Ground Track Tool

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Code Architecture

groundTrack.m

- Function with 10-dimensional input vector
- Outputs are latitude, longitude, $\mathbf{r}_{IJK}$, $\mathbf{r}_{ECEF}$, Azimuth, Elevation

groundTrackVizualize.m

- Script that initializes initial conditions for orbit
- Calls groundTrack.m to obtain solutions
- Generates plots to visualize the solutions

r_{ijk} & r_{ECEF} Trajectory

```
function nu2 = orbitPropogate(nu1,e,mu,a,TOF,k)
n = sqrt(mu/a^3);
E1 = 2*atan(sqrt((1-e)/(1+e))*tan(nu1/2));
M = n*TOF + E1 - e*sin(E1) + 2*pi*k;
E2 = kepler(M,e);
nu2 = 2*atan(sqrt((1+e)/(1-e))*tan(E2/2));
```

- **orbitPropogate.m**: function (developed in Mars project) that outputs true anomaly for a given time of flight.
  - Used in a for loop to create true anomaly values for each point in orbit
- Convert orbital elements & true anomaly values to state vector to get $\mathbf{r}_{ijk}$ trajectory
- Multiply $\mathbf{r}_{ijk}$ by an R3 rotation matrix to get $\mathbf{r}_{ECEF}$ trajectory
  - Input to R3 is Greenwich Sidereal Time ($\omega t+\Theta_{g0}$), where ω is the rotation rate of the earth
  - Therefore, R3 input changes with each for loop iteration
- Each trajectory plotted with an Earth-sized sphere object at the origin

Ground Track

For each iteration, latitude and longitude obtained by the following trigonometric functions:

- Latitude = arcsin($\frac{r_{ECEFz}}{|\boldsymbol{r_{ECEF}}|}$)
- Longitude = arctan2(r_{ECEFy}, rE_{CEFx})

Longitude & Latitude was plotted on a flat earth map, with Longitude on the x-axis and Latitude on the y-axis

Azimuth & Elevation

Converted $\mathbf{r}_{\mathbf{ECEF}}$ into Azimuth and Elevation by the following procedure:

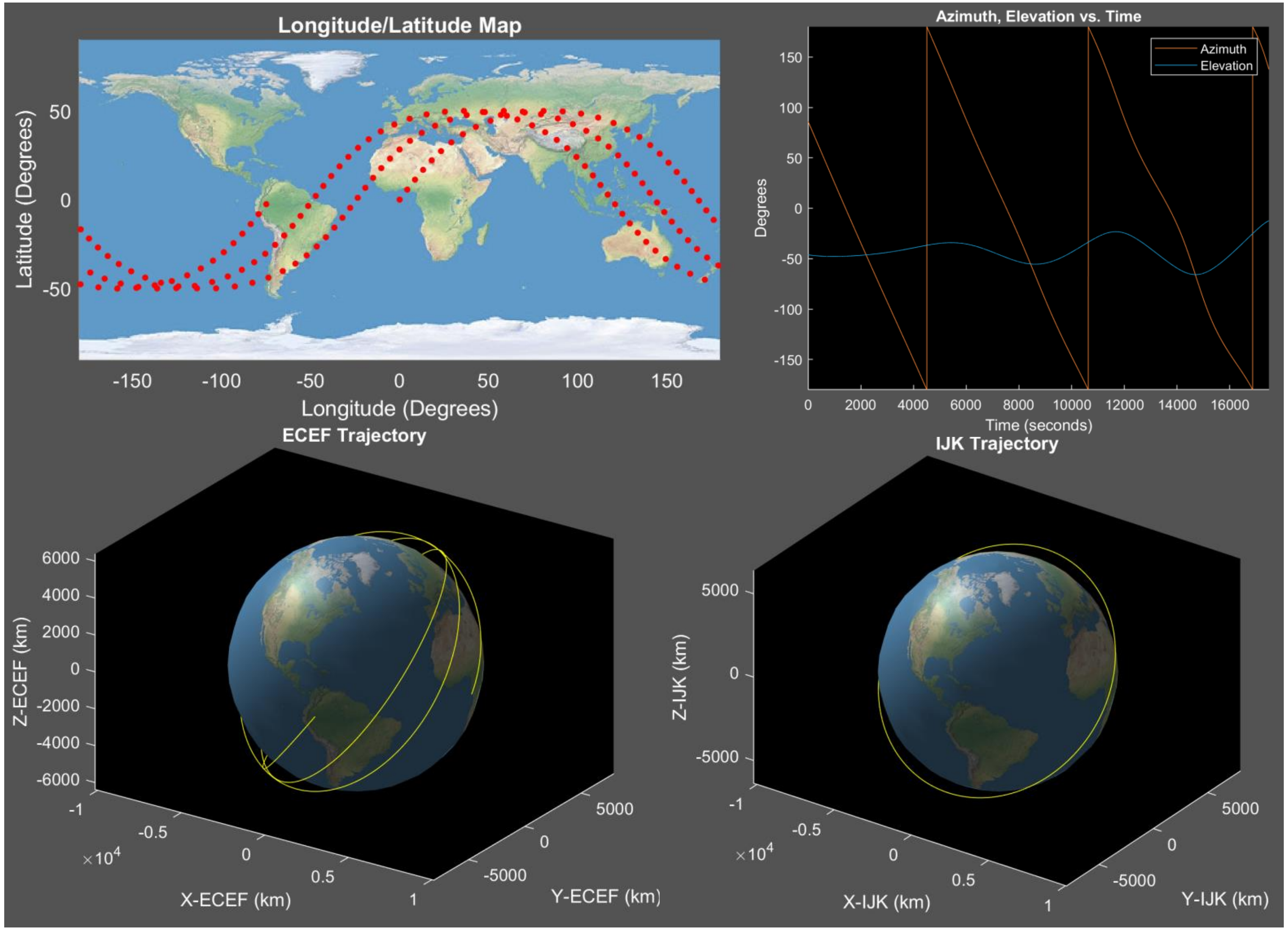
1) Obtain $\mathbf{r}_{\mathbf{SEZ}}$ by the following rotation matrix: `inv(R3(-ObsLon)*R2(ObsLat-pi/2))`

2) Subtract the radius of the earth to obtain $\boldsymbol{\rho}_{\mathbf{SEZ}}$

3) Calculate Azimuth by Az = arctan2(ρ_{SEZy},-ρ_{SEZx})

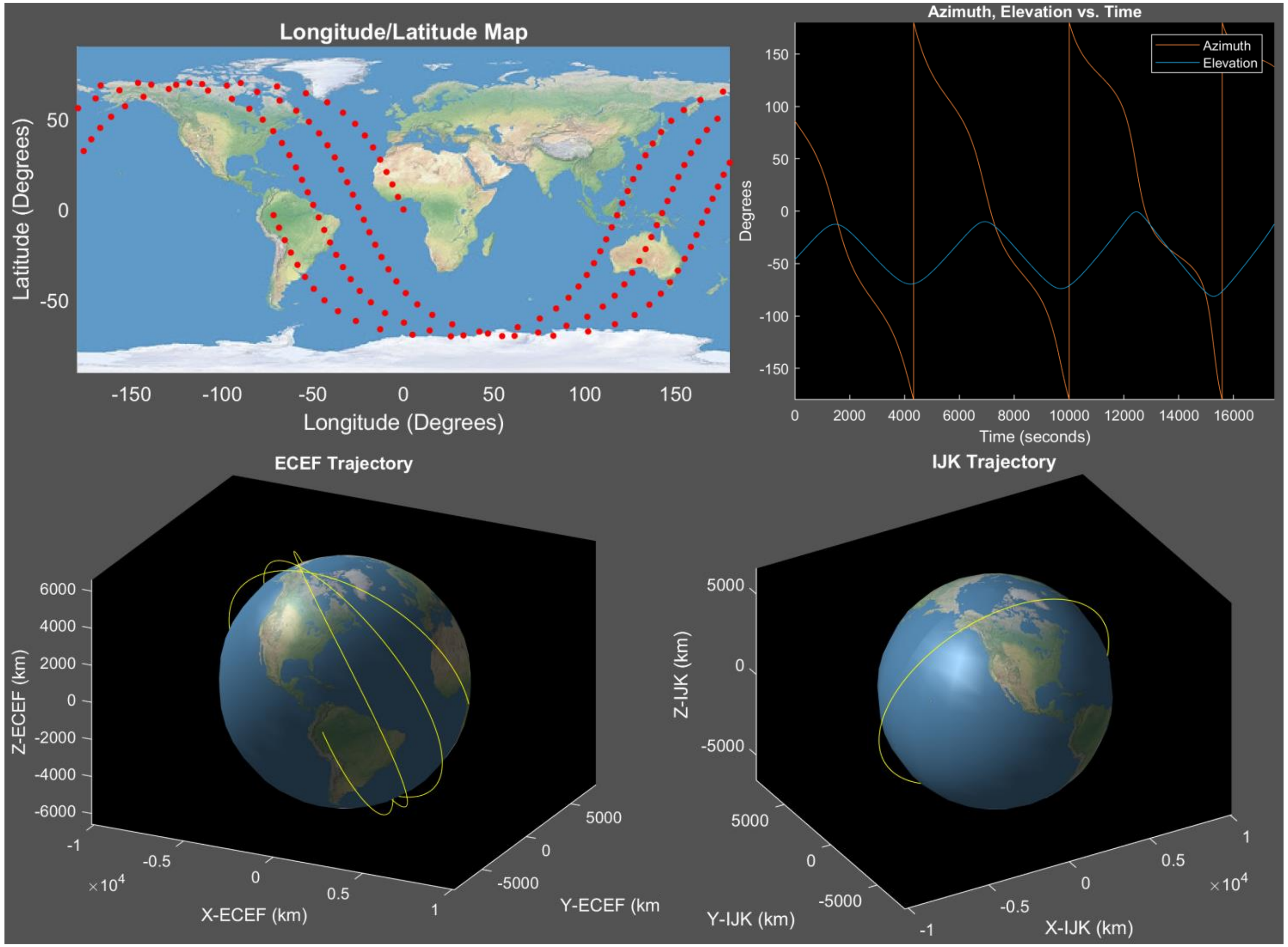
4) Calculate Elevation by El = arcsin($\frac{\rho_{\mathrm{SEZz}}}{|\boldsymbol{\rho}_{\mathbf{SEZ}}|}$)

a) [a e i ω Ω ν] = [7000 0.01 50 0 0 0]



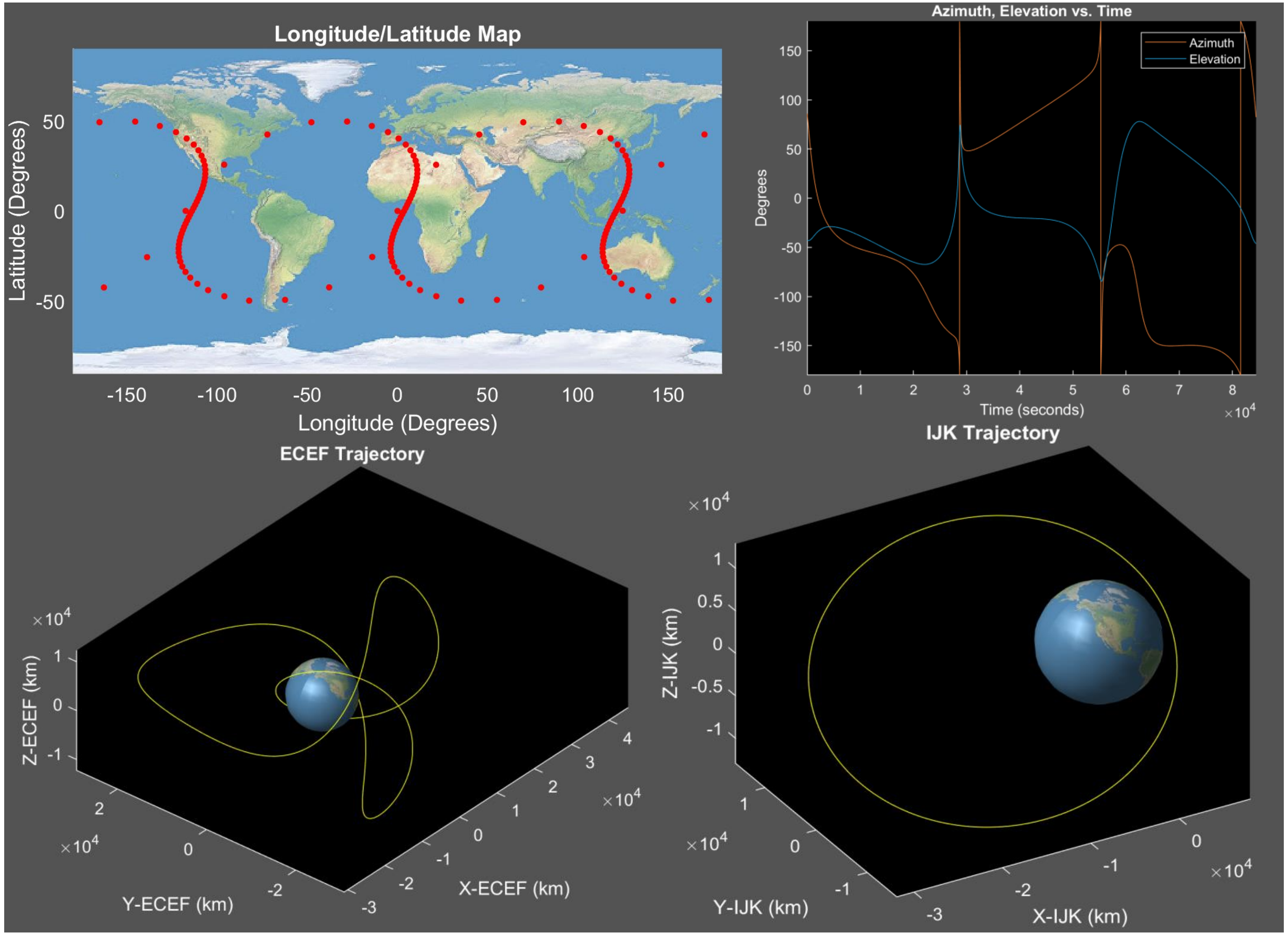
- Low eccentricity means that ground track speed is fairly consistent, seen by near-equal spacing between dots
- Inclination gives spacecraft good coverage for most of the earth's population
  - Travels east on map because inclination is less than 90 degrees

b) [a e i ω Ω ν] = [7000 0.01 110 0 0 0]



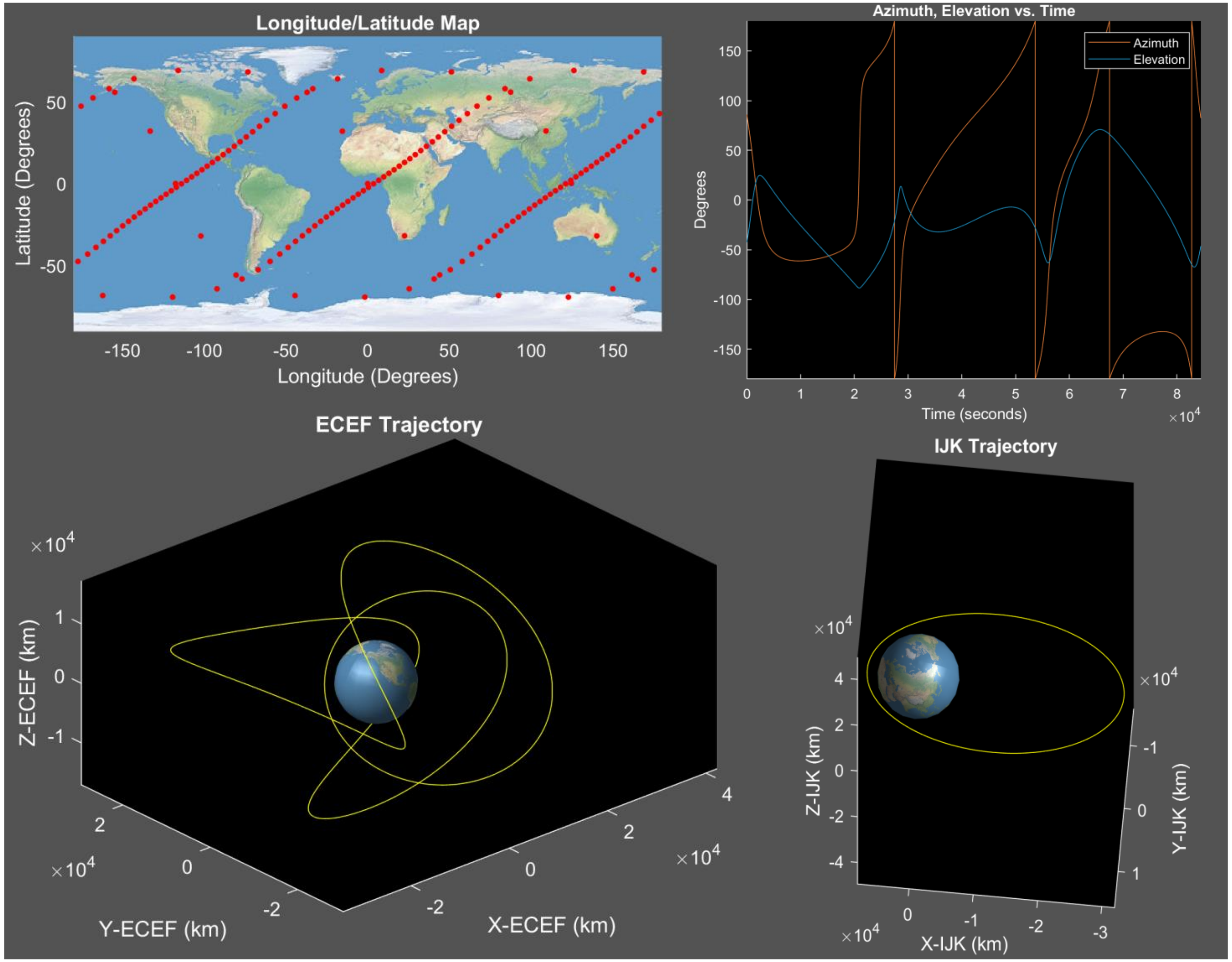
- Inclination greater than previous scenario, resulting in coverage of greater latitude ranges
  - Travels west on map since inclination is above 90 degrees
- Spacing between dots still relatively equal, and similar to the previous problem
  - Same altitude

c) [a e i ω Ω ν] = [20000 0.6 50 0 0 0]



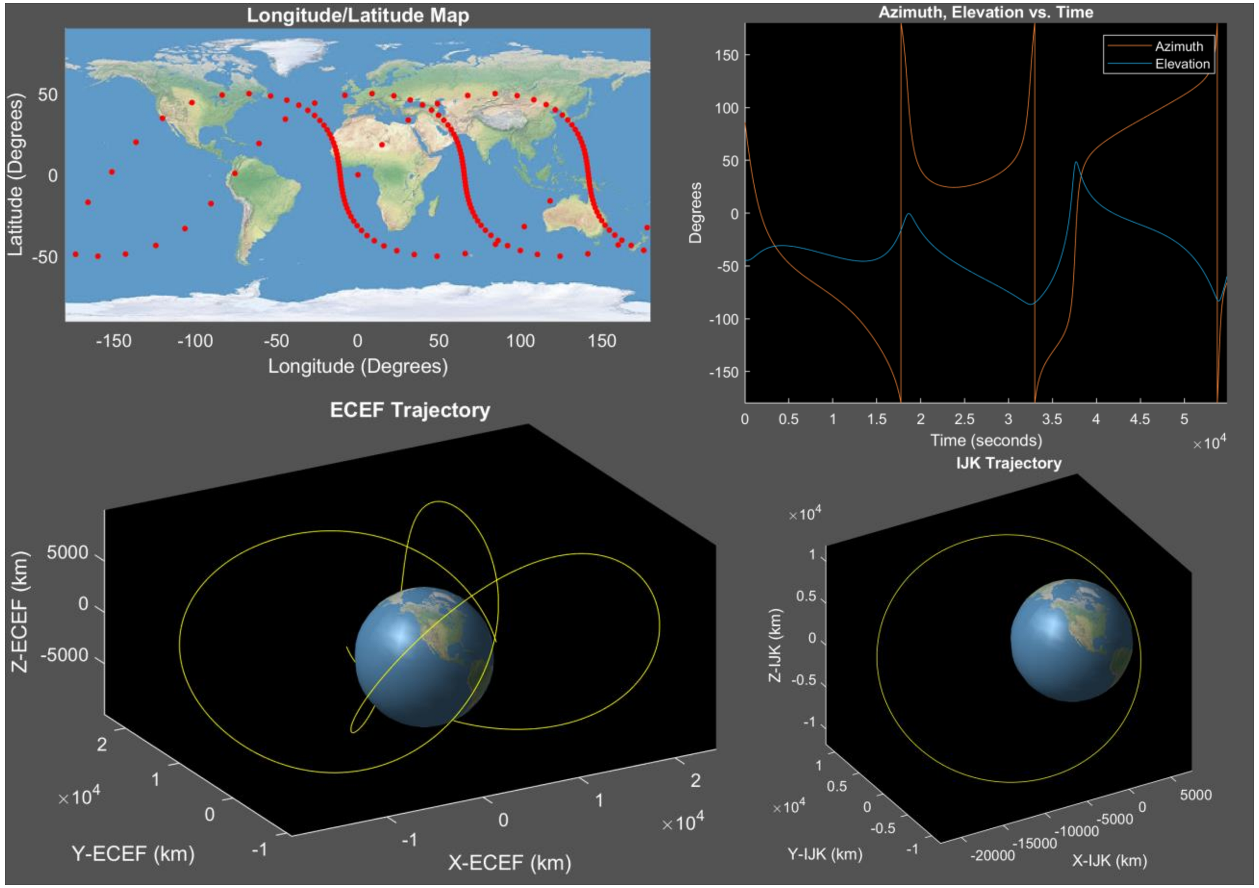
- High eccentricity, ground track speed varies greatly
    - Spacing between dots unequal
- Inclination is same as (a), meaning range of coverage is similar
    - Travels east
- Larger altitude means minimum spacing of dots is much smaller than previous problems
- Pattern close to repeating every three orbits

d) [a e i ω Ω ν] = [20000 0.6 110 0 0 0]



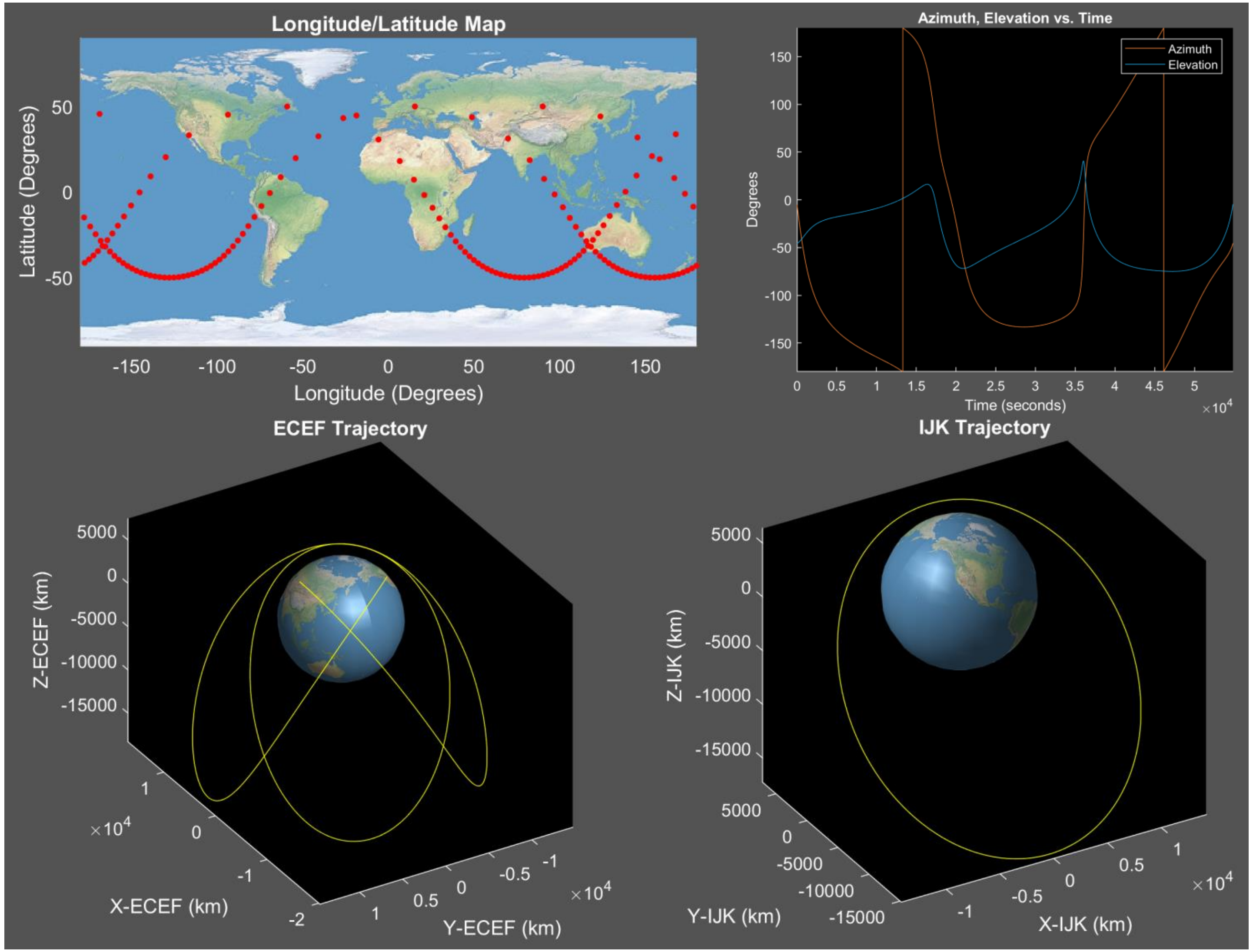
- High eccentricity leads to large variation in dot spacings
- Inclination greater than (c), meaning the range of coverage is greater
  - Travels west on map
- Patter close to repeating every three orbits

e) [a e i ω Ω ν] = [15000 0.5 50 0 0 0]



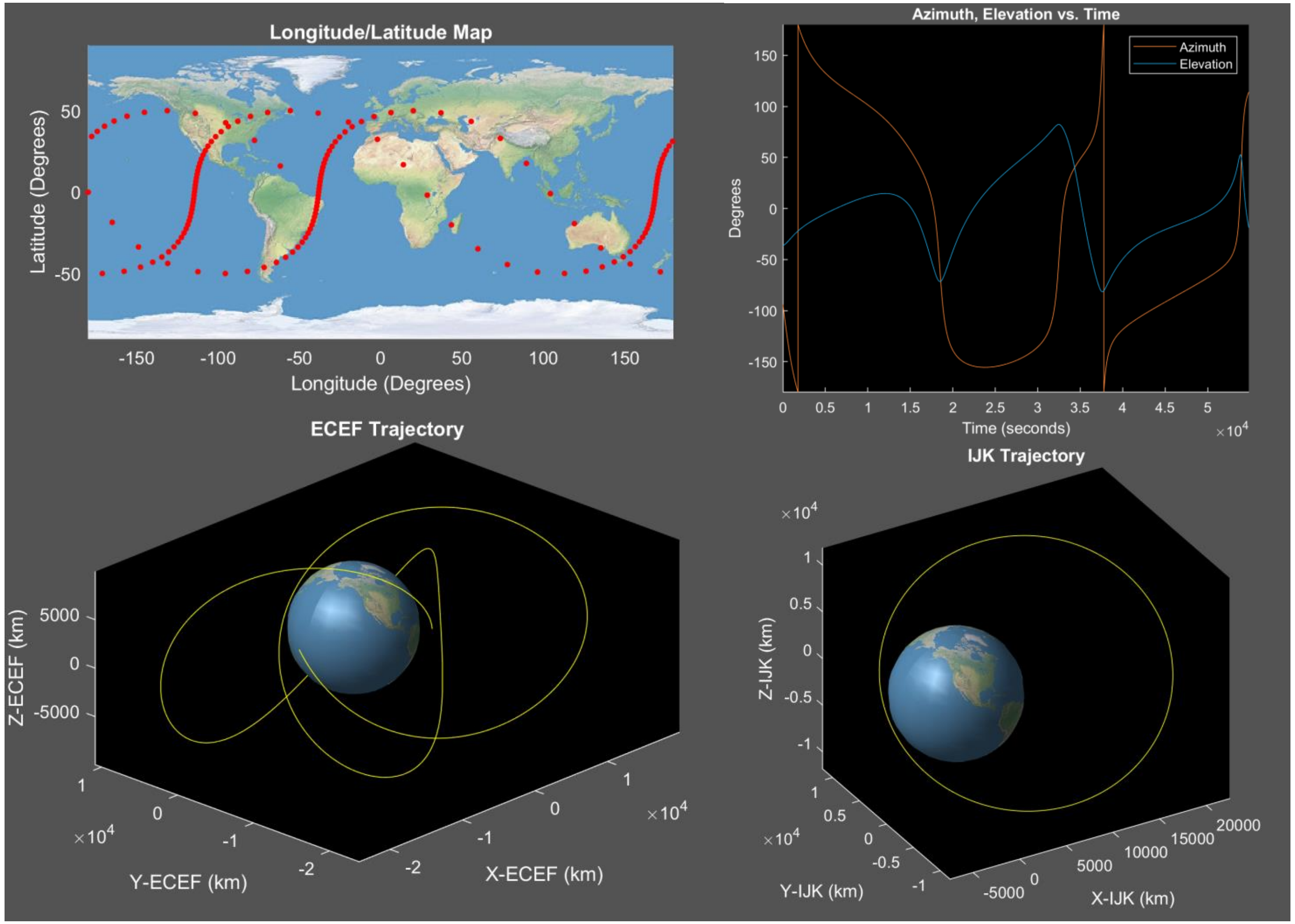
- High eccentricity seen by closely spaced dots at apogee and farther dots at perigee
- Inclination same as (a) and (c), provides similar coverage

f) [a e i ω Ω ν] = [15000 0.5 50 90 0 0]



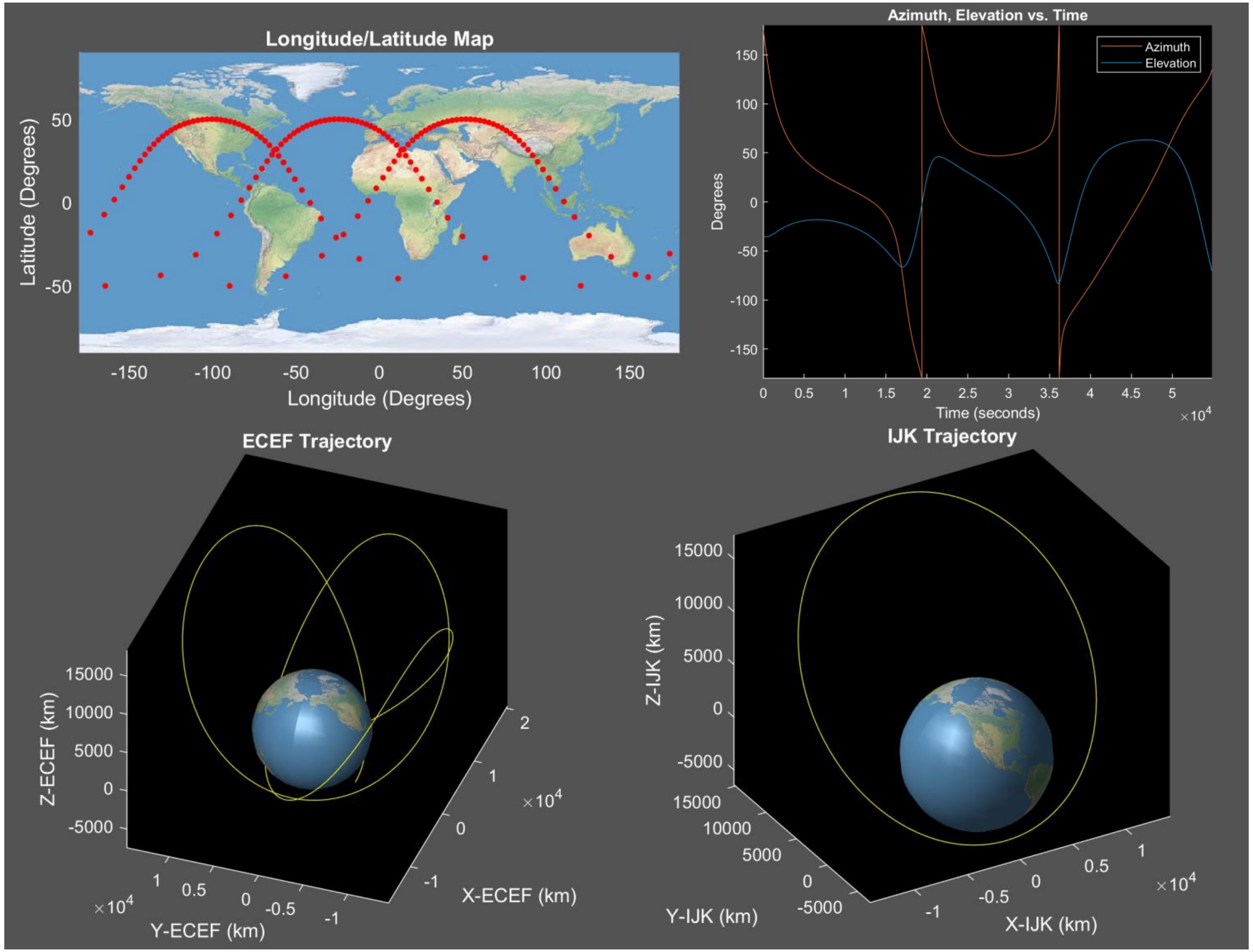
- LAN shifted by 90 degrees from (e)
  - Slow part of ground track rotated 90 degrees counter-clockwise, now in southern hemisphere
- 50-degree inclination provides similar latitude ranges to previous problems
- High eccentricity provides variation in ground track speed

g) [a e i ω Ω ν] = [15000 0.5 50 180 0 0]



- LAN shifted by 90 degrees again
  - Results in 90-degree shift counter-clockwise for ground track
  - Pattern is a reflection of (e)
- Latitude range, and ground track step variation similar to (e) and (f)

h) [a e i ω Ω ν] = [15000 0. 5 50 270 0 0]



- LAN shifted by 90 degrees again
  - Apogee now in the northern hemisphere
  - 90-degree rotation counter-clockwise
  - Reflection of (f)
  - Provides good coverage for population centers across globe
- Ground track step variation and Latitude ranges similar to previous scenarios

Repeat Ground Track Problem

To determine orbit, loop through M and N until semi-major axis is within the bounds specified [6678, 6683] km

$$a_{RGT} = \mu^{1/3}\left(\frac{M}{N\omega_B}\right)^{2/3}$$

Semi-Major Axis: 6680.256342908875 km

Earth Revolutions (M): 7

Spacecraft Orbits (N): 111

Time of repeat period = N*Orbit Period = 111*5433.8 s = 6.981 days

Repeat Ground Track Problem

- This trajectory covers the surface of the earth well, due to its high inclination
  - Useful if the satellite requires global coverage to achieve its mission
- Orbits are equally spaced for this repeat ground track
  - Angle between orbits = 360/N = 3.2432 deg
- Required field of view = 3.2432/2

  = **1.6216 degrees**