Workbook 2
GNSS Satellite orbits and clocks computation

Master's Degree in Aerospace Engineering
Satellite Navigation
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Objectives of Workbook 2

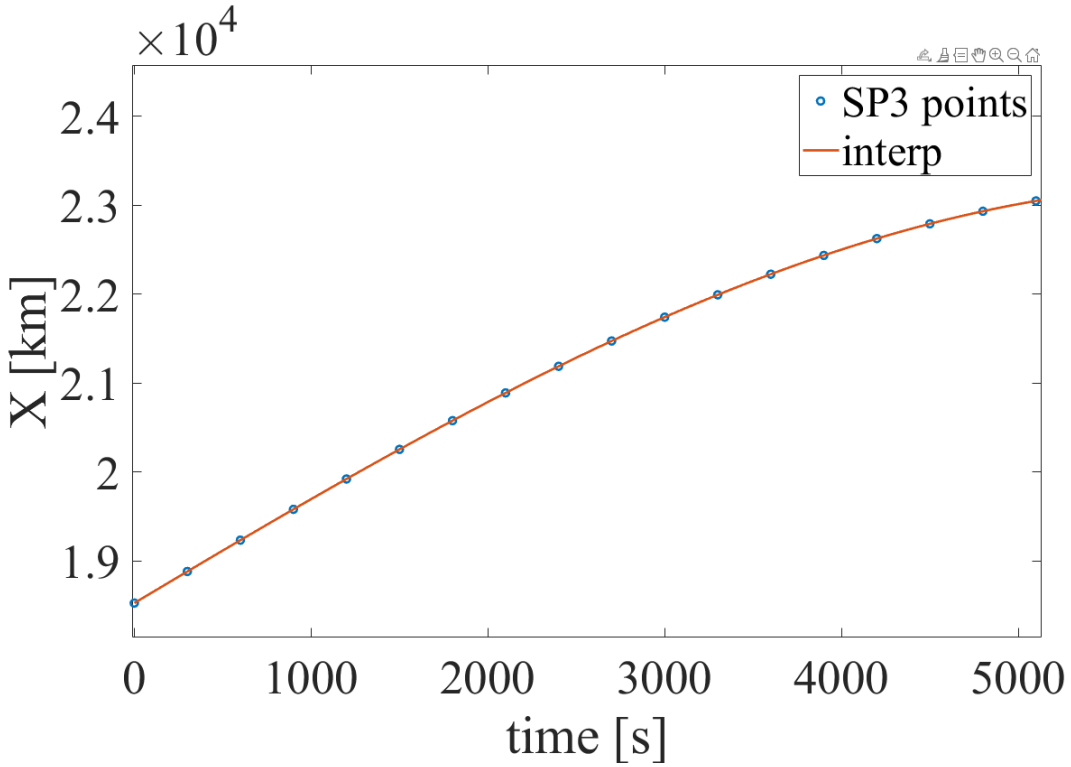
1. Compute GNSS satellite positions and clock error using two types of data:
   a. precise products downloaded from the IGS website
   b. data transmitted with the Broadcast Navigation Message
      - ✓ GPS, Galileo and BeiDou GNSS systems
      - ✓ GLONASS GNSS system
2. 3D visualization of the orbits
3. Compare the accuracy of the two methods
4. Generate the skyplot for a given user location
5. Compute and plot the orbital elements of the osculating orbit

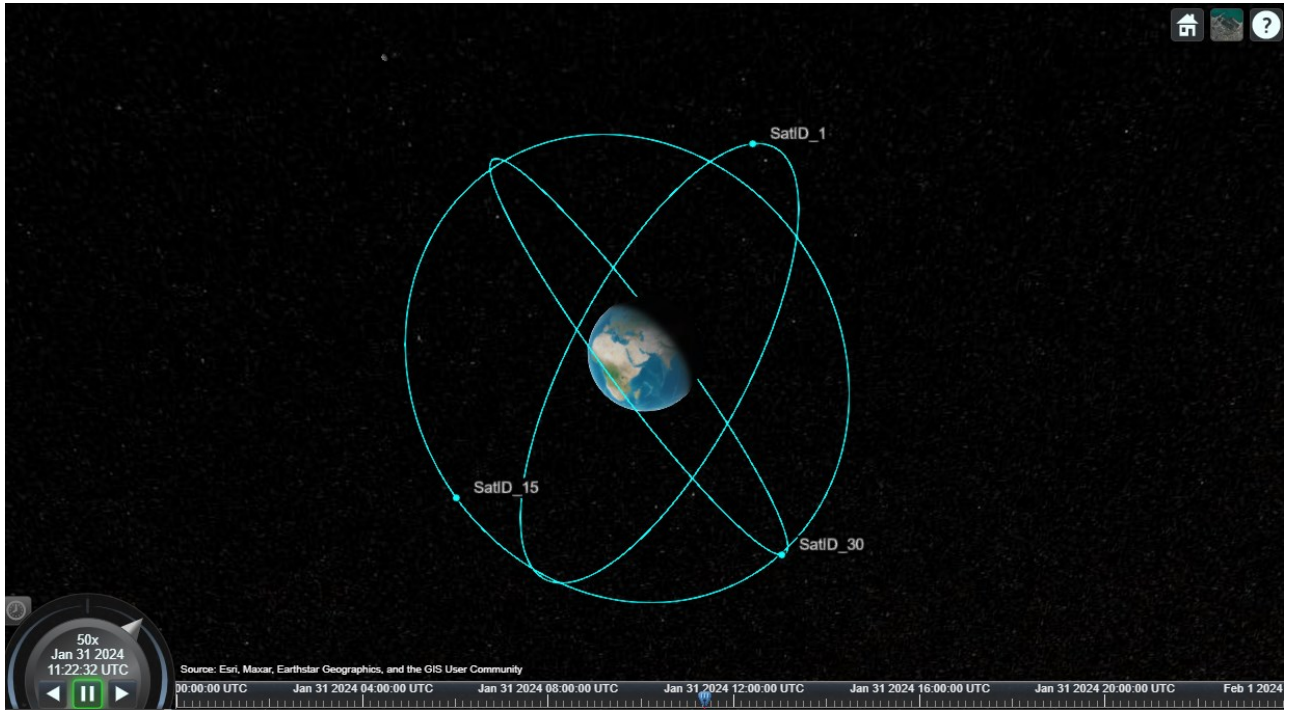
Reference weblinks and other useful web resources

- Weblink for downloading precise products and Broadcast ephemeris (Navigation Message):
  - ✓ http://navigation-office.esa.int/products/gnss-products/
  - ✓ https://cddis.nasa.gov/archive/gnss/data/daily/
- Other useful web resources:
  - ✓ https://geodesy.noaa.gov/CORS/resources/gpscals.shtml
  - ✓ https://www.labsat.co.uk/index.php/en/gps-time-calculator

Useful Matlab functions

- To read SP3 files and import data in Matlab:
  - ✓ read_sp3_multiconstellation
  - ✓ https://cddis.nasa.gov/archive/gnss/data/daily/
- To import data in Matlab from a navigation RINEX file:
  - ✓ rinexread
- To visualize satellite orbits:
  - ✓ satelliteScenario





GLONASS DIFFERENTIAL EQUATIONS

$$\vec{y}(t) = \begin{bmatrix} x(t) \\ \dot{x}(t) \\ y(t) \\ \dot{y}(t) \\ z(t) \\ \dot{z}(t) \end{bmatrix}$$

$$\dot{\vec{y}}(t) = \begin{bmatrix} y_2 \\ -\frac{\mu y_1}{r^3} + \frac{3}{2} J_2 \frac{\mu r_e^2}{r^5} y_1 \left(1 - \frac{5y_5^2}{r^2}\right) + \omega_e^2 y_1 + 2\omega_e y_4 + \ddot{y}_{1LS} \\ y_4 \\ -\frac{\mu y_3}{r^3} + \frac{3}{2} J_2 \frac{\mu r_e^2}{r^5} y_3 \left(1 - \frac{5y_5^2}{r^2}\right) + \omega_e^2 y_3 - 2\omega_e y_2 + \ddot{y}_{3LS} \\ y_6 \\ -\frac{\mu y_5}{r^3} + \frac{3}{2} J_2 \frac{\mu r_e^2}{r^5} y_5 \left(3 - \frac{5y_5^2}{r^2}\right) + \ddot{y}_{5LS} \end{bmatrix}$$

GLONASS DIFFERENTIAL EQUATIONS

- $dydt(1) = y_2$
- $dydt(2) = -\frac{\mu y_1}{r^3} + \frac{3}{2} J_2 \frac{\mu r_e^2}{r^5} y_1 \left(1 - \frac{5y_5^2}{r^2}\right) + \omega_e^2 y_1 + 2\omega_e y_4 + \ddot{y}_{1LS}$
- $dydt(3) = y_4$
- $dydt(4) = -\frac{\mu y_3}{r^3} + \frac{3}{2} J_2 \frac{\mu r_e^2}{r^5} y_3 \left(1 - \frac{5y_5^2}{r^2}\right) + \omega_e^2 y_3 - 2\omega_e y_2 + \ddot{y}_{3LS}$
- $dydt(5) = y_6$
- $dydt(6) = -\frac{\mu y_5}{r^3} + \frac{3}{2} J_2 \frac{\mu r_e^2}{r^5} y_5 \left(3 - \frac{5y_5^2}{r^2}\right) + \ddot{y}_{5LS}$