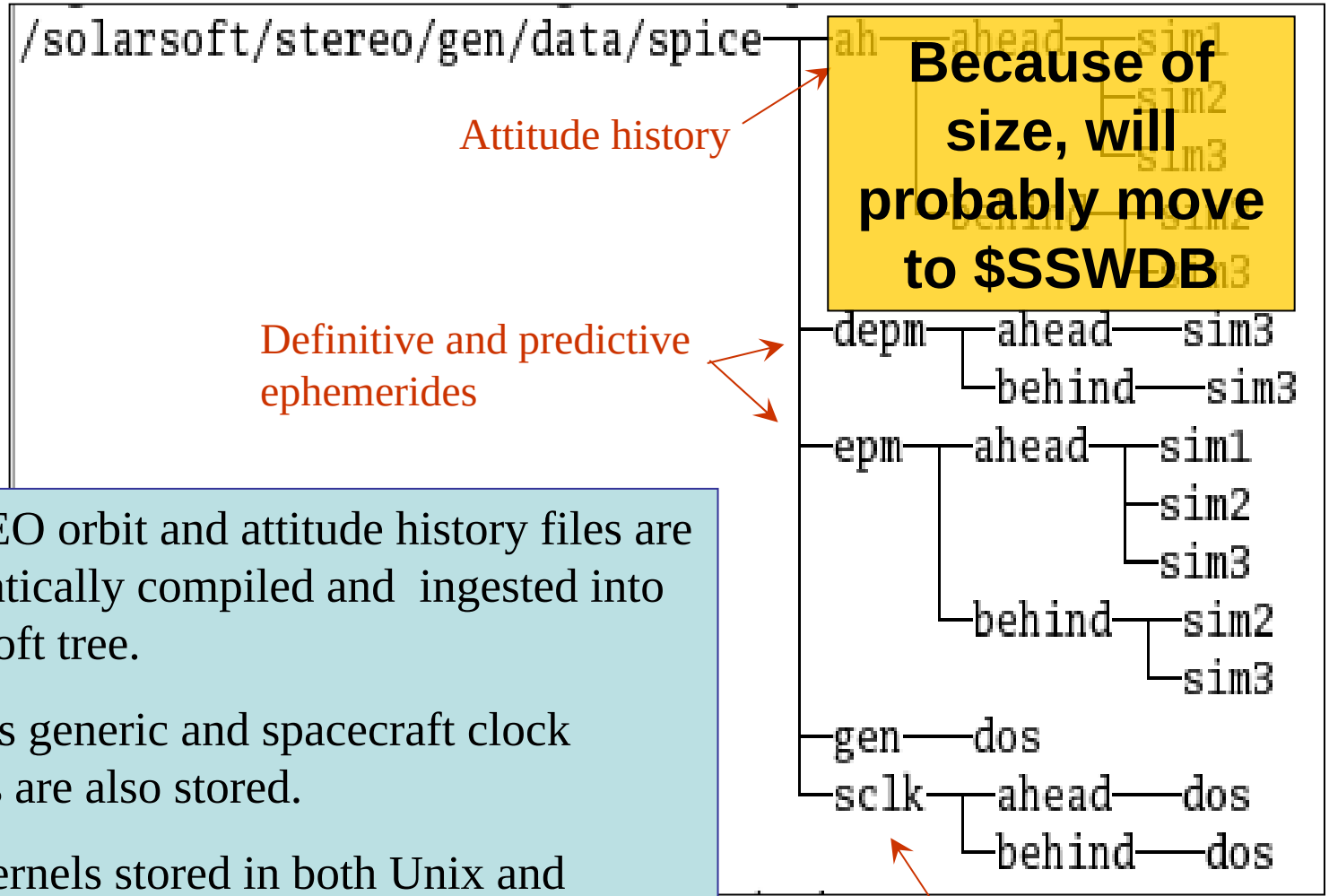
STEREO SPICE Tutorial

- It’s been the intention of the STEREO Science Center to make the use of SPICE kernels by the instrument teams as simple as possible
- The SSC has taken on the responsibility of organizing the SPICE orbit and attitude files, and writing general software to access them.
- All the software and data files are distributed as part of SolarSoft.
- We’ve also now gotten permission to distribute the SPICE/IDL library as part of SolarSoft

STEREO SPICE Kernels within SolarSoft



- STEREO orbit and attitude history files are automatically compiled and ingested into SolarSoft tree.
- Various generic and spacecraft clock kernels are also stored.
- Text kernels stored in both Unix and Windows formats—automatically selected.

SolarSoft Kernel Lists

```
ah/
attitude_history_ahead_sim1.dat
attitude_history_ahead_sim2.dat
attitude_history_ahead_sim3.dat
attitude_history_behind_sim2.dat
attitude_history_behind_sim3.dat
definitive_ephemerides_ahead_sim3.dat
definitive_ephemerides_behind_sim3.dat
depm/
ephemerides_ahead.dat
ephemerides_ahead_sim1.dat
ephemerides_ahead_sim2.dat
ephemerides_ahead_sim3.dat
ephemerides_behind.dat
ephemerides_behind_sim2.dat
ephemerides_behind_sim3.dat
epm/
gen/
sclk/
stereo_kernels.dbd
stereo_kernels.dbf
stereo_kernels.dbh
stereo_kernels.dbx
```

database

- Text files, in top directory, contain lists of current kernels, and the order to load them in.
- SolarSoft routines use these lists to know what kernels to load.
- Will be automatically generated during the mission.
- Database used to keep track of kernels.
- Example text files for Simulations 1, 2, and 3.

```
##################################################################
#  Sample pre-launch list of attitude history files from Mission Sim 3  #
##################################################################

sim3/ahead_2006_304_01.ah.bc
sim3/ahead_2006_305_01.ah.bc
sim3/ahead_2006_306_01.ah.bc
sim3/ahead_2006_307_01.ah.bc
sim3/ahead_2006_310_01.ah.bc
sim3/ahead_2006_311_01.ah.bc
```

Example text file

Running the Software

- Need to be fairly up-to-date with SolarSoft
- Select one or more STEREO instruments, and set up SolarSoft, e.g.

```
> setenv SSW_INSTR "ssc secchi"
> source $SSW/gen/setup/setup.ssw
```

- Running “sswidl” should produce a message like the following:

```
Registering DLM /.../lib/icy.dlm
```

- On Solaris, one must use “sswidl -32” to run IDL in 32-bit mode.

Spacecraft Positions

- The basic routine for deriving spacecraft coordinates (and velocities) is GET_STEREO_COORD, e.g.

  Coord = GET_STEREO_COORD(Date, ‘Ahead’)

- Can also be used for Sun, Moon, or planets.
- Supports a wide variety of coordinate systems through the SYSTEM keyword (e.g. SYSTEM=‘GSE’). Default is HCI.
- SPICE kernels will be automatically loaded the first time the routine is called.
- CONVERT_STEREO_COORD can be used to convert between coordinate systems, e.g.

  CONVERT_STEREO_COORD, Date, Coord, ‘HCI’, ‘GSE’

  converts from HCI to GSE coordinates

Longitude and Latitude

- GET_STEREO_LONLAT returns the position as a radial distance, longitude, and latitude, e.g.

  LonLat = GET_STEREO_LONLAT(Date, ‘Ahead’)

- Accepts same keywords as GET_STEREO_COORD.
- CONVERT_STEREO_LONLAT can be used to convert between coordinate systems, e.g.

  CONVERT_STEREO_LONLAT, Date, LonLat, ‘HCI’, ‘GSE’

  converts from HCI to GSE coordinates.

- Can be used for converting star positions.

Spacecraft Attitude

- Basic routine for returning the spacecraft attitude is GET_STEREO_CMAT, e.g.

  Cmat = GET_STEREO_CMAT(Date, ‘Ahead’)

- Attitude returned as a C-matrix formed of the **x**, **y**, and **z** unit vectors, such that, in IDL,

  $V_{INSTRUMENT}$ = Transpose(Cmat) # $V_{REFERENCE}$

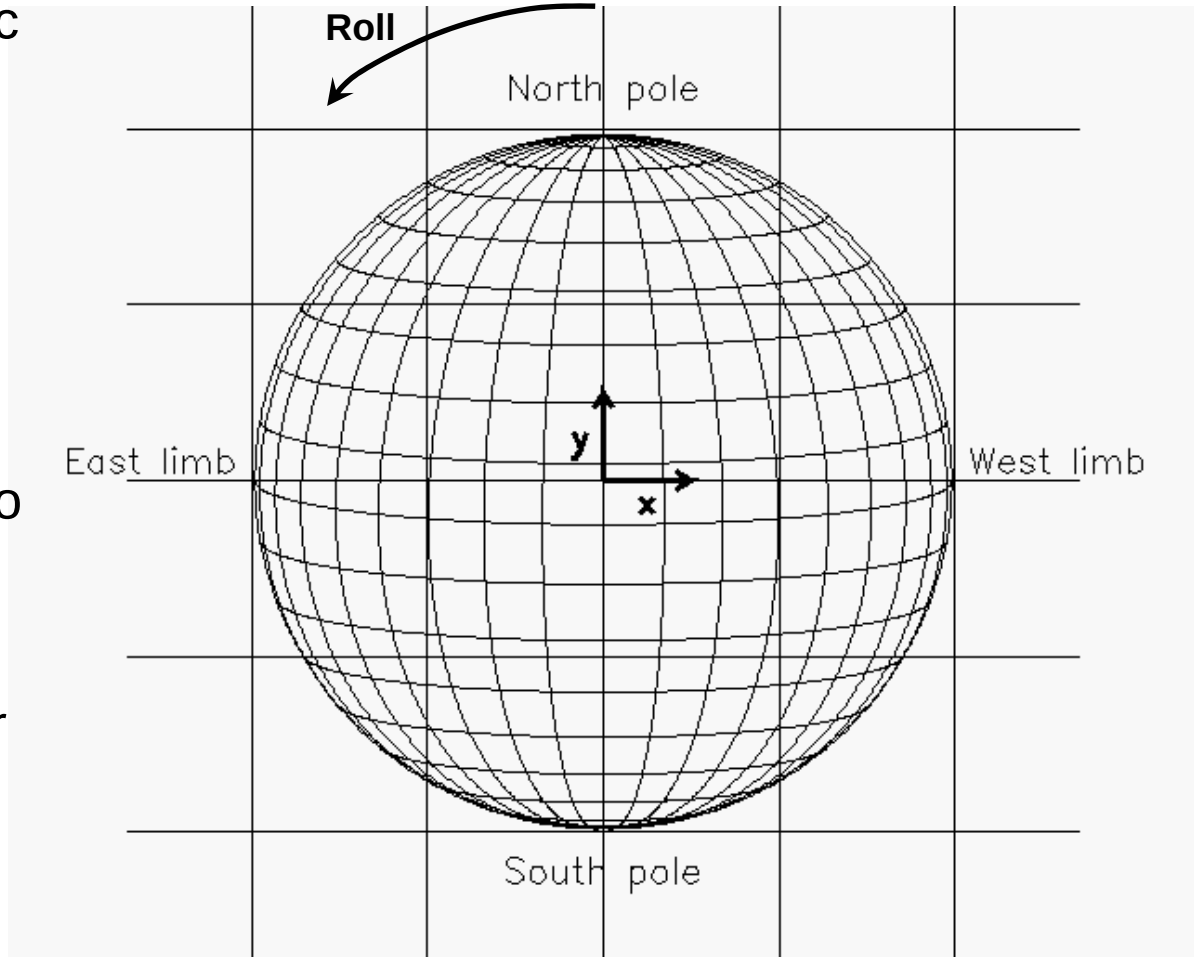
  (where $V_{INSTRUMENT}$ and $V_{REFERENCE}$ are row vectors).

- Recent change will return “predicted” attitude for dates without an attitude history file.
  - Assumes perfect alignment in STEREO Science Pointing coordinate system
  - Only works for dates covered by an ephemeris file.

Spacecraft Attitude as Angles

- GET_STEREO_HPC_POINT returns pointing as used within FITS files

- X and Y pointing in arc seconds, relative to disk center.
- Roll in degrees from solar north. Diagram shows direction of spacecraft rotation--image would appear to rotate in opposite direction
- *Do we need any other derived pointing products?*



Miscellaneous Routines

- **GET_STEREO_CARR_ROT**: Returns Carrington rotation number of subsolar point.
- **GET_STEREO_SEP_ANGLE**: Returns separation angle between spacecraft or other bodies.
- **STEREO_COORD_INFO**: Prints out synopsis of spacecraft positions.

Maintenance routines

- **SPICE_KERNEL_REPORT**: Reports which kernels are loaded.
- **GET_STEREO_SPICE_RANGE**: Reports the time range covered by a SPICE kernel.
- **GET_STEREO_KERNEL**: Reports which ephemeris or attitude history file is being used for a given date and spacecraft.

Loading Kernels

- Normally, the loading of kernels is automatic.
- One can load kernels by hand through LOAD_STEREO_SPICE
  - To load kernels from the mission simulation (e.g. /SIM3)
  - To reload kernels (with /RELOAD keyword)
  - To load specific kernels
- Use LOAD_STEREO_SPICE_GEN to load only the generic kernels (planetary ephemerides, leap seconds, spacecraft clocks, frame definitions).
- Multiple calls won't do anything unless called with /RELOAD. That allows LOAD_STEREO_SPICE to be embedded within routines without causing unnecessary reloading.
- Also UNLOAD_STEREO_SPICE & UNLOAD_STEREO_SPICE_GEN

Positional Coordinate Systems—Geocentric

GEI	Geocentric Equatorial Inertial	X=First point of Aries, Z=Geographic north pole
GEO	Geographic	X=Greenwich meridian on equator Z=Geographic north pole
GSE	Geocentric Solar Ecliptic	X=Earth-Sun line Z=Ecliptic north pole
MAG	Geomagnetic	Z=Dipole axis X=along meridian containing dipole axis Y=along geographic equator
GSM	Geocentric Solar Magnetospheric	X=Earth-Sun line Z=projection of dipole axis
SM	Solar Magnetic	Z=dipole axis Y=perpendicular to Earth-Sun line

Positional Coordinate Systems—Heliocentric

HCI	Heliocentric Inertial (default)	Z=Solar rotational axis X=Solar ascending node on ecliptic
HAE	Heliocentric Aries Ecliptic	X=First point of Aries Z=Ecliptic north pole
HEE	Heliocentric Earth Ecliptic	X=Sun-Earth line Z=Ecliptic north pole
HEEQ	Heliocentric Earth Equatorial	Z=Solar rotational axis X=Along solar central meridian as seen from Earth
CARR	Carrington Heliographic	Z=Solar rotational axis X=Along Carrington prime meridian

Pointing Coordinate Systems

HGRTN	Heliocentric Radial-Tangential-Normal	X=Sun-spacecraft line Z=Projection of solar rotational axis
RTN	Radial-Tangential-Normal (default) (spacecraft-centered)	Same as HGRTN (only origin is different)
HPC	Helioprojective-Cartesian (FITS files—used by GET_STEREO_HPC_POINT)	Z=Sun-spacecraft line Y=Projection of solar rotational axis (Differs from RTN only in notation—not supported by GET_STEREO_COORD)
HERTN	Heliocentric Ecliptic RTN *(New)*	X=Sun-spacecraft line Z=Projection of ecliptic north pole
SCI	STEREO Science Pointing	X=Spacecraft-Sun line Z=Projection of Earth-spacecraft line (Ahead upside-down)
STPLN	STEREO Mission Plane (*New—for stereo pairs*)	X=Spacecraft-Sun line X-Y plane contains both spacecraft