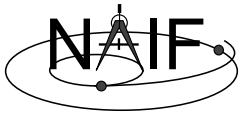




Navigation and Ancillary Information Facility

SPICE Event Finding Subsystem

October 2007



Topics

Navigation and Ancillary Information Facility

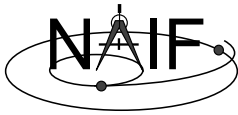
- **Overview**
- **Eclipse Events**
- **Occultation Events**
- **Field-of-View Events**
- **Numeric Events**
- **Window Math**



Overview

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- The NAIF team is working to add a new subsystem to the SPICE Toolkits. This subsystem is designed to identify the times or time intervals of particular geometric events.
 - CSPICE, Icy, and Mice will include some or all event finding functionality.
- The event subsystem algorithms detect four types of events:
 - Eclipse
 - Occultation
 - Field-of-View
 - Numerical
- The first three types describe a specific set of geometric conditions identified with the corresponding type name. The fourth type describes a geometric quantity satisfying a numeric relationship.
- NAIF has not determined a release date for the subsystem.



Eclipse -1

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- The eclipse detection algorithm identifies twelve eclipse configurations (as observed from the eclipsed body).
- Eclipse models assume a spherical shape for eclipser and eclipsed bodies. A sphere or point object can represent the illumination source.



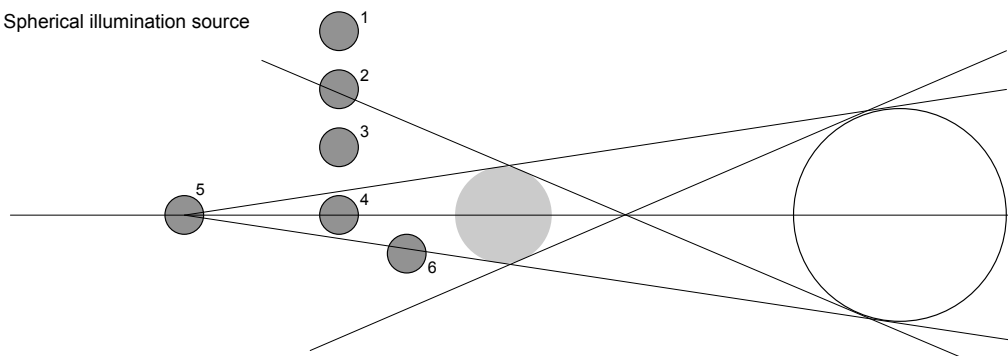
Eclipse - 2

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● Eclipsed body

● Eclipser body

○ Spherical illumination source



- 1: Eclipsed body in full illumination
- 2: Eclipsed body partially illuminated, partially in the penumbra
- 3: Eclipsed body exclusively in the penumbra
- 4: Eclipsed body completely in the umbra (NAIF defines this state as also in the penumbra.)
- 5: Eclipsed body fully in penumbra with complete umbral shadow on body
- 6: Eclipsed body partially in penumbral and partially in umbral regions

Event Finding Subsystem

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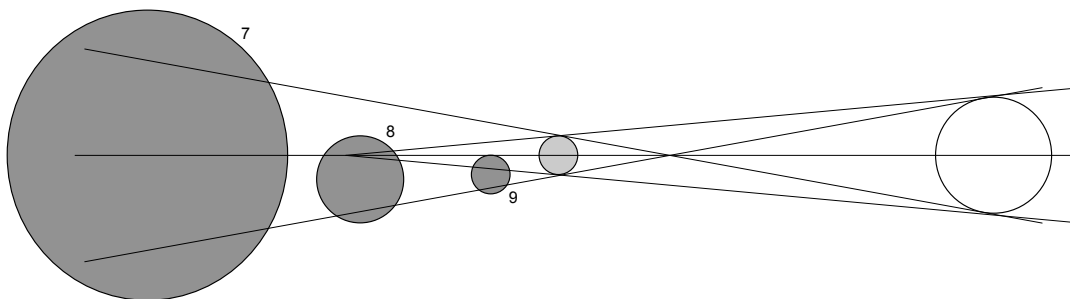
Eclipse - 3

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● Eclipsed body

● Eclipser body

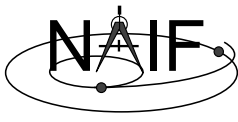
○ Spherical illumination source



- 7: Eclipsed body partially illuminated with the penumbral shadow completely on body, no umbral shadow
- 8: Eclipsed body in illuminated, penumbral, and umbral regions with full umbral shadow on body
- 9: Eclipsed body in illuminated, penumbral, and umbral regions without full umbral shadow on body




Event Finding Subsystem

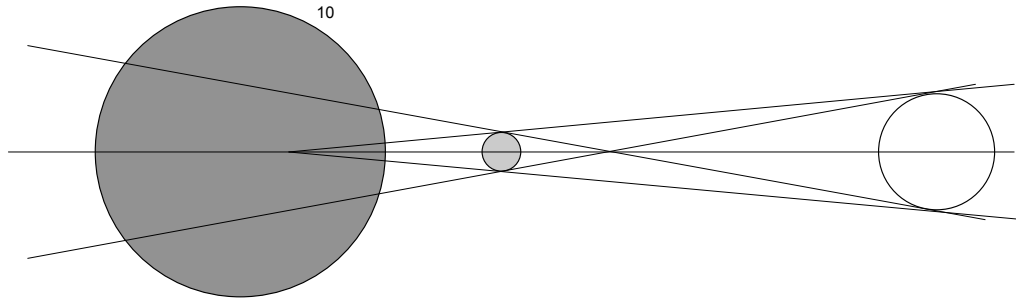
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Eclipse - 4

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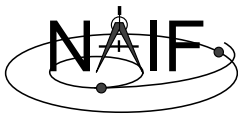
-  Eclipsed body
-  Eclipser body
-  Spherical illumination source



10: Eclipsed body partially illuminated with the penumbral and umbral shadows both fully on body




Event Finding Subsystem

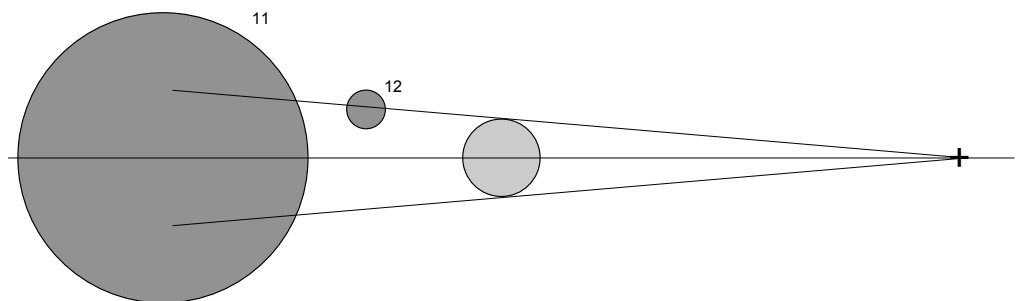
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Eclipse - 5

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-  Eclipsed body
-  Eclipser body
-  Point illumination source



11: Eclipsed body partially illuminated with full umbral shadow on body, no penumbral shadow

12: Eclipsed body partially illuminated, partially in the umbra shadow, no penumbral shadow

Note, these configurations exist only for point illumination sources.

Event Finding Subsystem

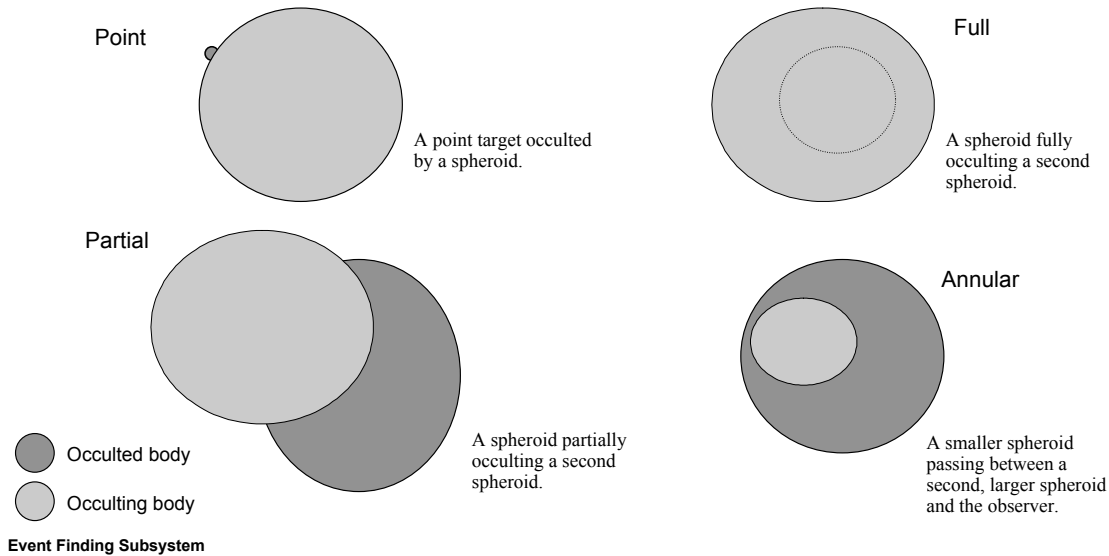
8



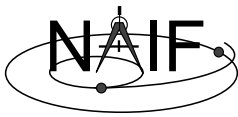
Occultation

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- The occultation detection algorithm identifies configurations with a triaxial ellipsoid modeling the occulting body. A triaxial ellipsoid or point object models the occulted body.



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Field-of-View

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- The field-of-view detection algorithm identifies configurations where an instrument field-of-view intersects or contains a body of interest. The instrument's field-of-view properties are defined in a SPICE instrument kernel.
 - The field-of-view detection algorithms answer questions of the form:
 - » “Given a time interval $[t1, t2]$ and a body, at what times within $[t1, t2]$ does the body intersect the instrument field-of-view?” (Can I see it, if so, when?)
 - In order to answer questions of the form:
 - » “Given a time interval $[t1, t2]$ and a set of bodies, which bodies will intersect the instrument field-of-view across $[t1, t2]$?” (What can I see?)
- The user performs a field-of-view search over $[t1, t2]$ for each body.

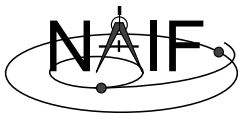


Numeric - 1

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- The numerical event detection algorithms identify configurations where a particular scalar geometric quantity satisfies some relationship, as defined by an operator and a reference value, or a unary operator.
- Geometric quantities:
 - Angular separation: observed angular separation between limbs
 - Angular speed: magnitude of angular velocity of apparent target about an observer
 - Angular rate: the time derivative of the apparent angular separation
 - Apparent angular diameter
 - Range: $||r||$
 - Range rate: $d(||r||)/dt$
 - Elongation angle: Sun-observer-target angle
 - Phase angle: observer-target-Sun angle
 - Coordinate: an element of the position vector in a particular coordinate system and reference frame. The position vector is defined as either “observer to target” or “sub observer point on target.”
 - » Coordinate systems and the corresponding coordinates:

• RECTANGULAR:	X,	Y,	Z
• CYLINDRICAL:	RANGE,	LONGITUDE,	Z
• GEODETIC:	LONGITUDE,	LATITUDE,	ALTITUDE
• LATITUDINAL:	RANGE,	LONGITUDE,	LATITUDE
• RA/DEC:	RANGE,	RIGHT_ASCENSION,	DECLINATION
• SPHERICAL:	RANGE,	COLATITUDE,	LONGITUDE



Numeric - 2

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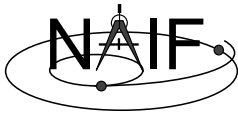
- Applicable operators:
 - > (quantity > reference_value)
 - = (quantity = reference_value)
 - < (quantity < reference_value)
 - ABSMAX (quantity)
 - ABSMIN (quantity)
 - LOCMAX (quantity)
 - LOCMIN (quantity)
- Examples of detectable events using a numeric event search:
 - periapsis or closest approach
 - » minimum distance between a body and center or between two bodies
 - apoapsis
 - » maximum distance between a body and center
 - pointing constraints
 - » angular separation between the look direction and Sun direction
 - boundary confinement
 - » a vehicle sub-point on a body lies within a latitude/longitude range
 - node crossings
 - » Z coordinate of a body position in equator based frame equals zero



Windows Math

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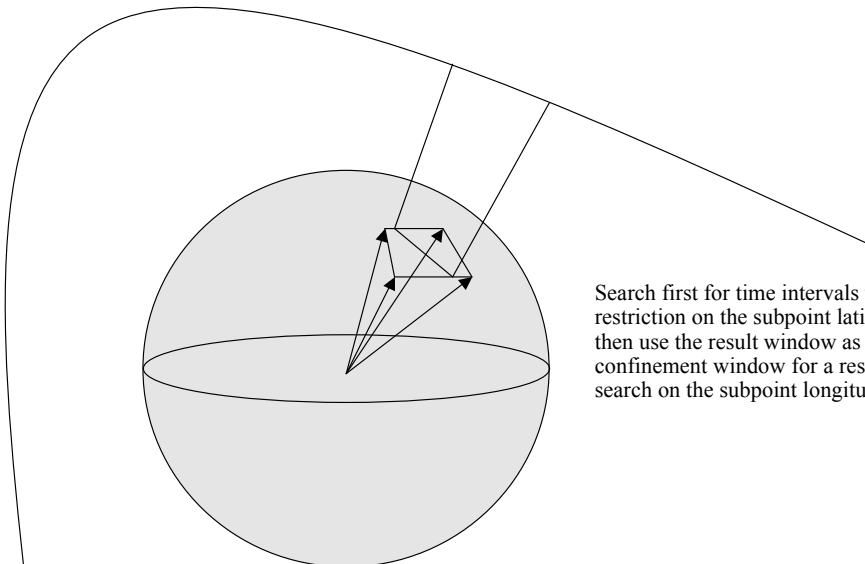
- The events subsystem uses the SPICE windows data type as an input, named the confinement window, to define the time intervals to search. A window is also used as an output, named the result window, during which the event of interest occurs.
 - Windows are collections of zero or more ordered, disjoint intervals of double precision numbers. The event finder subsystem uses windows to define the initial search times and final result times.
 - The Toolkit contains a family of routines for creating windows and performing “set arithmetic” on them (union, intersection, difference, etc.).
- This windows based implementation allows a user to perform multiple searches where the window result of one search is used as the input (confinement) for the next, either to satisfy a restriction on multiple conditions or as a refinement process.
 - Note, the physics of a multi-event geometry may be such that the search for one event will proceed faster than another and markedly reduce the measure of the search space for the next search.



Example - 1

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- Time interval for which the subpoint of a vehicle passes through a latitude/longitude “box.”



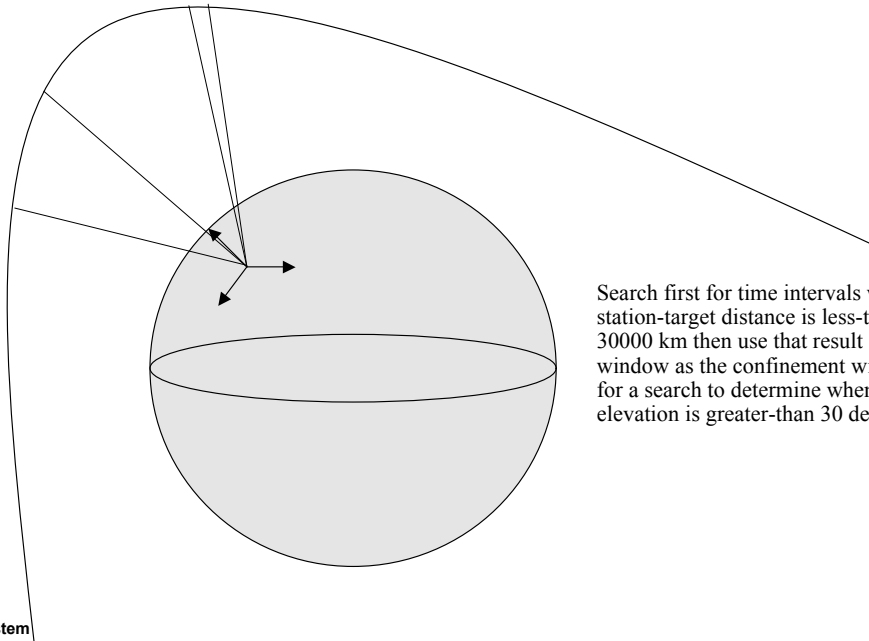
Search first for time intervals with the restriction on the subpoint latitude, then use the result window as the confinement window for a restriction search on the subpoint longitude.



Example - 2

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- Time intervals for which an orbiter passes in line-of-sight of a station, with a local elevation above 30 degrees, with a maximum distance of 30000 km.



Search first for time intervals where station-target distance is less-than 30000 km then use that result window as the confinement window for a search to determine when elevation is greater-than 30 degrees.