SMOS: UTC TIME TO LONGITUDE - LATITUDE TOOL

1. DESCRIPTION OF THE EXECUTABLE ROUTINES

The following items have been delivered as part of the UTC to Longitude/Latitude tool:

- Linux 32-bit executables:
  - `utc2lonlat_tools/LINUX/utc2lonlat`
  - `utc2lonlat_tools/LINUX/utc2lonlatfile`
- Linux 64-bit executables:
  - `utc2lonlat_tools/LINUX64/utc2lonlat`
  - `utc2lonlat_tools/LINUX64/utc2lonlatfile`
- Windows 32-bit executables:
  - `utc2lonlat_tools/WINDOWS/utc2lonlat.exe`
  - `utc2lonlat_tools/WINDOWS/utc2lonlatfile.exe`
  - Auxiliary libraries:
    - `utc2lonlat_tools/WINDOWS/libxml2.dll`
    - `utc2lonlat_tools/WINDOWS/iconv.dll`
    - `utc2lonlat_tools/WINDOWS/zlib1.dll`
    - `utc2lonlat_tools/WINDOWS/pthreadVC2.dll`
- Example data files:
  - Input telemetry file:
    - `utc2lonlat_tools/input/PVT__combined_20100108T090222.txt`
  - Input SMOS Orbit Scenario File:
    - `utc2lonlat_tools/input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF`
  - Output file:
    - `utc2lonlat_tools/output/output_data.txt`

Details about each one of these items and some usage hints are given in the next sections.

1.1 Change history

Issue	Change Description	Date
1.0	First version	25/01/2010
1.1	Compute directions to Sun (azimuth and elevation)	18/10/2010
1.2	Support POF/ROF as input. Use time correlations from file. Add longitude and latitude of the intersection of the boresight direction with the Earth	14/05/2011
1.3	Compute minimum and maximum Sun elevation in orbit	16/06/2011
1.4	Bug fix: under some circumstances, the minimum and maximum Sun elevation angles are not calculated	23/07/2012

2. EXAMPLE PROGRAM INTERFACE DESCRIPTION

2.1 Executable program *utc2lonlat*

For the requested UTC time, the executable program *utc2lonlat* computes, among other parameters, the geocentric longitude and geodetic latitude of the sub-satellite point. It requires a SMOS Orbit Scenario File as input. The data generated by the executable is provided via the standard output.

2.1.1 Command line input parameters description

The command line parameters of the executable routine are the following (provided in the order in which they have to be supplied):

- orbit_scenario_filename : Filename of the SMOS Orbit Scenario File. It may include the path.
- utc_time: Requested UTC time in CCSDS-A ascii time format "yyyy-mm-ddThh:mm:ss.uuuuuu"
- attitude_mode: allowed values NOMINAL, ZENITH or INERTIAL
  If the attitude mode is INERTIAL, additional parameters need to be supplied as input:
  - start_utc_time_inertial: Service Request Start UTC time in CCSDS-A ascii time format "yyyy-mm-ddThh:mm:ss.uuuuuu"
  - inertial_ra: Right_Ascension in J2000 [deg]
  - inertial_dec: Declination in J2000 in [deg]

2.1.2 Command line output parameters description

The following parameters are given as output:

Orbit Number
Seconds since ANX
Geocentric Longitude of the SSP [deg]
Geodetic Latitude of the SSP [deg]
Geodetic Altitude of the SC [m]
[X,Y,Z] in meters (Earth-Fixed CS)
Sun Azimuth in Attitude Frame [deg]
Sun Elevation in Attitude Frame [deg]
Sun Xi
Sun Eta
Sun Visibility Flag (0=ECLIPSE; 1=VISIBLE)
Geocentric Longitude of the Boresight [deg]
Geodetic Latitude of the Boresight [deg]
Minimum Sun Elevation in orbit (assuming the same attitude mode for the complete orbit) [deg]
Maximum Sun Elevation in orbit (assuming the same attitude mode for the complete orbit) [deg]

Note: The Geocentric Longitude and Geodetic Latitude of the intersection point of the Boresight line-of-sight with the Earth ellipsoid are set to zero for attitude modes INERTIAL and ZENITH.

2.1.3 Examples

2.1.3.1 Nominal Attitude

The executable program can be called in the following way:

- From Linux shell

```
./utc2lonlat  ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF 2010-02-03T12:00:00.000000 NOMINAL
```

- From Windows command prompt window

```
utc2lonlat.exe  ..\input\SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF 2010-02-03T12:00:00.000000 NOMINAL
```

The executable program shows the following messages and output data:

```
UTC2LONLAT v1.4: MANUAL MODE
----------------------------

Input data:
```

```
UTC Time: 2010-02-03T12:00:00.000000
Orbit File: ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF
Attitude Mode: NOMINAL

Output data:
UTC Time: 2010-02-03T12:00:00.000000
Orbit Number: 1344
Seconds since ANX: 2784.912594
Geocentric Longitude [deg]: 91.913037
Geodetic Latitude [deg]: 12.702785
Geodetic Altitude [m]: 761294.422137
[X,Y,Z] in meters (Earth-Fixed CS): [-232532.852852, 6961810.570578, 1560752.068995]
Sun Azimuth in Attitude Frame [deg]: 66.089215
Sun Elevation in Attitude Frame [deg]: 16.927614
Sun Xi: -0.874569
Sun Eta: 0.387753
Sun Visibility Flag (0=ECLIPSE; 1=VISIBLE): 1
Geocentric Longitude of the Boresight [deg]: 90.933239
Geodetic Latitude of the Boresight [deg]: 8.306513
Minimum and Maximum Sun Elevation in orbit 1344 [deg]: -26.198571 26.213028
```

2.1.3.2 *Zenith Attitude*

The executable program can be called in the following way:

- From Linux shell

```
./utc2lonlat  ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF 2010-02-03T12:00:00.000000 ZENITH
```

- From Windows command prompt window

```
utc2lonlat.exe  ..\input\SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF 2010-02-03T12:00:00.000000 ZENITH
```

The executable program shows the following messages and output data:

```
UTC2LONLAT v1.4: MANUAL MODE
----------------------------

Input data:
UTC Time: 2010-02-03T12:00:00.000000
Orbit File: ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF
Attitude Mode: ZENITH

Output data:
UTC Time: 2010-02-03T12:00:00.000000
Orbit Number: 1344
Seconds since ANX: 2784.912594
Geocentric Longitude [deg]: 91.913037
Geodetic Latitude [deg]: 12.702785
Geodetic Altitude [m]: 761294.422137
[X,Y,Z] in meters (Earth-Fixed CS): [-232532.852852, 6961810.570578, 1560752.068995]
Sun Azimuth in Attitude Frame [deg]: 115.057203
Sun Elevation in Attitude Frame [deg]: -2.112565
Sun direction in Attitude Frame: (-0.905270 0.423235 0.036863)
Sun Xi: -0.905270
Sun Eta: -0.423235
Sun Visibility Flag (0=ECLIPSE; 1=VISIBLE): 1
Geocentric Longitude of the Boresight [deg]: 0.000000
Geodetic Latitude of the Boresight [deg]: 0.000000
Minimum and Maximum Sun Elevation in orbit 1344 [deg]: -25.157898 25.142827
```

2.1.3.3 *Inertial Attitude*

The executable program can be called in the following way:

- From Linux shell

```
./utc2lonlat  ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF 2010-02-03T12:00:00.000000 INERTIAL 2010-02-03T12:00:00.000000 45.0 12.5
```

- From Windows command prompt window

```
utc2lonlat.exe  ..\input\SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF 2010-02-03T12:00:00.000000 INERTIAL 2010-02-03T12:00:00.000000 45.0 12.5
```

The executable program shows the following messages and output data:

```
UTC2LONLAT v1.4: MANUAL MODE
----------------------------

Input data:
UTC Time: 2010-02-03T12:00:00.000000
Orbit File: ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF
Attitude Mode: INERTIAL
Inertial Pointing Start UTC Time: 2010-02-03T12:00:00.000000
Inertial Pointing Right Ascension J2000 [deg]: 45.000000
Inertial Pointing Declination J2000 [deg]: 12.500000

Output data:
UTC Time: 2010-02-03T12:00:00.000000
Orbit Number: 1344
Seconds since ANX: 2784.912594
Geocentric Longitude [deg]: 91.913037
Geodetic Latitude [deg]: 12.702785
Geodetic Altitude [m]: 761294.422137
[X,Y,Z] in meters (Earth-Fixed CS): [-232532.852852, 6961810.570578, 1560752.068995]
Sun Azimuth in Attitude Frame [deg]: 115.061655
Sun Elevation in Attitude Frame [deg]: -2.055360
Sun Xi: -0.905270
Sun Eta: -0.423321
Sun Visibility Flag (0=ECLIPSE; 1=VISIBLE): 1
Geocentric Longitude of the Boresight [deg]: 0.000000
Geodetic Latitude of the Boresight [deg]: 0.000000
Minimum and Maximum Sun Elevation in orbit 1344 [deg]: -2.059609 -2.042104
```

2.2 Executable program *utc2lonlatfile*

For a list of UTC times (extracted from a telemetry file provided as input), the executable program *utc2lonlatfile* computes, among other parameters, the list of geocentric longitudes and geodetic latitudes of the sub-satellite point. It requires a SMOS Orbit Scenario File as input. The data generated by the executable is stored in an output file.

2.2.1 Command line input parameters description

The command line parameters of the executable routine are the following (provided in the order in which they have to be supplied):

- orbit_scenario_filename : Filename of the SMOS Orbit Scenario File. It may include the path.
- telemetry_filename : Filename of the Telemetry file. It may include the path.
- output_filename: Filename of the output file. It may include the path.
- attitude_mode: allowed values NOMINAL, ZENITH or INERTIAL
  If the attitude mode is INERTIAL, additional parameters need to be supplied as input:
  - start_utc_time_inertial: Service Request Start UTC time in CCSDS-A ascii time format "yyyy-mm-ddThh:mm:ss.uuuuuu"
  - inertial_ra: Right_Ascension in J2000 [deg]
  - inertial_dec: Declination in J2000 in [deg]

2.2.2 Input Telemetry file

Excerpt of the input telemetry file *PVT__combined_20100108T090222.txt*:

```
# Exported Parameter(s) from GRAINS
# Parameter List:
SPC00174        SPC00176        SPC00178
# Time Window Start (Date, Time, DOY):
2010-004T00:00:00.182Z
# Time Window End (Date, Time, DOY):
2010-004T00:59:59.014Z
# Number of samples (per parameter and total):
3000    3000    3000    9000
# Number of parameters:
3
# Name  Unit    Description     Data Type       Max     Min     Avg     StdDev
SPC00174                PVT_X_Pos       sInt    605569713.000000        -694953856.000000    -
257763482.367667        414749337.370943
SPC00176                PVT_Y_Pos       sInt    87979803.000000 -194494629.000000       -97181
325.730000      81805788.688480
SPC00178                PVT_Z_Pos       sInt    649621754.000000        -706826621.000000    -
234070084.460000        448063009.089051
# DATE  TIME    SPC00174        SPC00176        SPC00178
2010-004T00:00:00.182Z  605569713       87979803        -368626637
2010-004T00:00:01.382Z  605008115       87695519        -369616530

[…]
```

2.2.3 Output file format description

The format of the output file is the following:

- Column 1: UTC Time in CCSDS-A ASCII format “yyyy-mm-ddThh:mm:ss.uuuuuu”
- Column 2: Orbit Number
- Column 3: Seconds since ascending node crossing
- Column 4: Geocentric Longitude of the SSP [deg]
- Column 5: Geodetic Latitude of the SSP [deg]
- Column 6: Geodetic Altitude of the SC [m]
- Column 7: X Coordinate of the Earth Fixed position vector [m]
- Column 8: Y Coordinate of the Earth Fixed position vector [m]
- Column 9: Z Coordinate of the Earth Fixed position vector [m]
- Column 10: Sun Azimuth angle in Attitude Frame [deg]
- Column 11: Sun Elevation angle in Attitude Frame [deg]
- Column 12: Sun Xi component
- Column 13: Sun Eta component
- Column 12: Sun Visibility Flag (ECLIPSE=0; VISIBLE=1)
- Column 14: Geocentric Longitude of the intersection point of the Boresight line-of-Sight with the Earth ellipsoid [deg]
- Column 15: Geodetic Latitude of the intersection point of the Boresight line-of-Sight with the Earth ellipsoid [deg]
- Column 16: Minimum Sun Elevation in orbit (assuming the same attitude mode for the complete orbit) [deg]
- Column 17: Maximum Sun Elevation in orbit (assuming the same attitude mode for the complete orbit) [deg]

Note: The Geocentric Longitude and Geodetic Latitude of the intersection point of the Boresight line-of-sight with the Earth ellipsoid are set to zero for attitude modes INERTIAL and ZENITH.

Excerpt of example output file *output_data.txt*:

```
# UTC Time    Orbit Number    Seconds since ANX        Geocentric Longitude [deg]   Geodetic
Latitude [deg]   Geodetic Altitude [m]    (X,Y,Z) in meters (Earth-Fixed CS)  Sun Azimuth [deg]
Sun Elevation [deg]  Sun Xi  Sun Eta   Sun Visibility Flag     Boresight Geocentric Longitude
[deg]     Boresight Geodetic Latitude [deg]  Minimum Sun Elevation in orbit [deg]   Maximum Sun
Elevation in orbit [deg]
# ------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
-----------------
2010-01-04T00:00:00.182000    905    3550.766101    264.524831     -32.887837     772140.855441
       -573405.339752 -5982215.171477 -3862789.167228       56.233610      -0.072316      -
0.831310       0.555808       1       263.229853     -37.315750     -32.438082     32.445781
2010-01-04T00:00:01.382000    905    3551.966101    264.504895     -32.958767     772170.171733
       -575029.919481 -5977266.831822 -3870210.436850       56.238389      -0.110899      -
0.831355       0.555738       1       263.208157     -37.386683     -32.438082     32.445781
[…]
```

2.2.4 Example

The executable program can be called in the following way:

- From Linux shell

```
./utc2lonlatfile  ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF
../input/PVT__combined_20100108T090222.txt ../output/output_data.txt NOMINAL
```

- From Windows command prompt window

```
utc2lonlatfile.exe  ..\input\SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF
..\input\PVT__combined_20100108T090222.txt ..\output\output_data.txt NOMINAL
```

The executable program shows the following messages:

```
UTC2LONLAT v1.4: FILE MODE
--------------------------

Input data:
Orbit Scenario File: ../input/SM_OPER_MPL_ORBSCT_20091102T031142_20251231T000000_331_008_1.EEF
Telemetry File: PVT__combined_20100108T090222.txt
Attitude Mode: NOMINAL
Output File: ./output/output_data.txt

Output file created successfully
```

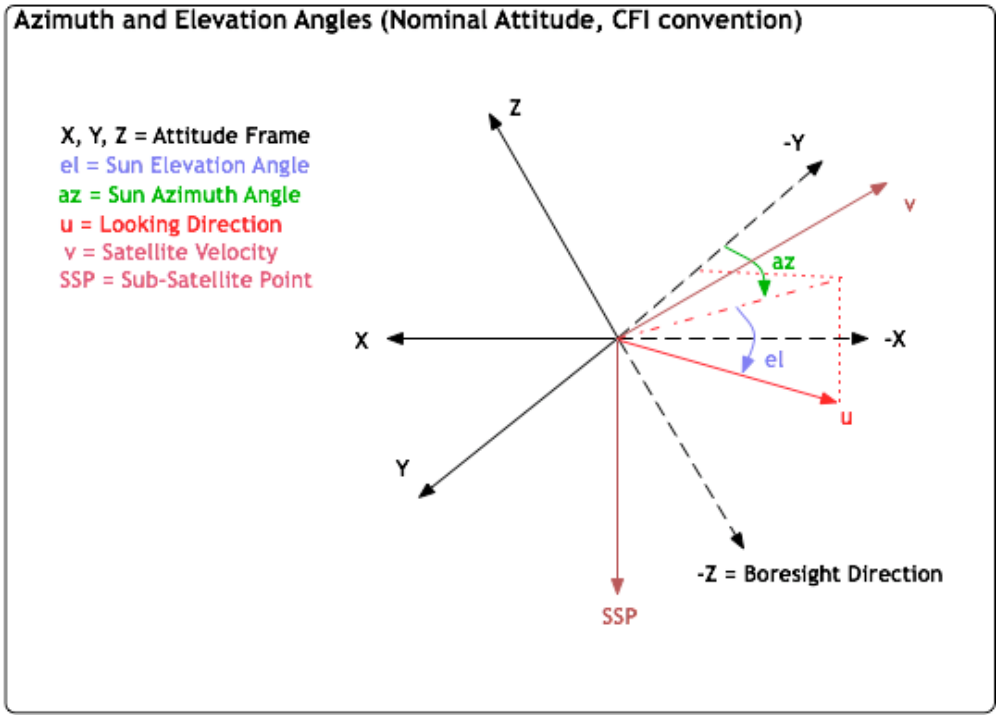
Note: For attitude modes ZENITH and INERTIAL, the command line would have to be modified equivalently to examples in sections 2.1.3.2. and 2.1.3.3.

3. ANNEX

3.1 Nominal Attitude

3.1.1 Azimuth and Elevation Angles in Attitude Frame (CFI Convention)

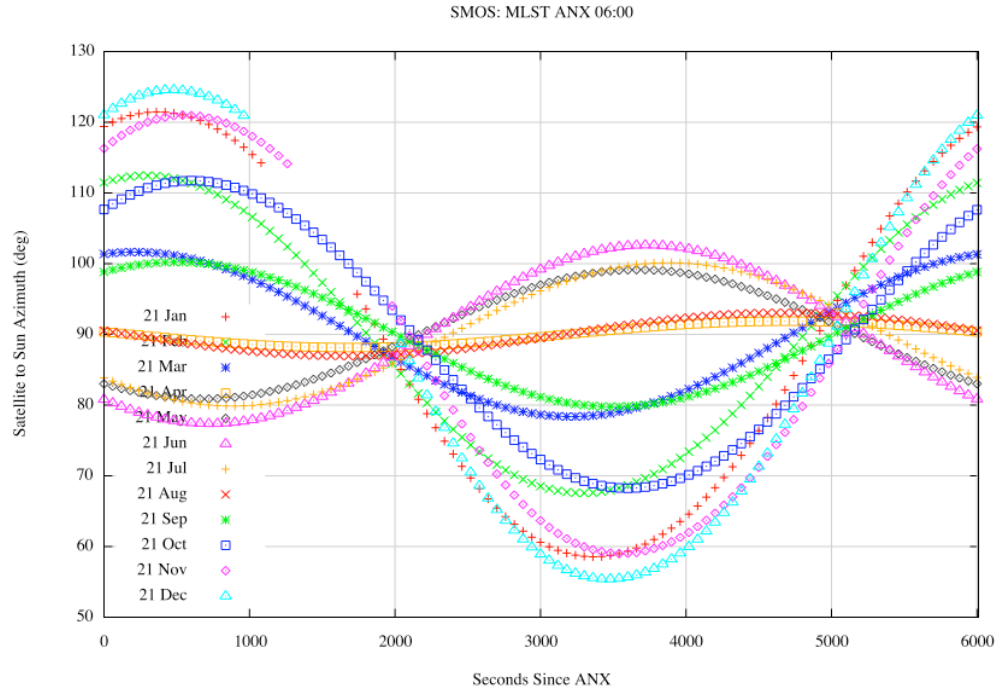
The following convention for Azimuth and Elevation angles is assumed:

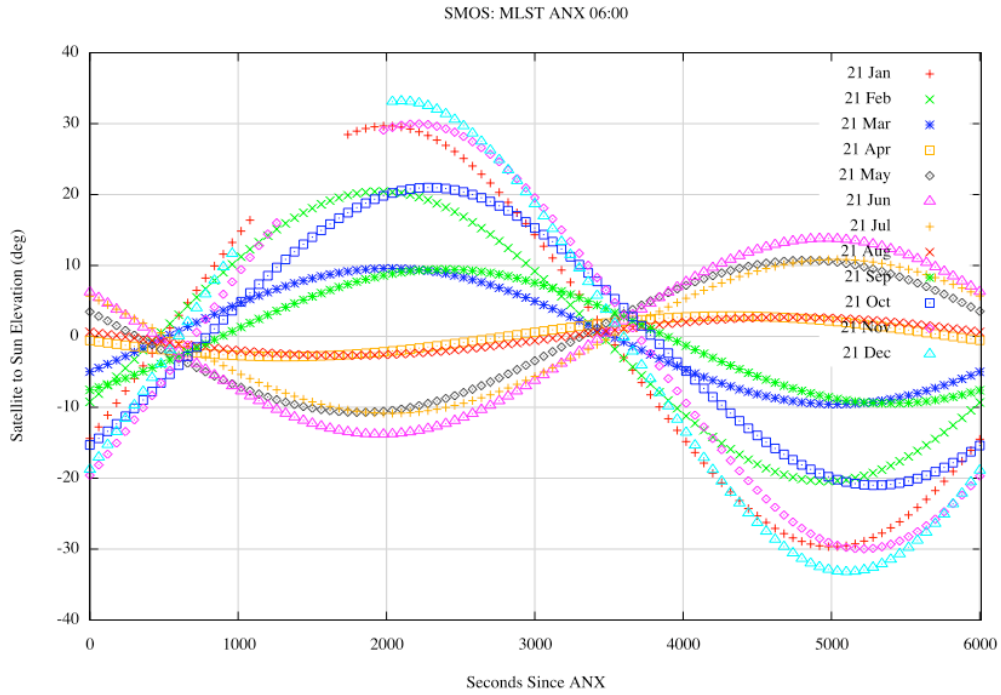


The Elevation Angle (allowed range between [-90, +90]) is positive when pointing downwards (-Z = elevation 90 degrees).
The Azimuth Angle (allowed range between [0, 360)) is positive from –Y towards –X.

3.1.2 Evolution of Sun Azimuth and Sun Elevation Angles

The following plots show the evolution of the direction to the Sun (expressed as Azimuth and Elevation angles wrt Nominal Attitude Frame) along an orbit. In order to represent the annual variation of the pointing direction to the Sun, one curve for each month is provided. The gaps correspond to periods in eclipse.

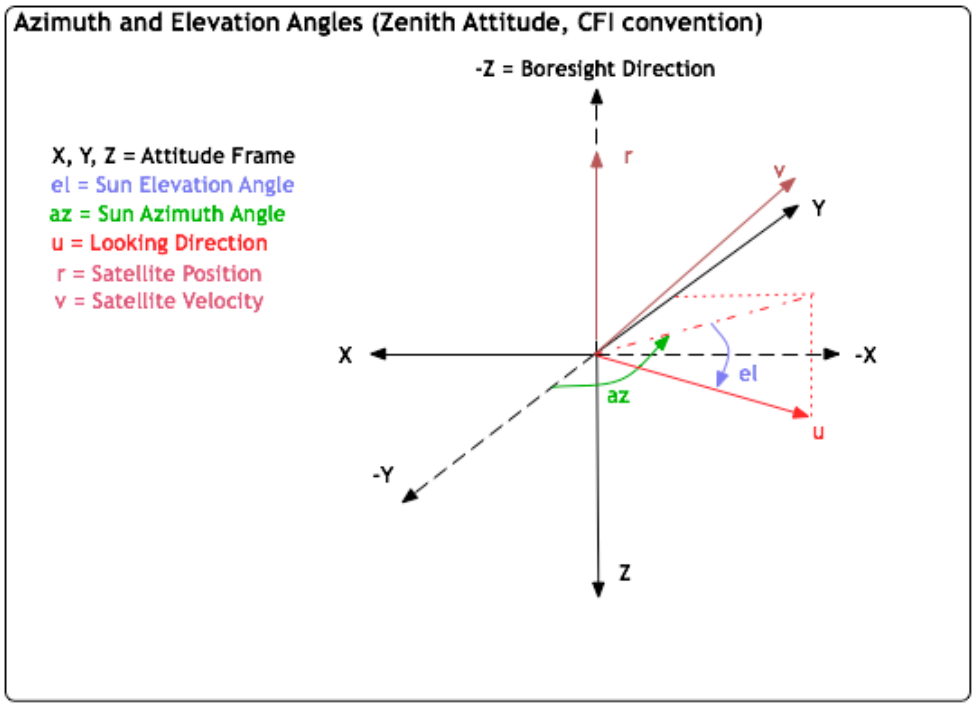




3.2 Zenith Attitude

3.2.1 Azimuth and Elevation Angles in Attitude Frame (CFI Convention)

The following convention for Azimuth and Elevation angles is assumed:

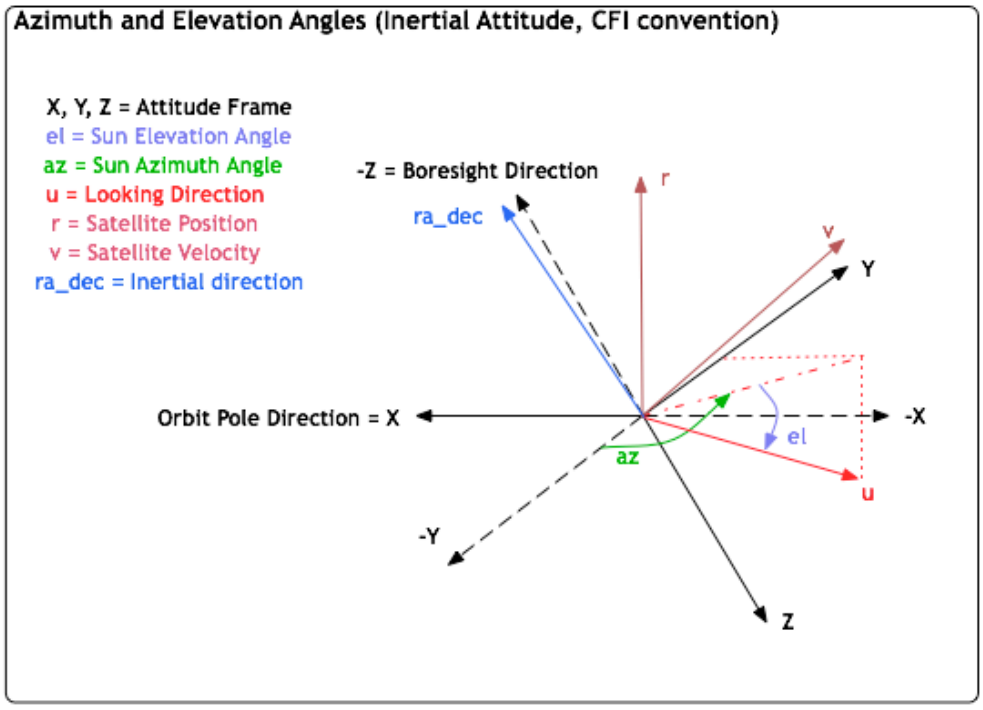


The Elevation Angle (allowed range between [-90, +90]) is positive when pointing upwards (-Z = elevation 90 degrees).
The Azimuth Angle (allowed range between [0, 360)) is positive from –Y towards –X.

3.3 Inertial Attitude

3.3.1 Azimuth and Elevation Angles in Attitude Frame (CFI Convention)

The following convention for Azimuth and Elevation angles is assumed:



The Elevation Angle (allowed range between [-90, +90]) is positive when pointing upwards (-Z = elevation 90 degrees).
The Azimuth Angle (allowed range between [0, 360)) is positive from –Y towards –X.