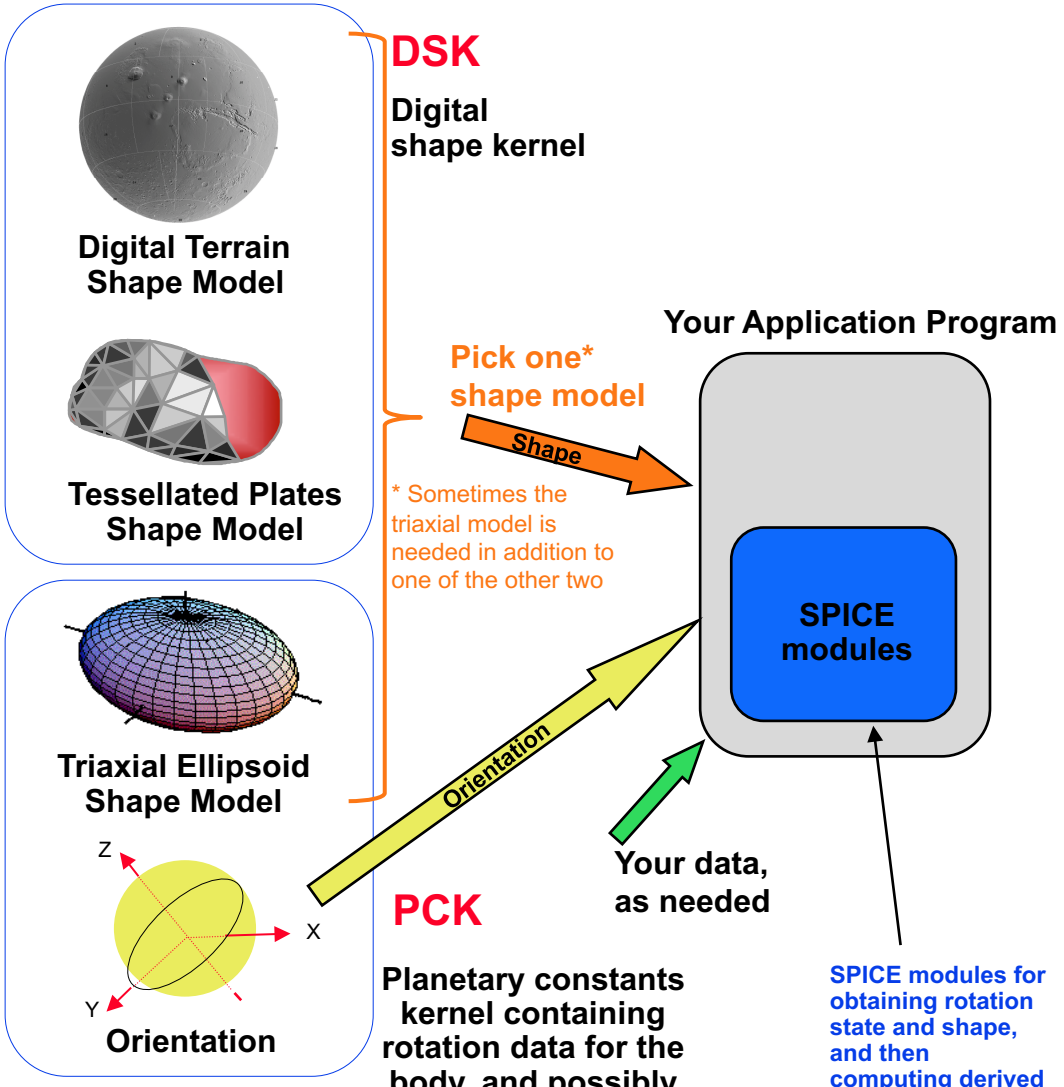
Orientation

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



Post-N66 DSK Updates-1

- **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

- **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.