Technische Universität Berlin
Flugführung und Luftverkehr

Aircraft Navigation

GNSS

Exercise lecture

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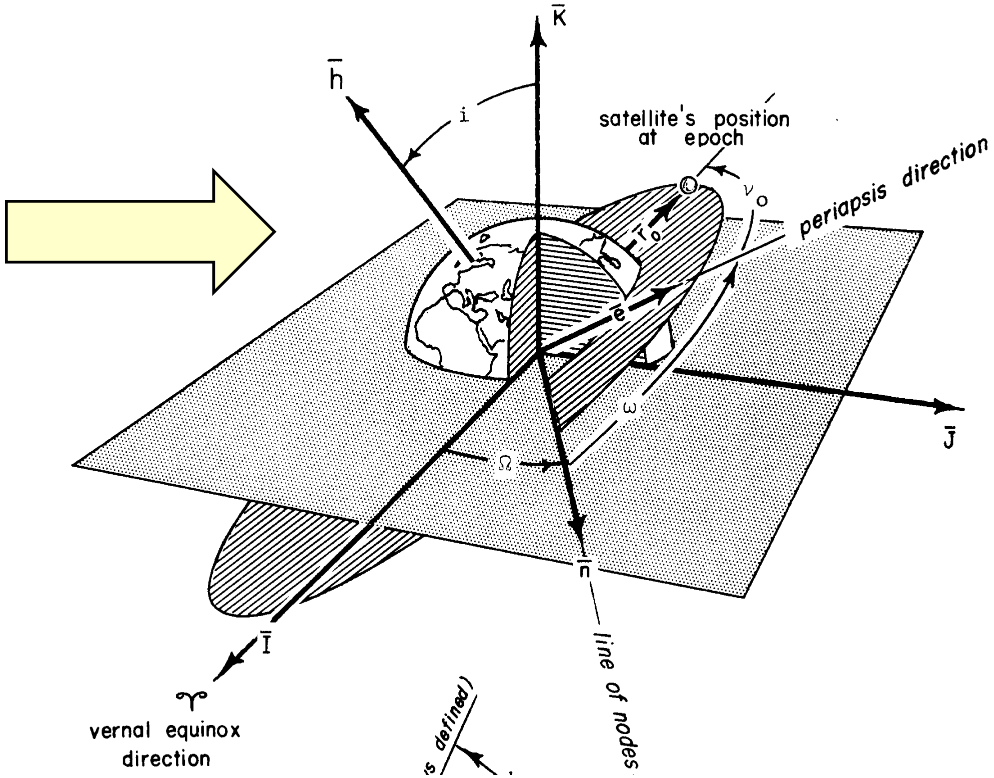
Satellite Position Calculation

- An important part of the GPS position calculation is the determination of the satellite position

$$PR_j = \sqrt{(x_u - x_j)^2 + (y_u - y_j)^2 + (z_u - z_j)^2} + c\delta t_u$$

- Given:
  - Set of Ephemeris data (also known as ephemerides)
  - Time (GPS time: seconds in week)
  - 'Ephcal'



Satellite Position Calculation – ‘Ephcal’

- (svpos, svclock, ecode) = ephcal(transmit_time, ephem, svid)
- Subroutine to calculate the position of a satellite in ECEF.
- Inputs:
  - **transmit_time**: time at which the satellite signal was transmitted
  - **ephem**: the ephemeris parameters (parameters that describe the satellite’s orbit)
  - **svid**: identification of the satellite
- Outputs:
  - **svpos**: satellite position in ECEF (3-by-1 vector)
  - **svclock**: satellite clock error (w.r.t. GPS time)
  - **ecode**: erorr code
    - ecode = 0: no detectable errors, ecode = 1: semi-major axis <= 0.0, ecode = 2: eccentric anomaly did not converge, ecode = 3: no ephemeris for this satellite

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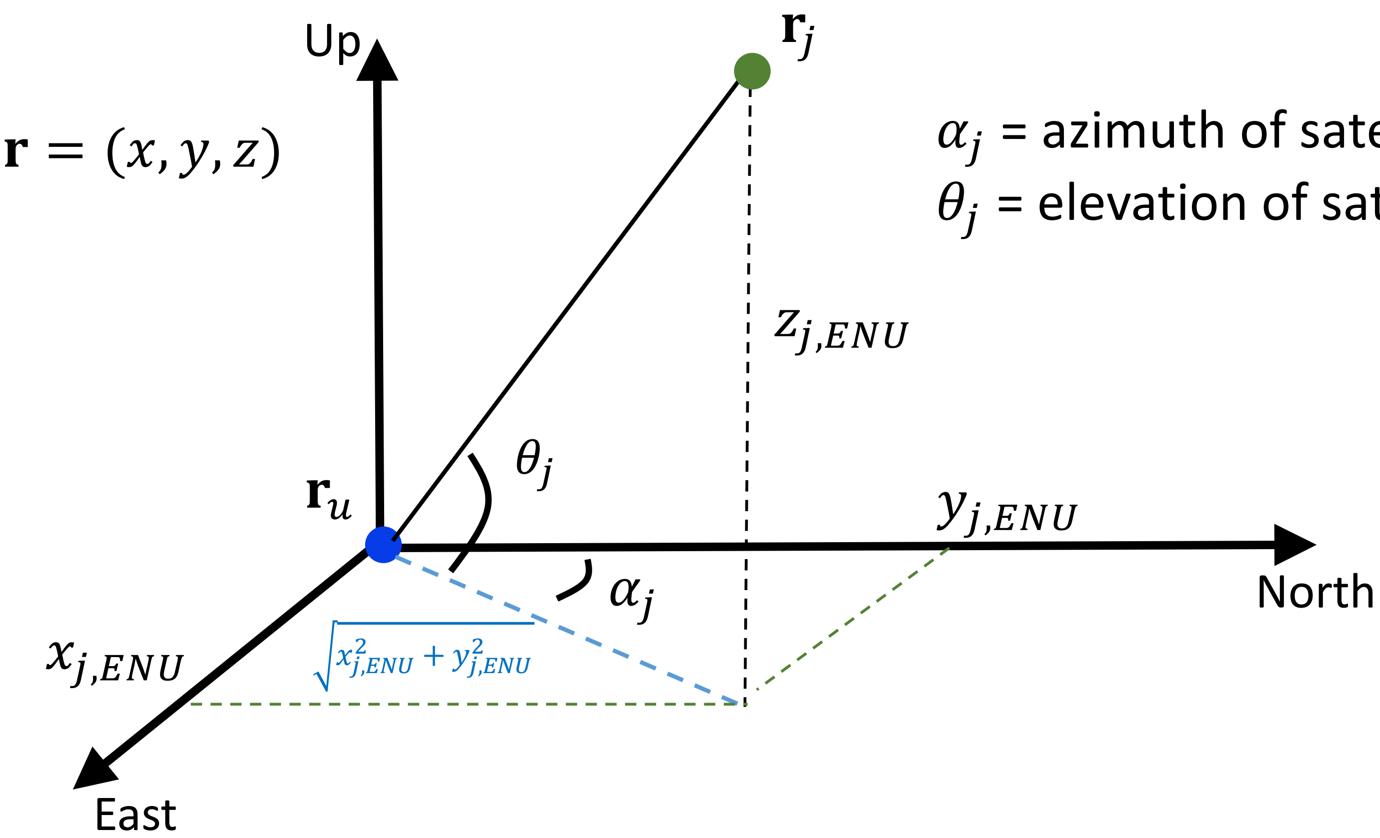
Satellite Elevation and Azimuth



α_j = azimuth of satellite 'j'
θ_j = elevation of satellite 'j'

$$\alpha_j = atan\left(\frac{x_{j,ENU}}{y_{j,ENU}}\right) \qquad \theta_j = atan\left(\frac{z_{j,ENU}}{\sqrt{x_{j,ENU}^2 + y_{j,ENU}^2}}\right)$$

Use 'atan2'

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Part 1

- Use the *template* provided on ISIS
  - comp_svpos_template.py
- Load the Ephemeris data from file '**ephem.dat**'
- For all satellites in the data set compute the **azimuth** and **elevation** and print the values

Time of Transmission (TOT) vs Reception (TOR)

- Typically, you have the time-of-reception, NOT the time-of-transmission. The time of transmission can then be estimated using:

$$TOT_j \approx TOR - \frac{PR_j}{c} - svclock_j$$

From measurement

From Ephcal

→ So, how do we typically go about solving this?

Time of Transmission (TOT) vs Reception (TOR)

$$TOT_j \approx TOR - \frac{PR_j}{c}$$

(svpos, $svclock_j$, ecode) = ephcal(TOT_j, ephem, svid)

Check for abs($svclock_j$) < 0.01)

$$TOT_j \approx TOR - \frac{PR_j}{c} - svclock_j$$

(svpos, $svclock_j$, ecode) = ephcal(TOT_j, ephem, svid)

Part 2

- Use the *template* provided on ISIS
  - comp_tot_svpos_template.m/py
- Load the pseudoranges and corresponding satellite ID’s from ‘**pr.dat**’
- Load the Ephemeris data from file ‘**ephem.dat**’
- For all satellites in the pr.dat data set
  - Implement time of transmission correction from the previous slide
  - compute the azimuth and elevation

Earth Rotation Correction – Sagnac Effect

- While the GNSS signal travels from the satellite to the user on the Earth (receiver), the Earth rotates. As the ECEF frame rotates with the Earth, the position at time-of-transmission must be adjusted to reflect the position at the time-of-reception.

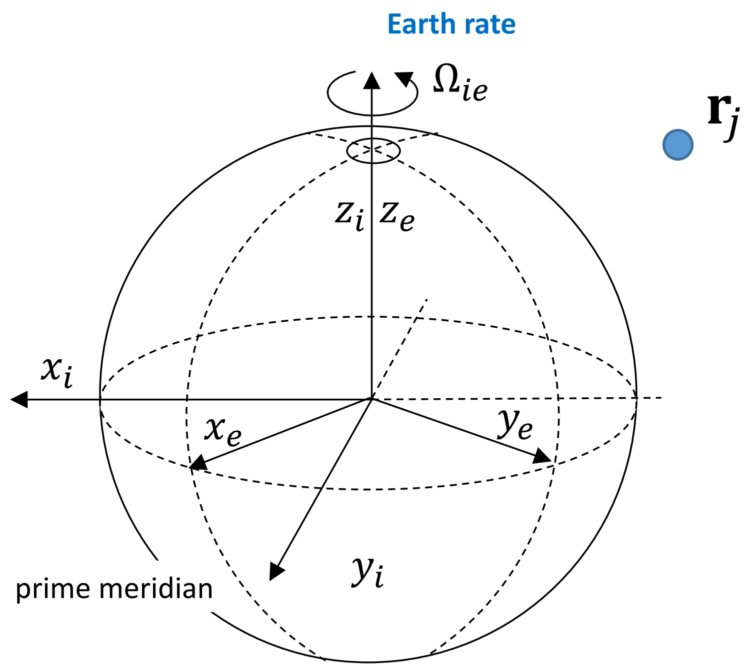
$$\Delta t = travel\ time = \frac{PR_j}{c} + svclock_j$$

Angle the Earth has rotated during signal travel time:

$$\Delta t \cdot \boldsymbol{\omega}_{ie} = \begin{bmatrix} 0 \\ 0 \\ \Delta t \cdot \Omega_{ie} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \alpha \end{bmatrix}$$

ECEF correction (add to ECEF coordinates):

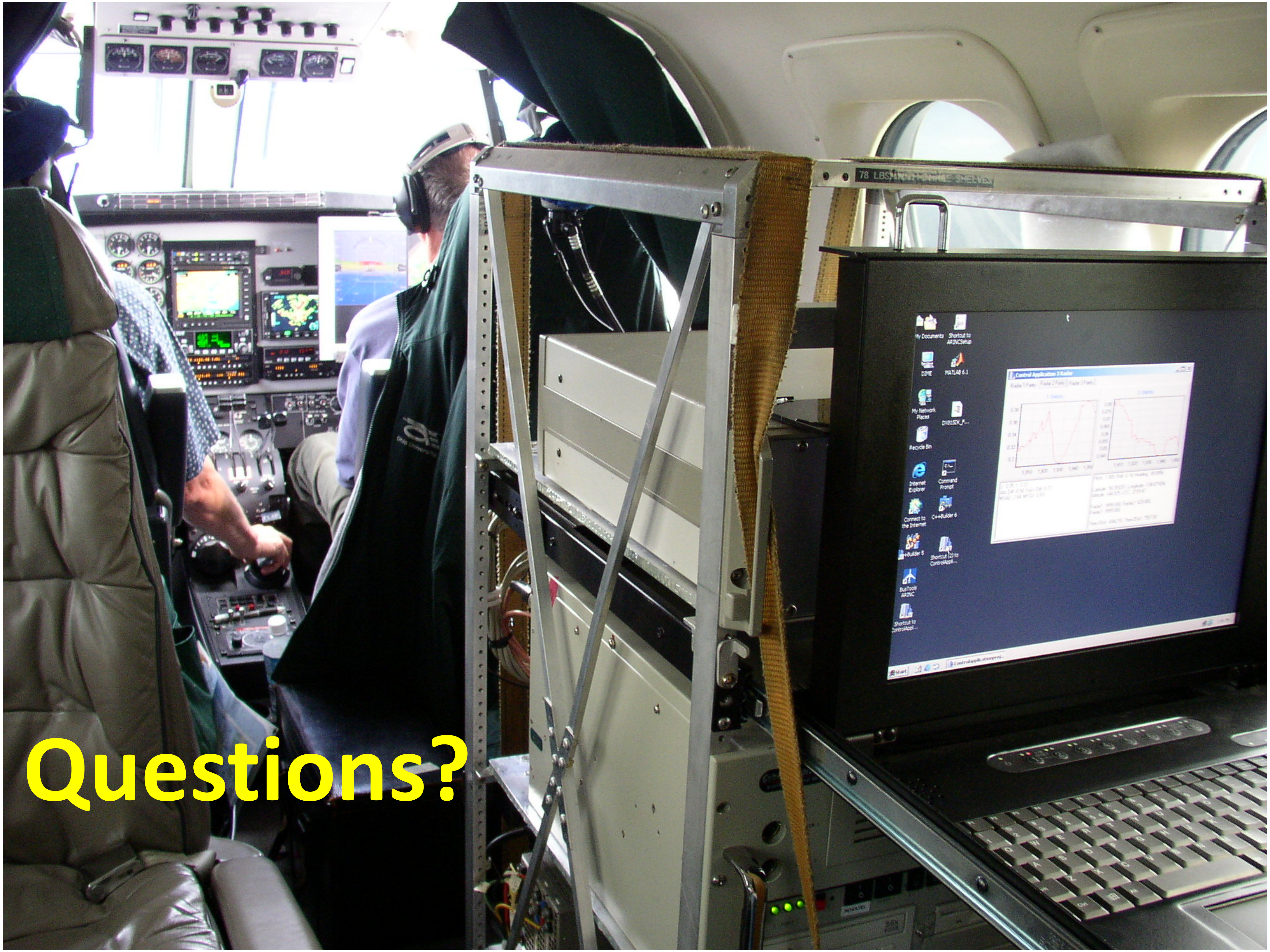
$$\Delta \mathbf{r}_{j,ECEF} = \Delta t \cdot \boldsymbol{\omega}_{ie} \times \mathbf{r}_{j,ECEF} = \begin{bmatrix} \alpha \cdot y_{j,ECEF} \\ -\alpha \cdot x_{j,ECEF} \\ 0 \end{bmatrix}$$

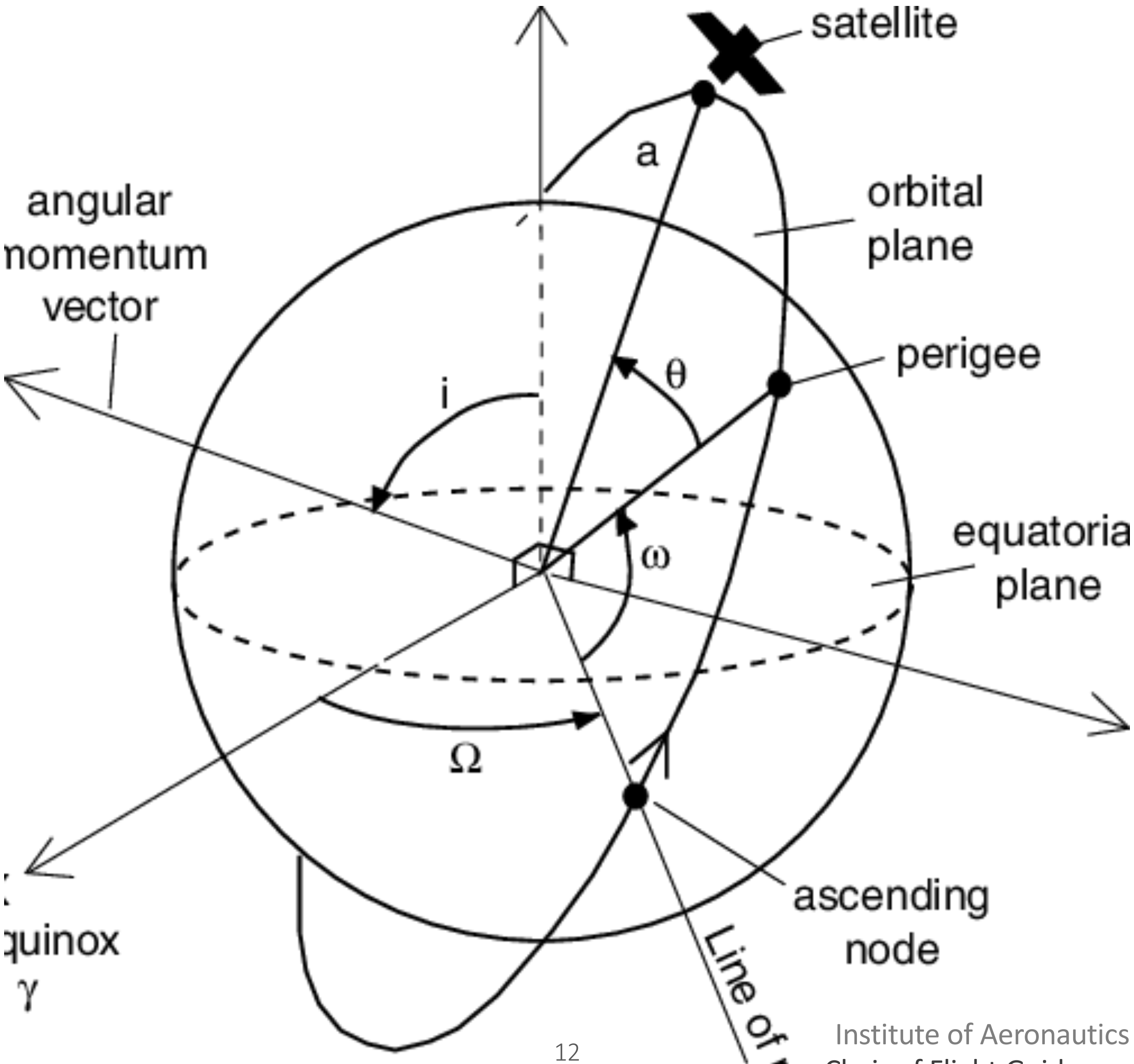


Ω_{ie} = eanvel in code

Part 3

- Build upon Part 2
- Compute the correction and add to the satellite position
- Compute the azimuth and elevation


Questions?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