Assignment 1: Satellite orbits and reference frames

The purpose of this assignment is to determine the positions of the GPS satellites at any given time, and by using your own position, find their locations in a local reference frame typically denoted the East, North, Up (ENU) frame. The ENU position of the satellites will allow us to determine the elevation and azimuth direction of the satellites.

While satellite positions are necessary to determine our GPS position, the ENU coordinates (especially elevation) are needed in compensating for/modelling GNSS errors.

The scripts you write for this assignment will therefore be needed for later assignments – both positioning and error modelling.

Part 1: SP3 files

The sp3 format contains precise satellite positions and clock errors. While satellite positions may be calculated from the Kepler parameters being broadcast from the satellites themselves, sp3 files contain more accurate coordinates, and are freely available online – thus, in this course we shall use the sp3 files (for more on Kepler parameters please sign up for course 30552 - Satellite Geodesy).

Sp3 files are simple text files that contain an x-, y-, and z-coordinate plus a clock error for each satellite, typically for every 5 or 15 minutes. To determine the satellite position at a given time, we must interpolate the positions to a given time.

Files may be downloaded directly from the ESA ftp server ftp://gssc.esa.int, but for this assignment, we will provide you with an sp3 file, which may be found in Contents on Learn in Lecture 1 folder.

Your tasks are now:

1. Download the sp3 file "COD0MGXFIN_20250190000_01D_05M_ORB.SP3" from Learn
2. Open the file with a text editor (such as Notepad++), and familiarize yourselves with the format. In general, an sp3 file has a header, followed by satellite positions for each epoch typically starting at midnight GPS time.
   Each satellite is denoted P*##: For instance, PG01 is GPS satellite 1, while PE15 is Galileo satellite no. 15 (G = GPS, E = Europe/Galileo, R = Russia/GLONASS, C = China/BeiDou).

Part 2: Satellite positions

You must now read sp3 file into either Matlab or Python and determine satellite positions (and clock error). Therefore, your tasks are now:

1. Make a script to read all sp3 data from the sp3 file into either Matlab or Python.
   Make sure the script can read any sp3 file – you must use it again later in the course with another file.
2. Plot the positions of the GPS satellites given in the file. You must make a plot showing the orbits of all 32 GPS satellites for the 24 hours given in the sp3 files.
   Please plot a spherical Earth, and use even axis' for the plot, such as shown in Figure 1 (perhaps with better coloring to distinguish the satellite orbits)

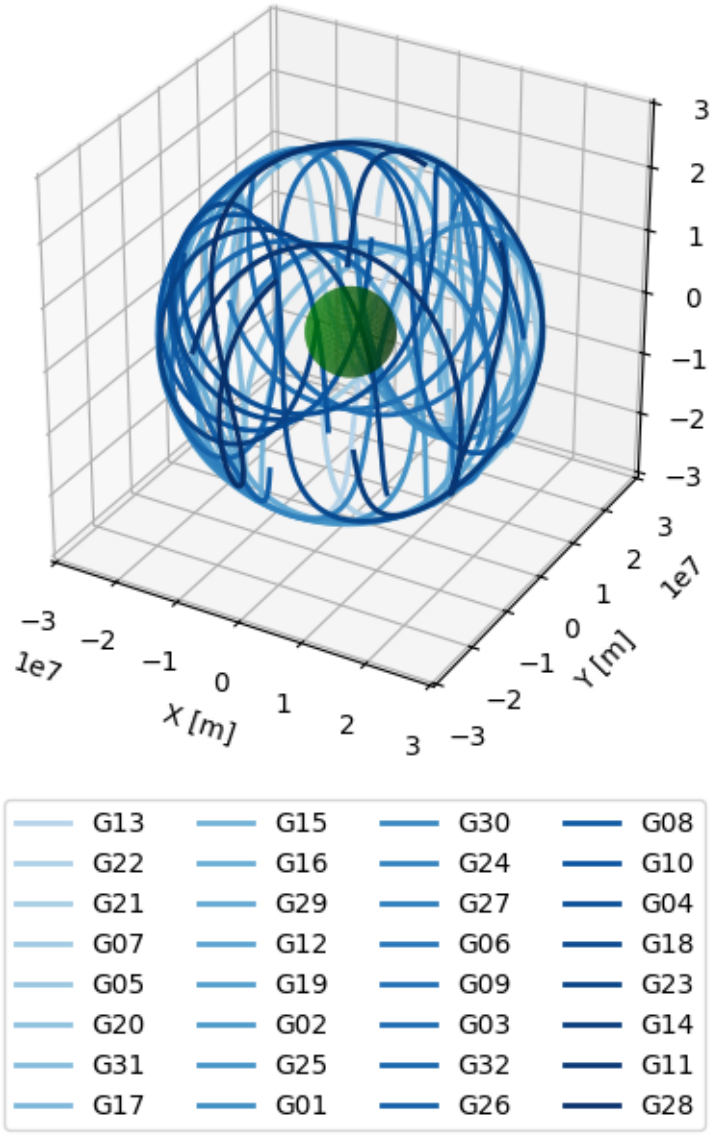

Figure 1 - Example of 24-hour ECEF-plot of GPS satellites

3. Make a script that interpolates the position of the satellites to a given set of times. Make sure that:
    a. You can interpolate the position of each individual satellite to an individual time (we need to find a position for each satellite at a unique timestamp)
    b. You use either spline, cubic or polynomial interpolation (not linear) for the best result.
    c. Your interpolation must be able to account for timescales as small as milliseconds!
4. Finally, plot satellite positions of all 32 GPS satellites for times:
    a. 2025-01-19 10:42:51:30.152
    b. 2025-01-19 12:29:11:22.378
    c. 2025-01-19 14:03:39:52.814

    Each of these should be plotted in a separate 3D plot like Figure 1, but with static positions instead of moving orbits.

Part 3: Determine ENU coordinates and make a skyplot.

In this part of the assignment, you must determine the satellite positions in the sky by converting the satellite positions to East, North, Up (ENU) coordinates. Your tasks are now:

1. Make a (Matlab or Python) function for converting the ECEF coordinates in the sp3 file to ENU coordinates. Use equation (8.14) from Hofmann-Wellenhof or use the equations presented on the whiteboard.
2. Convert all GPS positions from the sp3 file to ENU and make a skyplot (polar plot) of the satellite paths across the sky, similar to the one shown in Figure 2 below.

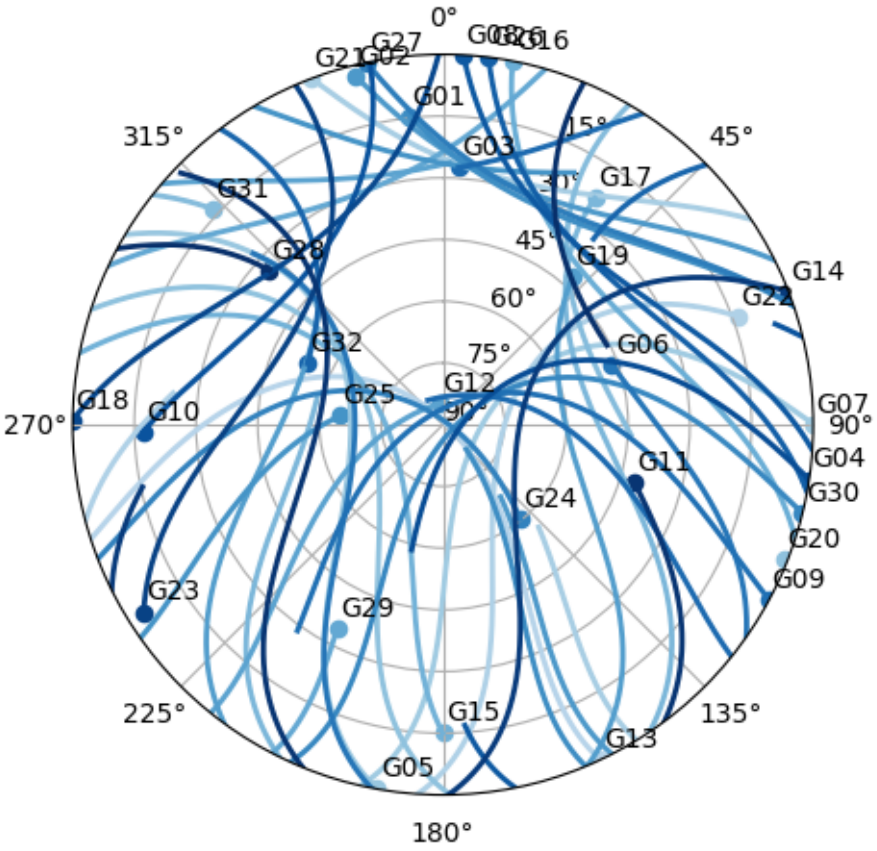

Figure 2 - Example of a skyplot (polar plot) of GPS satellites during 24 hours

You must now write a short report (approximately 5-7 pages), where you present your solutions to the tasks above. Besides showing plots and stating results, the report MUST contain some explanation of the theory and the equations that you use.

The report must be individual and should be handed in on Learn.