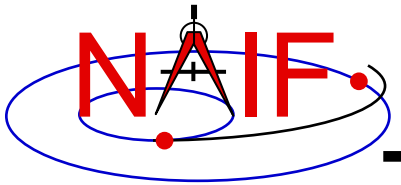
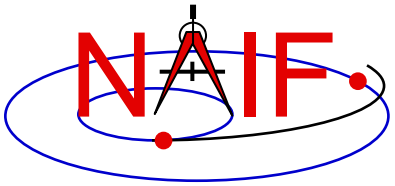


Navigation and Ancillary Information Facility

Digital Shape Kernel Subsystem (DSK)

January 2020



Topics

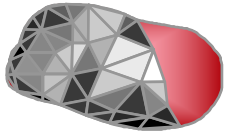
- DSK subsystem overview
- DSK shape representations
- N66 version of DSK subsystem
- DSK APIs and graphical depictions
- DSK API example
- DSK utility programs
- DSK concepts
- Writing and using DSK files

DSK Subsystem Overview

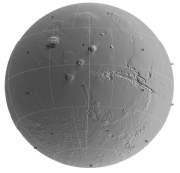
- **The DSK subsystem**
  - **enables SPICE-based applications to conveniently make use of high fidelity surface shape (topographic) data in geometry computations**
  - **serves as a format for transmission and archival of surface shape data**
  - **consists of SPICE software, DSK file format specifications,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

DSK Shape Representations

- **The DSK subsystem handles two representations of shape data**
  - **Tessellated plate model (Type 2)**

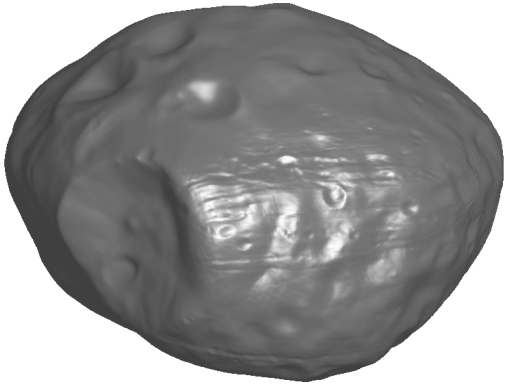


  - **Digital elevation model (development not yet finished) (Type 4)**

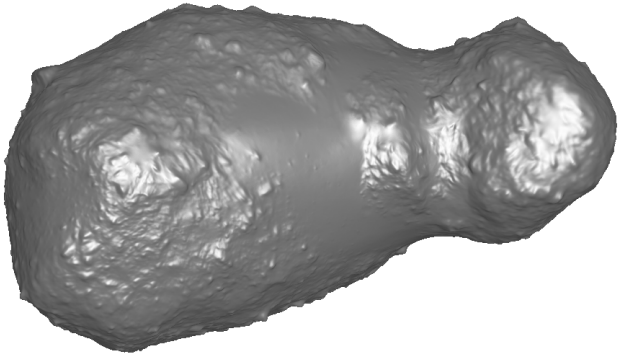


Tessellated Plate Model – Type 2

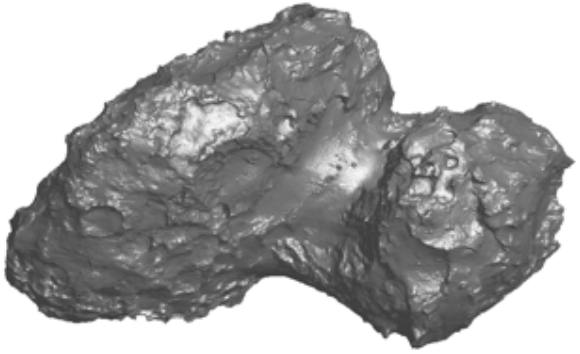
- The surface of the object is represented as a collection of triangular plates
- More flexible than digital elevation model: any arbitrary 3-D surface can be modeled
  - Surface could be a complicated shape with multiple surface points having the same latitude and longitude
    - » Examples: "dumbbell"-shaped asteroid, caves, arches
- Less efficient than digital elevation model (DSK Type 4) of similar resolution in terms of storage and computational speed



Phobos



Itokowa

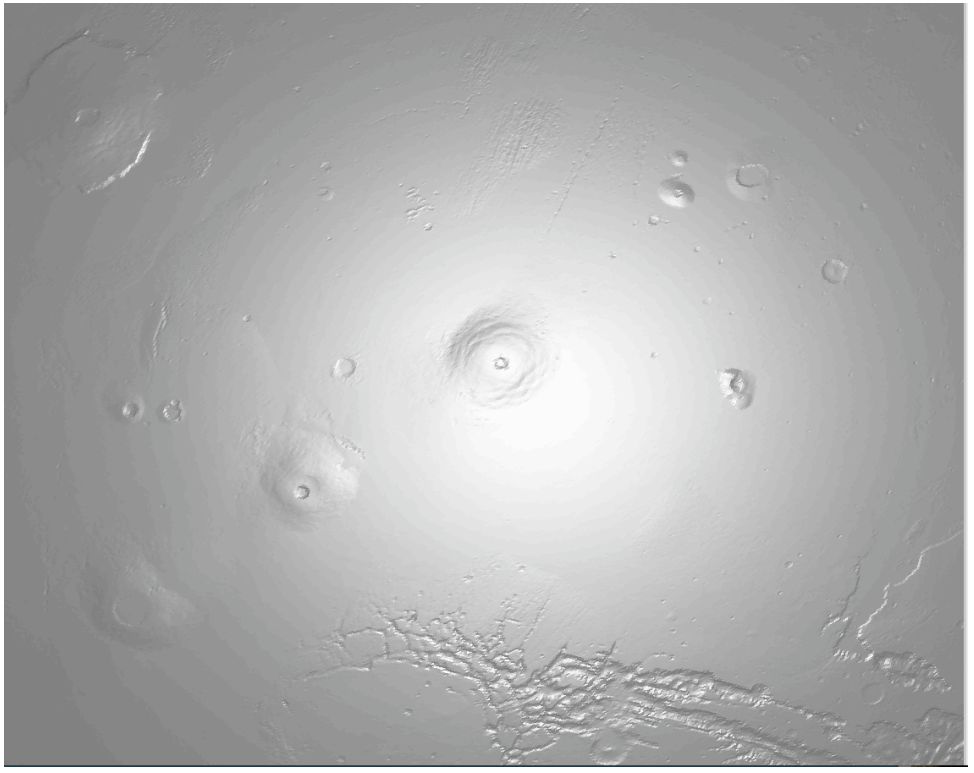


Churyumov-Gerasimenko

Digital Elevation Model – Type 4

- **Maps longitude/latitude to "elevation"**
  - **Elevation of a surface point can be defined as distance from the origin of a body-fixed reference frame or height above a reference ellipsoid**

- **Example: rendering of a piece of DSK data created from MGS laser altimeter (MOLA) Mars DEM**



N66 Toolkit with DSK

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

- **Support for Digital Elevation Model (DEM) (Type 4 DSK) will be added in a future Toolkit version**

Some DSK Features

- **Supports multi-segment, multi-file DSK data sets**
  - **Up to 5000 DSK files can be loaded simultaneously**
  - **Up to 10,000 DSK segments 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**

APIs Available in N66 Toolkits -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 pairs 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

APIs Available in N66 Toolkits -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

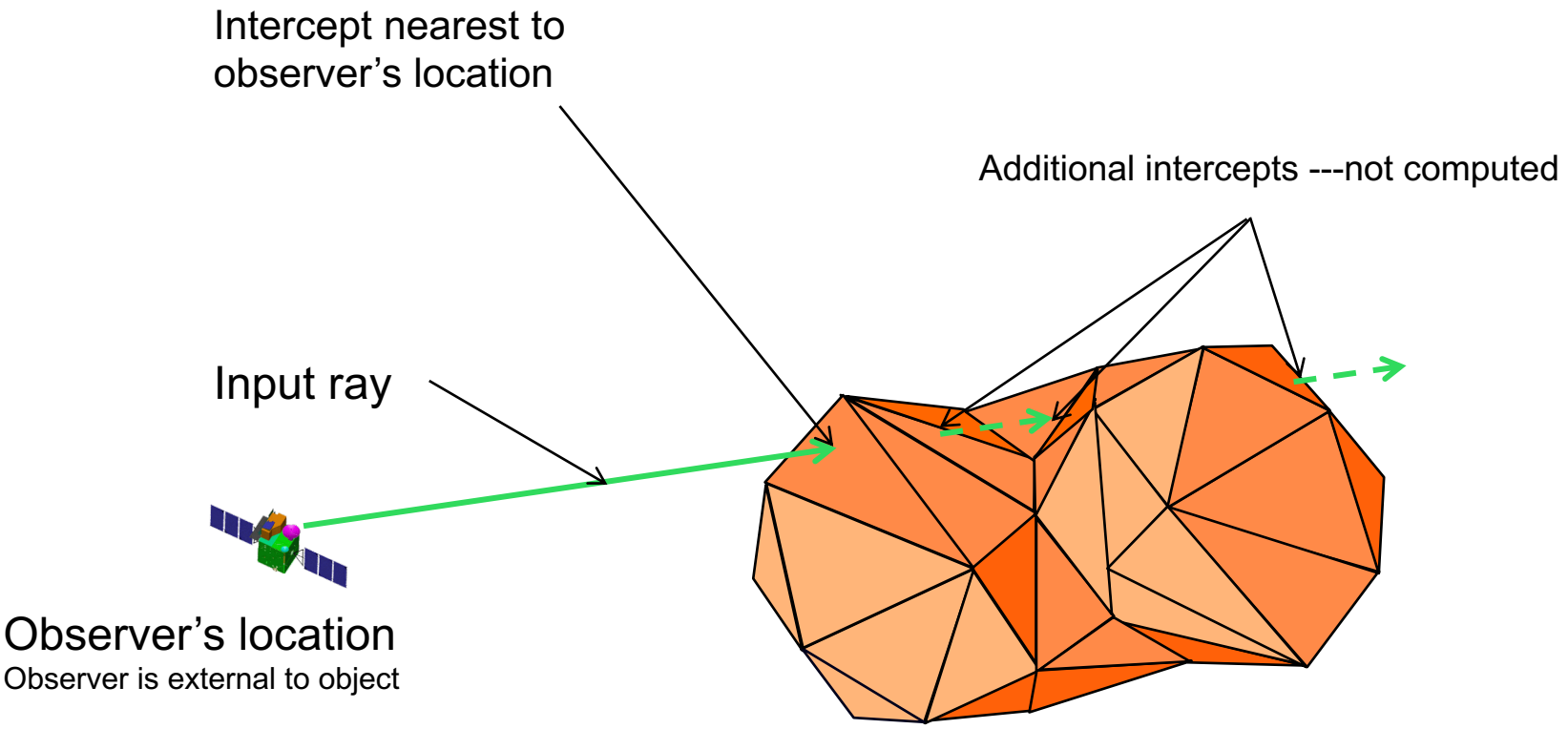


Plate Model Sub-observer Point

API: SUBPNT

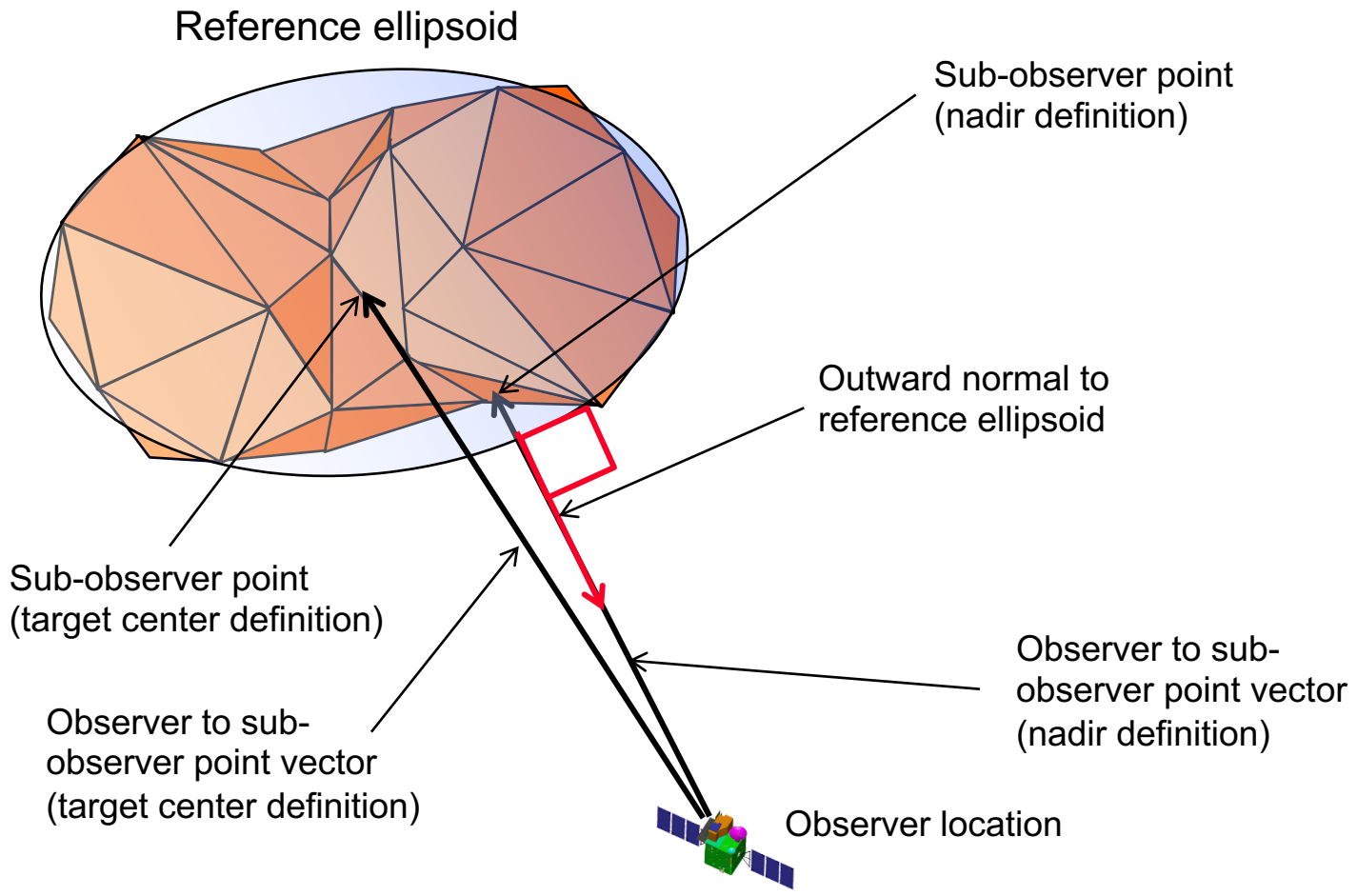


Plate Model Sub-solar Point

Navigation and Ancillary Information Facility

API: SUBSLR

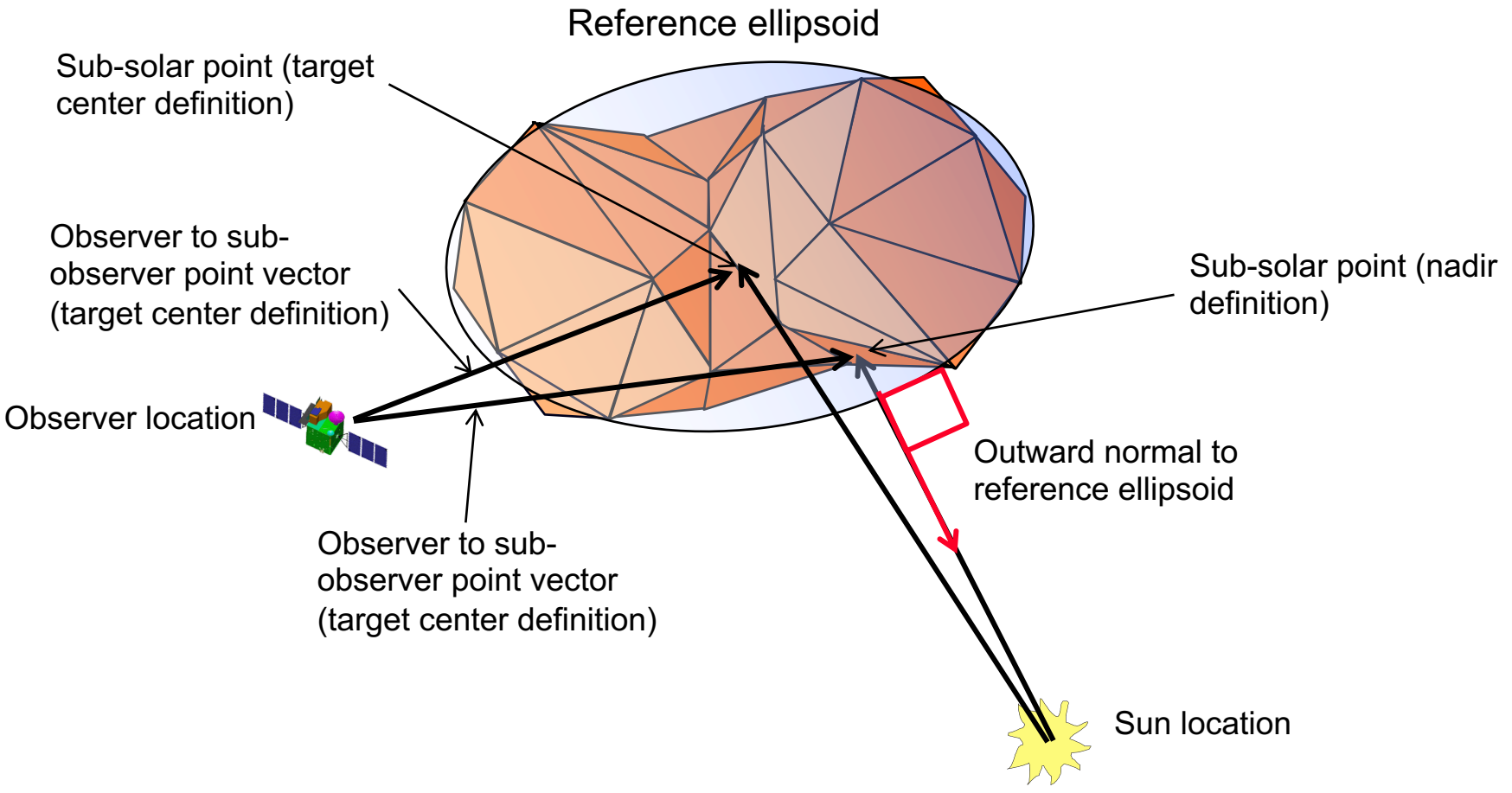
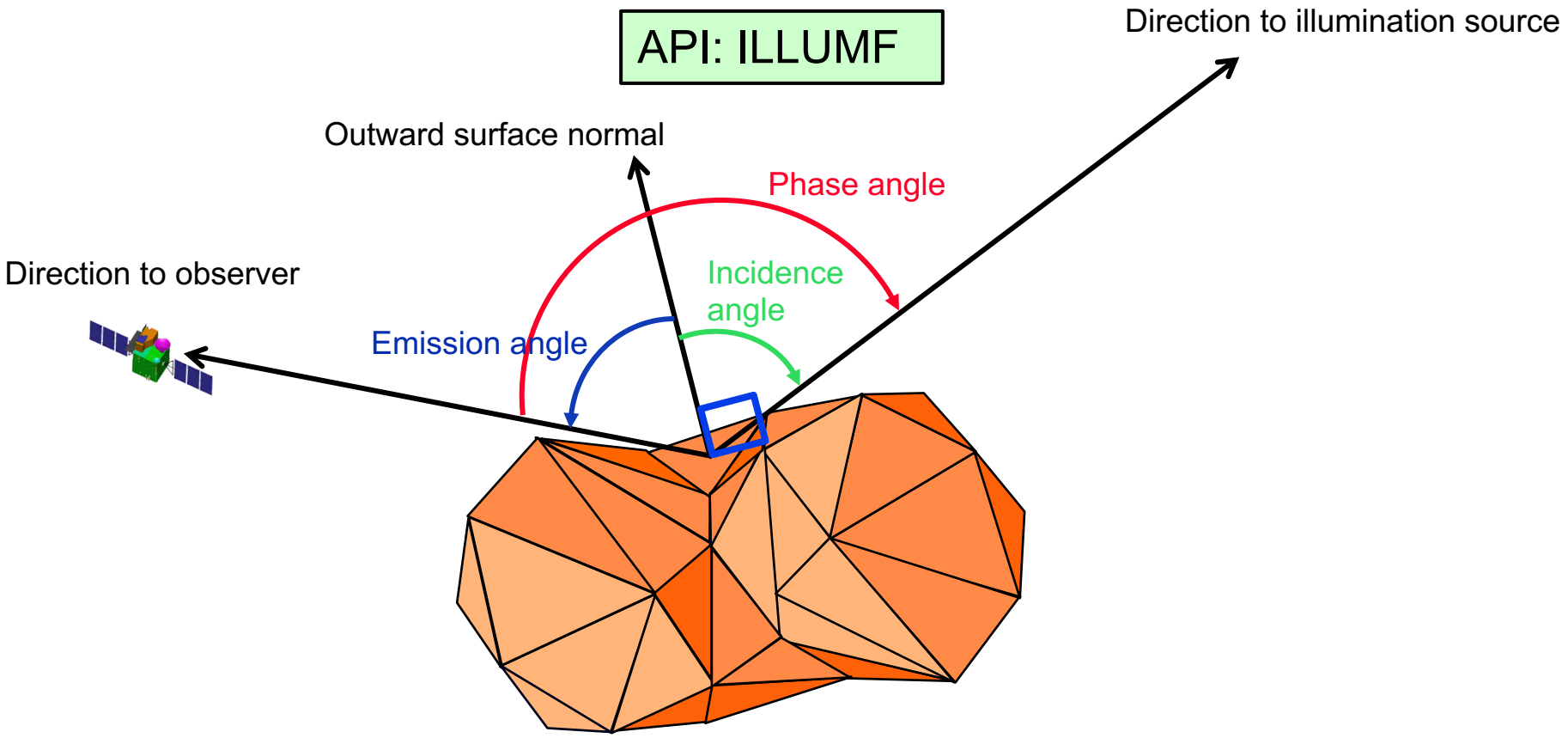


Plate model Illumination Angles

Navigation and Ancillary Information Facility

API: ILLUMF



Also returned:
- target epoch (corrected for light time),
- observer visibility flag,
- illumination source visibility flag

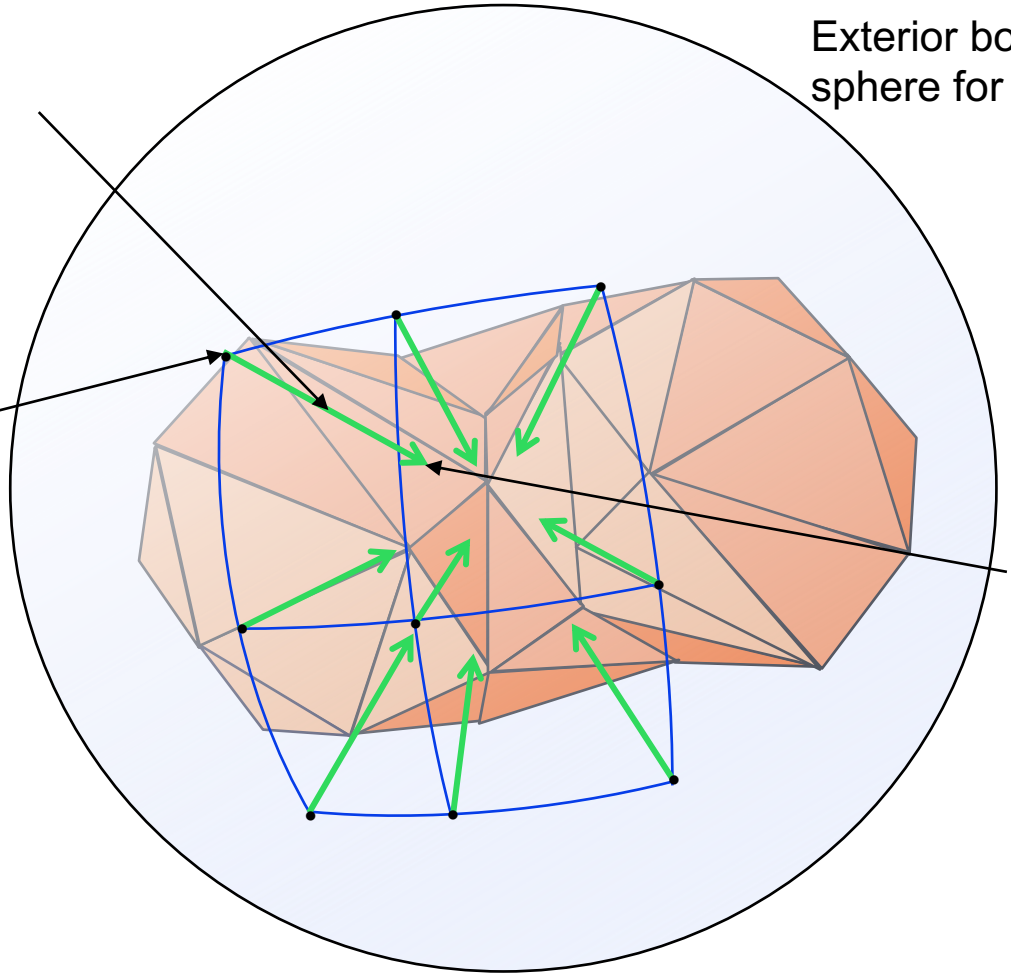
Plate Model Surface Point Grid

Navigation and Ancillary Information Facility

API: LATSRF

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

Exterior bounding sphere for target object



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 point on bounding sphere: planetocentric longitude and latitude of intercept match those of the sphere point. An intercept is computed for each input sphere point.

Plate Model Limb-1

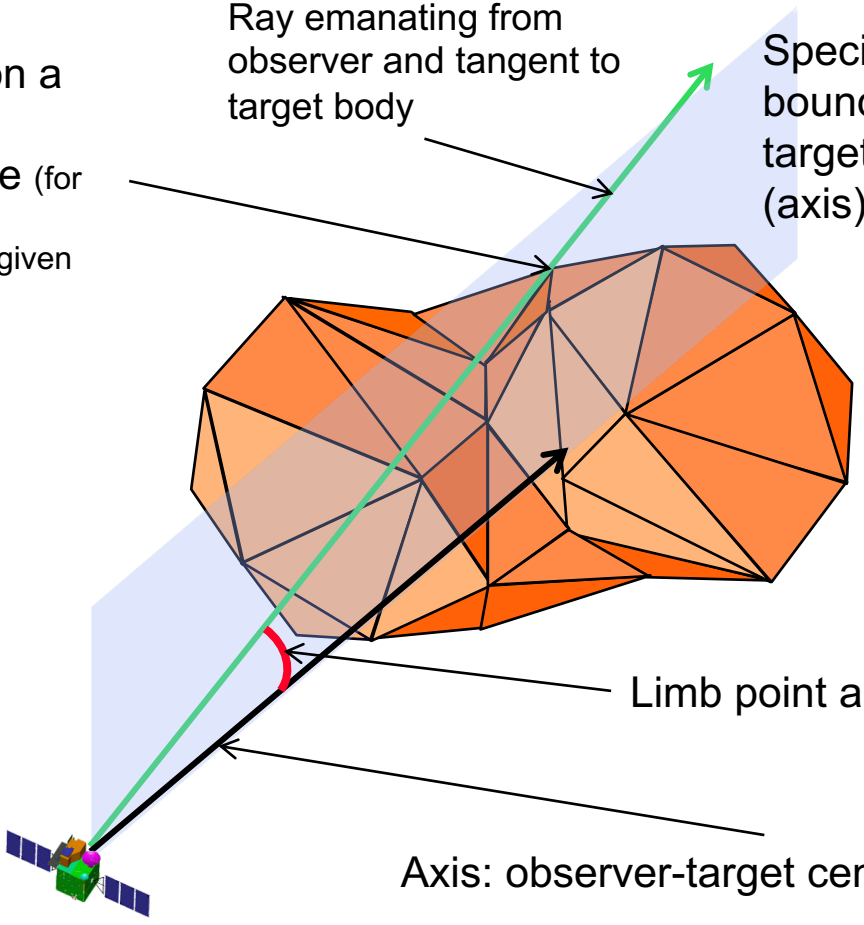
Navigation and Ancillary Information Facility

API: LIMBPT

Limb point---lies on a tangent ray in the selected half-plane (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

API: LIMBPT

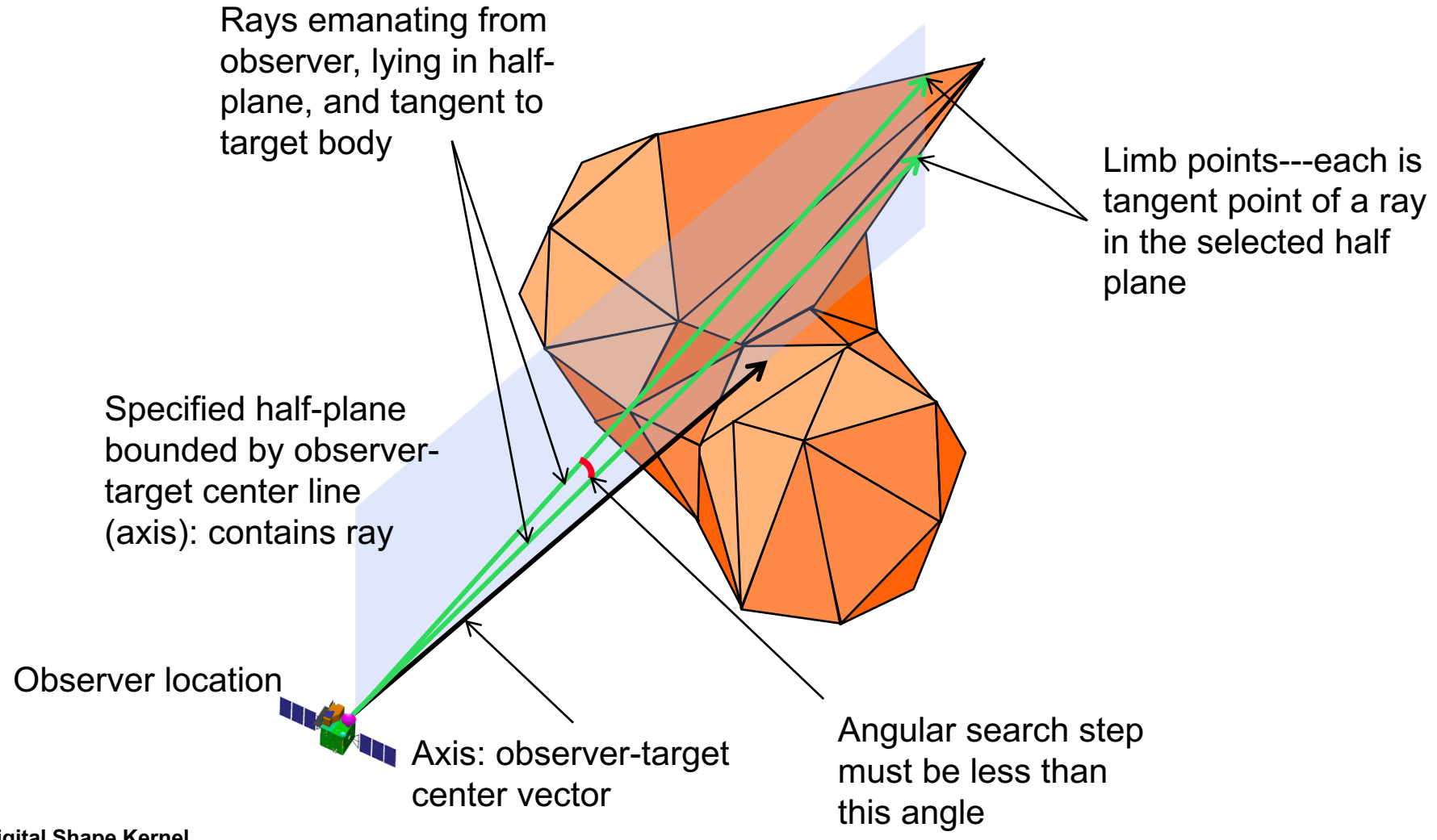


Plate Model Terminator-Umbral

Navigation and Ancillary Information Facility

API: TERMPT

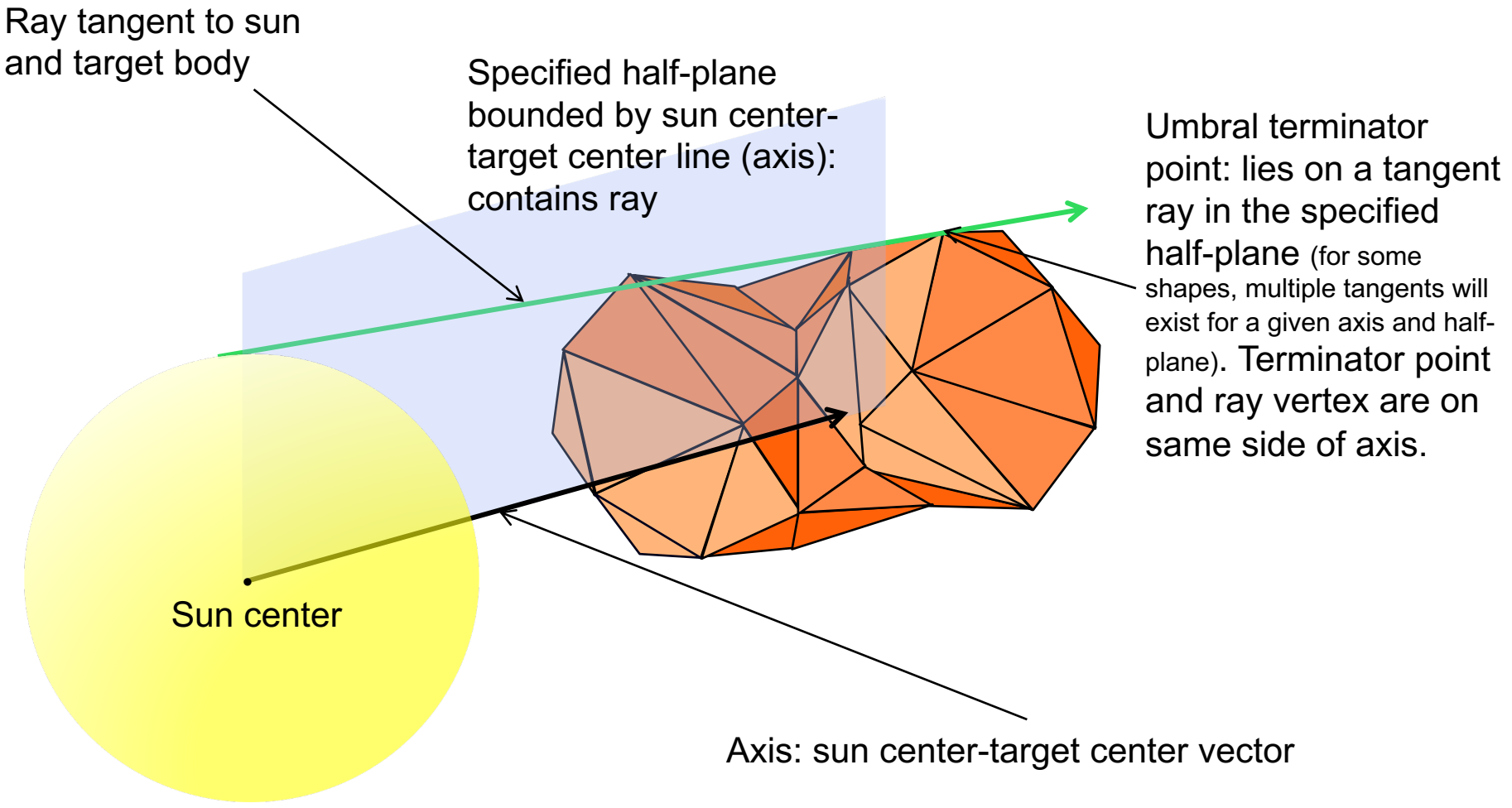
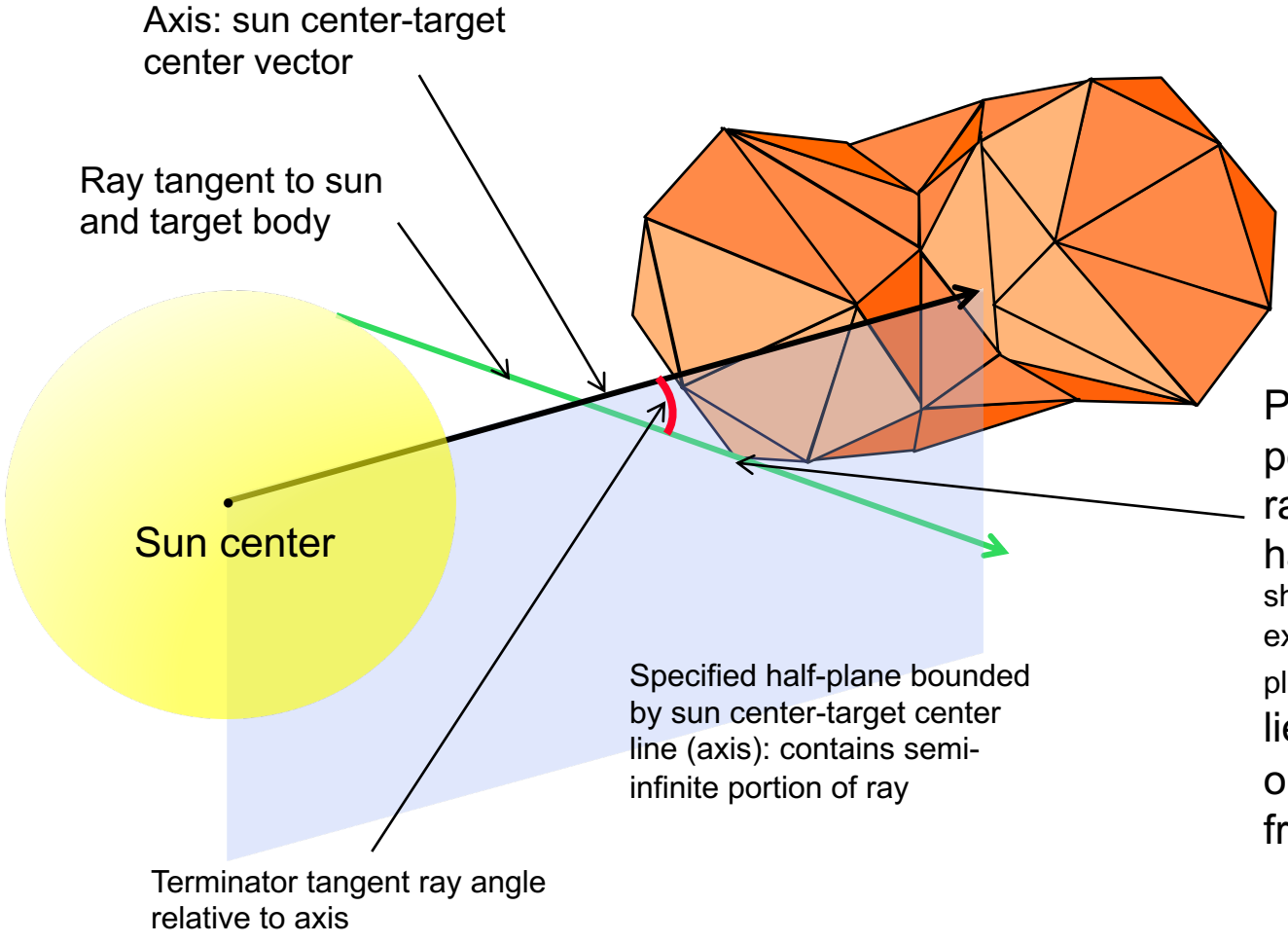


Plate Model Terminator-Penumbral

Navigation and Ancillary Information Facility

API: TERMPT



Penumbral terminator point: lies on a tangent ray in the specified half-plane (for some shapes, multiple tangents will exist for a given axis and half-plane). Terminator point lies in half-space on opposite side of axis from ray's vertex.

Example of API Using DSK - 1

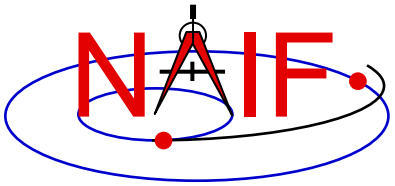
- **Find ray intercept point on target surface:**
  - **CALL SINCPT (METHOD, TARGET, ET, FIXREF, ABCORR, OBSRVR, DREF, DVEC, SPOINT, TRGEPC, SRFVEC, FOUND)**
  - **SINCPT is a high-level SPICE API.**
  - **The input string argument METHOD indicates the surface model to use.**
    - » **To model the target body shape using an 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.**

Fortran code example

Example of API Using DSK - 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

- **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**
  - "Surface" is 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**
  - Data class is a “hook” to differentiate kinds of data for different applications
    - » Distinct from concept of “data type”
  - Existing classes 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 the 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

Writing Shape and Orientation Kernels

Navigation and Ancillary Information Facility

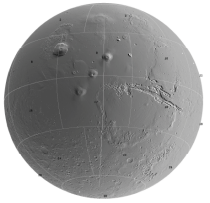
LAT/LON and height above ellipsoid or distance from center of frame (post N66)

Lists of plate model vertices and associated plates

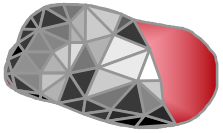
MKDSK Program

or SPICE Routines

(SPICE Toolkit)



Digital Terrain Shape Model



Tessellated Plates Shape Model

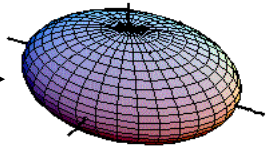
DSK

Digital shape kernel

Axes dimensions for tri-axial ellipsoid

Text editor

(Usually done by NAIF)

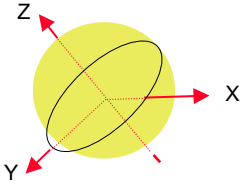


Triaxial Ellipsoid Shape Model

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

Text editor

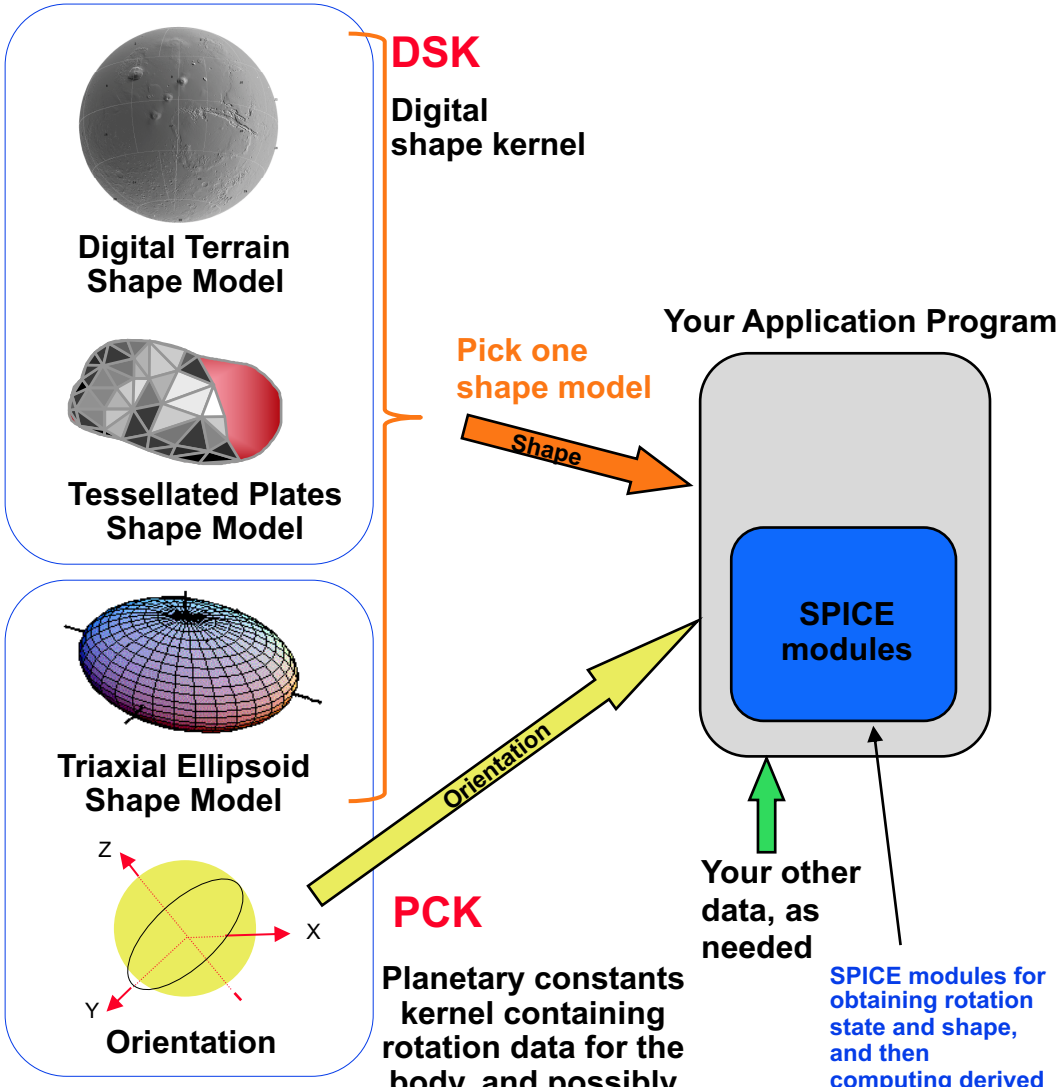
(Usually done by NAIF)



Orientation

PCK

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

Using Shape and Orientation Kernels

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