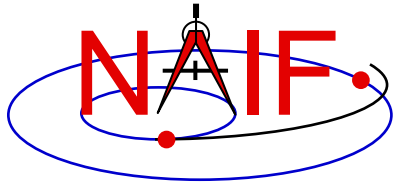


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Ephemeris Subsystem SPK

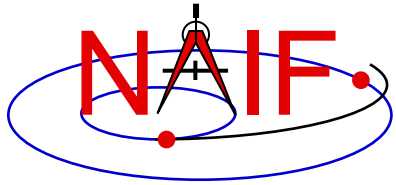
Focused on reading SPK files

January 2017



Navigation and Ancillary Information Facility

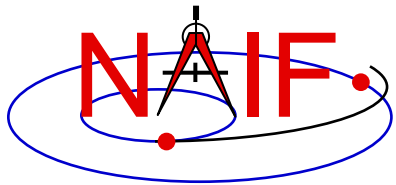
Overview of SPICE Ephemeris Data



A Picture is worth ...

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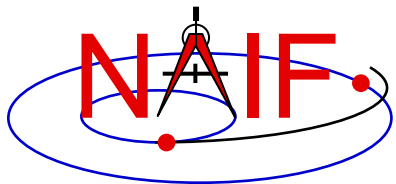
- **We'll start with a mostly pictorial view of ephemeris data and SPK files, just to ease you into this topic.**



SPICE Ephemeris Data

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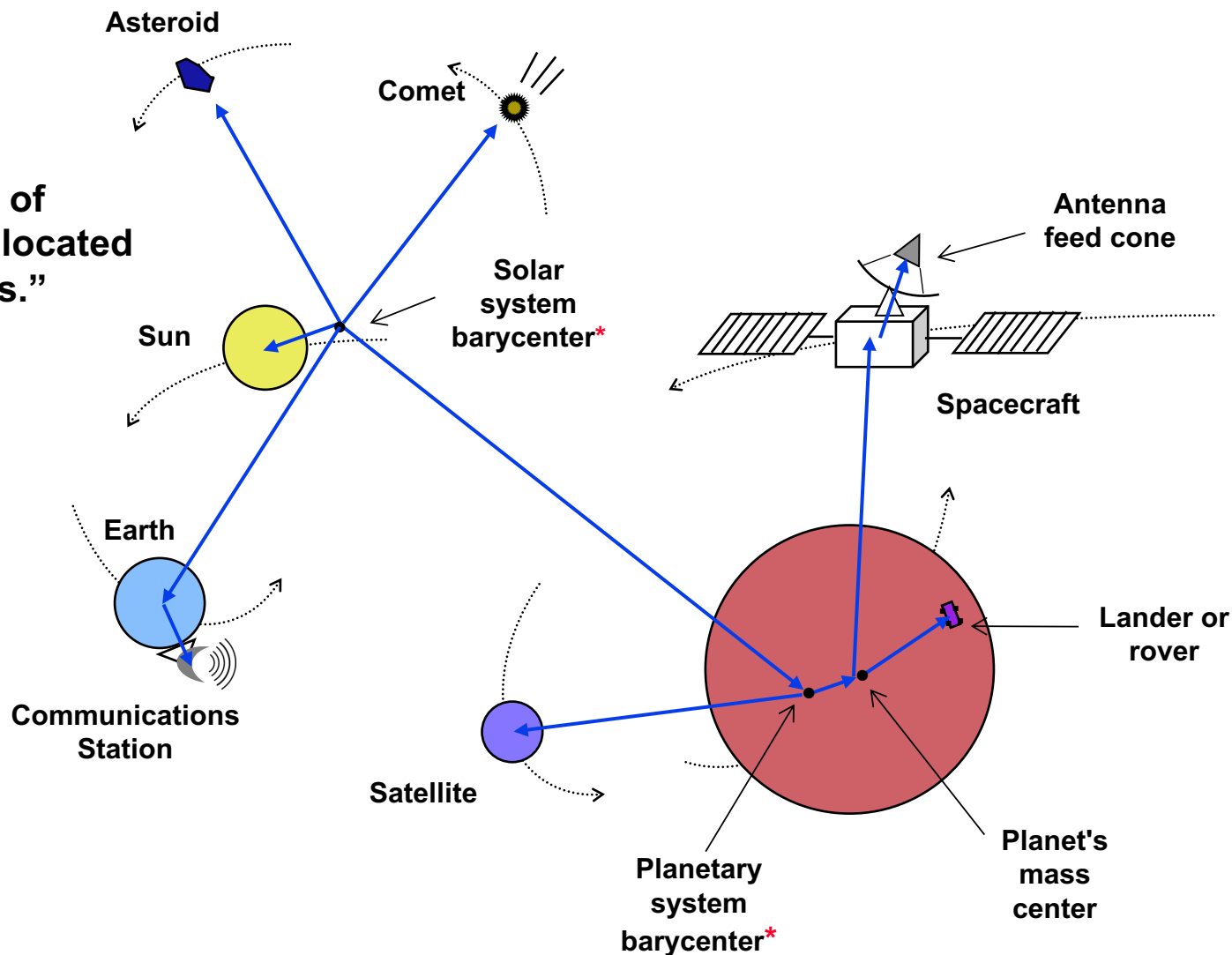
- **An SPK file contains ephemeris (trajectory) data for "ephemeris objects."**
 - “Ephemeris” means position and velocity as a function of time
 - » Position + velocity is often referred to as “state”
- **“Ephemeris objects” are spacecraft, planets, satellites, comets and asteroids.**
 - The following are also ephemeris objects:
 - » the center of mass of our solar system (solar system barycenter)
 - » the center of mass of a planet/satellite system (planet barycenter)
 - » a rover on the surface of a body
 - » a camera on top of a mast on a lander
 - » a transmitter cone on a spacecraft
 - » a deep space communications antenna on the earth
- **A single SPK file can contain data for multiple ephemeris objects, and often does**
- **See the next page for a pictorial representation of some of these objects.**



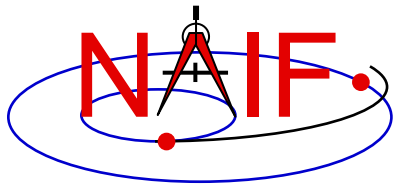
Examples of SPICE Ephemeris Objects

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The head and the tail of every **blue arrow** are located at “ephemeris objects.”



* A barycenter is the center of mass of a system of bodies, such as Saturn plus all of Saturn's satellites, or, the sun and all the planets, satellites, comets and asteroids in the solar system.

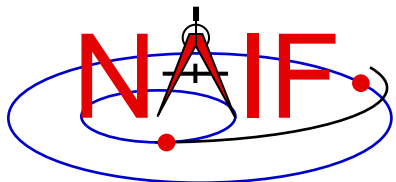


A Simple SPK File

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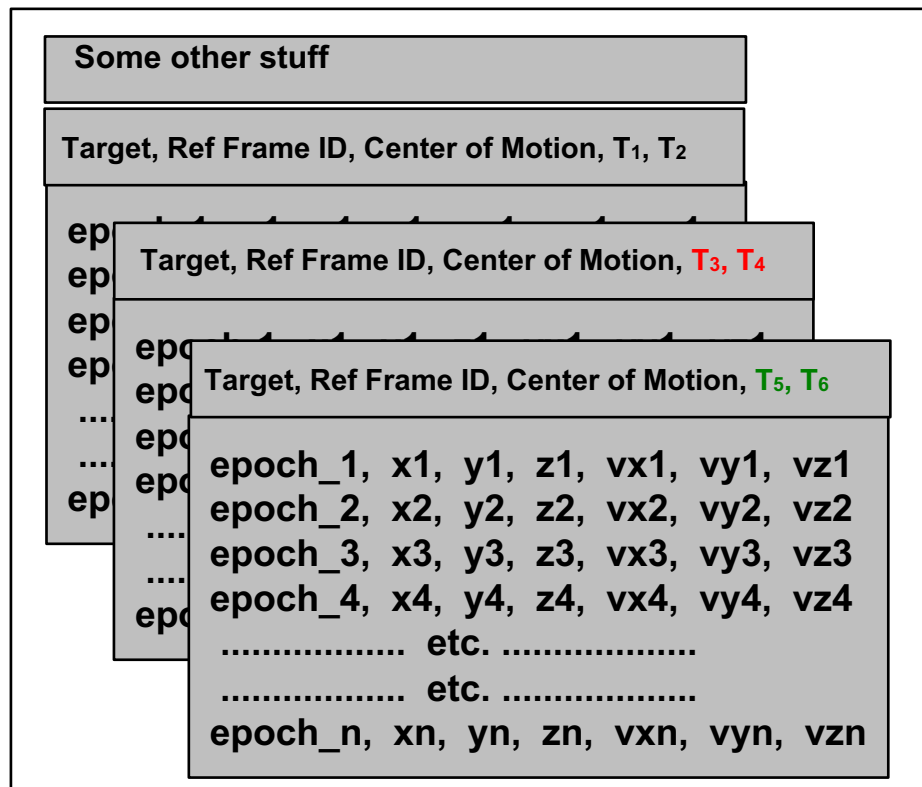
Some other stuff
Target, Ref Frame ID, Center of Motion, T_{start} , T_{stop}
epoch_1, x1, y1, z1, vx1, vy1, vz1
epoch_2, x2, y2, z2, vx2, vy2, vz2
epoch_3, x3, y3, z3, vx3, vy3, vz3
epoch_4, x4, y4, z4, vx4, vy4, vz4
..... etc.
..... etc.
epoch_n, xn, yn, zn, vxn, vyn, vzn

- **This very simple SPK file is made up of a single segment containing ephemeris data:**
 - for a single object (perhaps a spacecraft, an asteroid, or ...whatever)
 - given in a single reference frame (“coordinate frame”)
 - having a single center of motion
 - with data spanning from T_{start} to T_{stop}

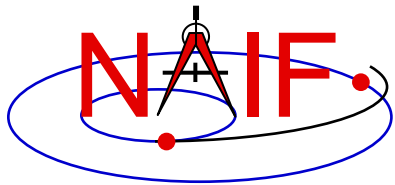


A More Substantial SPK File

Navigation and Ancillary Information Facility

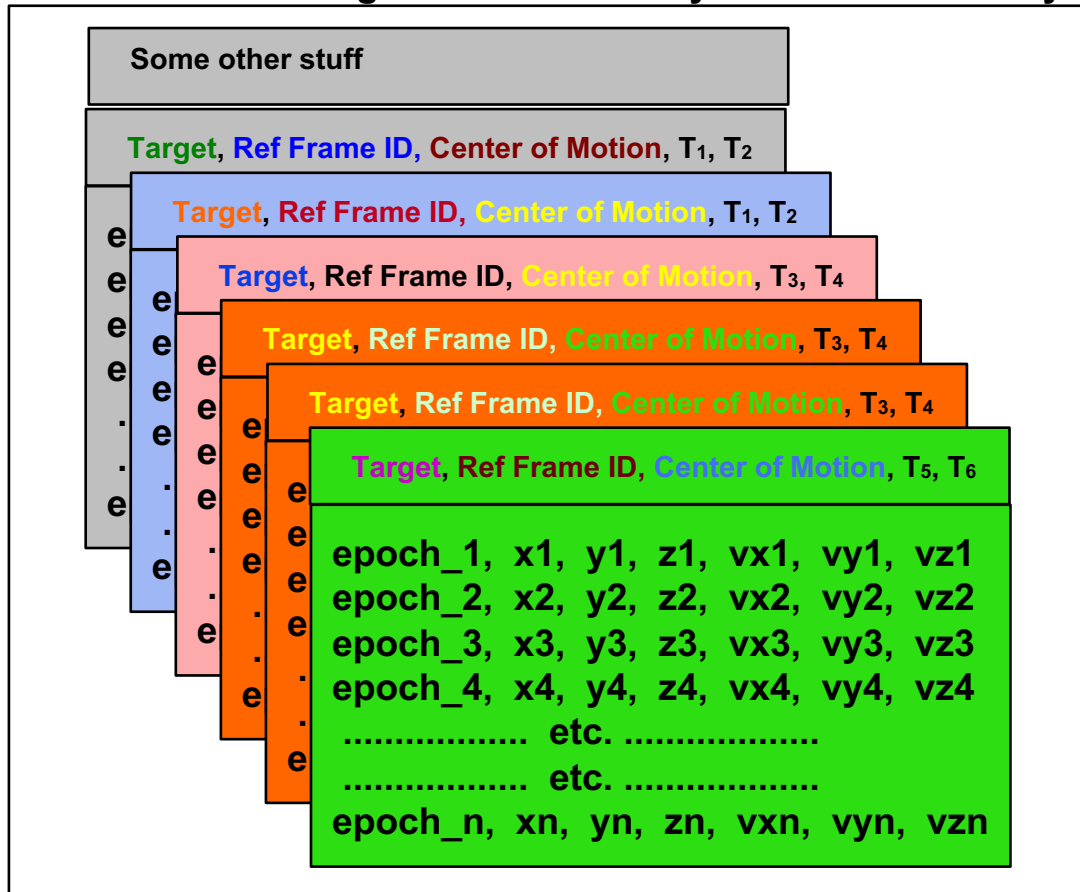


- **This more substantial SPK is made up of multiple segments containing ephemeris data:**
 - for a single object (perhaps a spacecraft, an asteroid, or ...???)
 - given in a single reference frame (“coordinate frame”)
 - having a single center of motion
 - with data spanning from T₁ to T₆

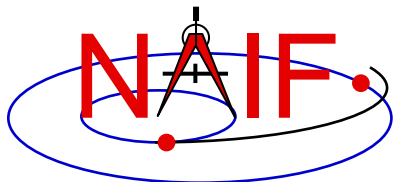


An Even More Substantial SPK File

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- This even more substantial SPK contains multiple segments having:
 - several objects
 - several reference frames
 - several centers of motion
 - several pairs of start and stop times



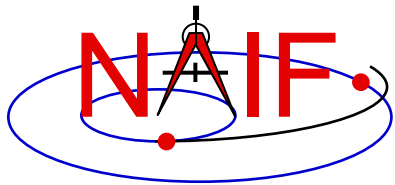
SPK Data are Continuous

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Cassini, Ref Frame ID, **Saturn bc**, T₁, T₂, Type 13

epoch_1, x1, y1, z1, vx1, vy1, vz1
epoch_2, x2, y2, z2, vx2, vy2, vz2
epoch_3, x3, y3, z3, vx3, vy3, vz3
epoch_4, x4, y4, z4, vx4, vy4, vz4

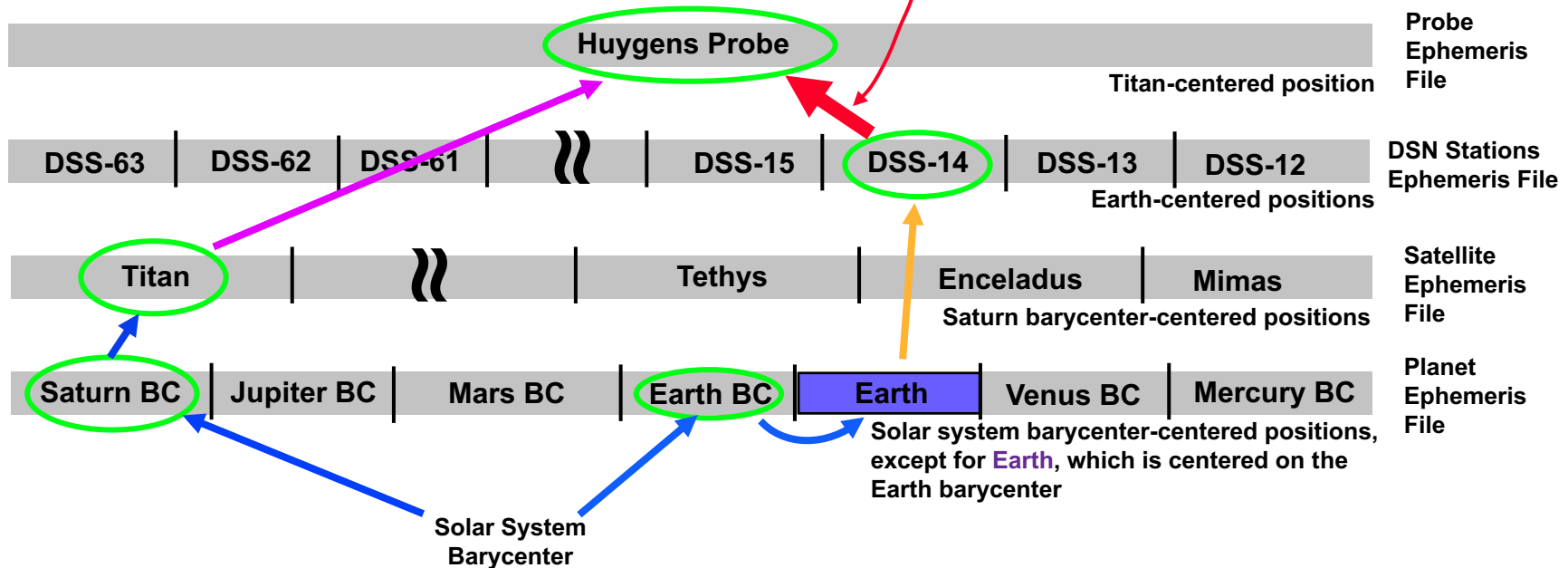
- Within the time bounds (T₁, T₂) of a segment, SPICE software will return a result—a state vector consisting of position and velocity—at **any** epoch... not just at the epochs of the ephemeris records
- In the example above, SPICE will return the position and velocity (the state) of the **Cassini spacecraft** relative to the **Saturn barycenter** at any time t where: $T_1 \leq t \leq T_2$

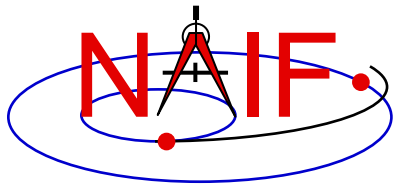


SPICE Chains SPK Data

Navigation and Ancillary Information Facility

- **SPICE automatically searches across all loaded SPK files to find the segments needed to compute the vectors needed to obtain the result the customer has asked for. SPICE chains these together using addition and subtraction.**
 - In this example the user wants the **position** of the Huygens probe sitting on the surface of Titan as seen from Deep Space Station 14.
 - SPICE computes this by chaining the **gold**, **blue** and **violet** chunks.









Automated Frame Transformation

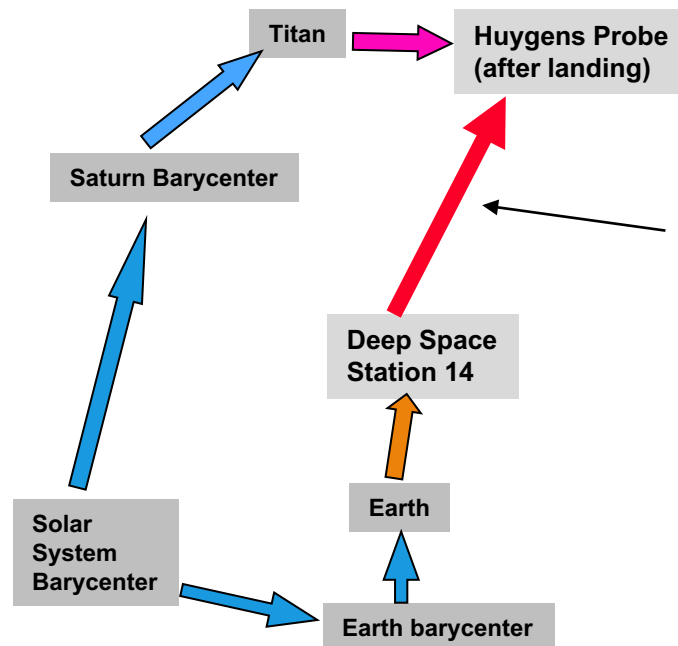
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- As part of the “chaining” process just mentioned...
 - position vectors are automatically rotated into a consistent reference frame
 - the final vector is rotated into the output reference frame requested by the user

Reference Frames Used

-  International Celestial Reference Frame (J2000)
-  Titan body-fixed frame (IAU_TITAN)
-  International Terrestrial Reference Frame (ITRF93)
-  DSS-14 topocentric reference frame (DSS-14_TOPO)

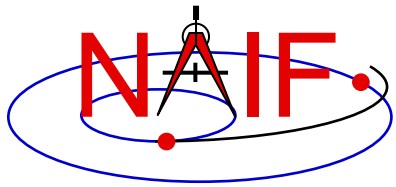
Ephemeris Segments Used



The **position** of the Huygens Probe relative to DSS-14, at time t , given in the DSS-14 topocentric reference frame, can be determined using a SINGLE Toolkit subroutine call.

A single subroutine call does it all!

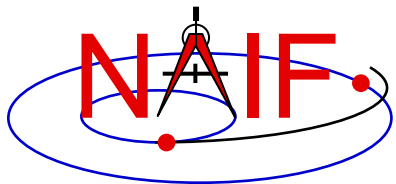
```
CALL SPKPOS ('HUYGENS_PROBE', t, 'DSS-14_TOPO', LT+S, 'DSS-14', POSITION, LT)
```



SPK Segment Order and Priority

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- **Within a single SPK file...**
 - The segments in an SPK file **need not be ordered** according to time or body.
 - But segment order **does imply priority**. If two segments from the same SPK file both contain data for a given target and time that satisfy a request, the SPK system selects the segment for which the **physical location** is positioned **later** in the file.
 - » The centers of motion, frames and SPK types are irrelevant to this selection.
- **If using two or more SPK files...**
 - Segments from SPK files loaded **later** have higher priority: if two segments from two different SPK files both contain data for a given target and time, the SPK system selects the segment from the SPK file that was loaded later.
 - » The centers of motion, frames and SPK types are irrelevant to this selection.



SPK File Coverage - 1

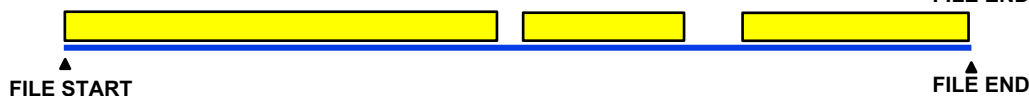
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- The time period over which an SPK file provides data for an ephemeris object is called the “coverage” or “time coverage” for that object.
 - An SPK file’s coverage for an object consists of one or more time intervals.
 - Often the coverage for all objects in an SPK file is a single, common time interval.

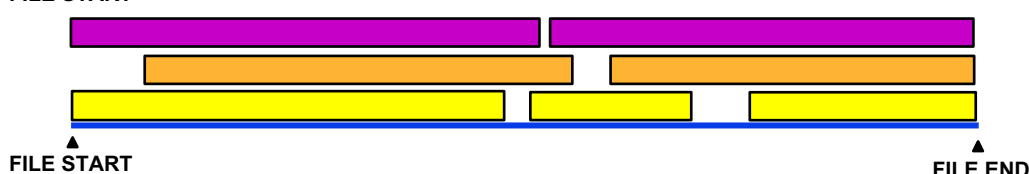
SPK file containing data for one object with no data gaps



SPK file containing data for one object, with two data gaps



SPK file containing data for three objects, each having different data gaps



SPK file containing data for three objects, each having different coverage but with no data gaps



SPK file containing data for several objects, each having the same coverage and with no data gaps

