Homework Assignment #09 (Constellations Part-2)

[Answer, Code]

Problem 1.

a) **Is there any indication in the paper what model was used for orbit propagation? Is there any result in Section 1&2 that might have altered based on drag and Secular Precession?**

There are frequent mentions of Low Earth Orbits (LEO) that are also non-geostationary (NGSO). I was not able to find a direct statement concerning an orbit propagation model. However, there are plenty of context clues indicating they were using classical orbital elements. Specifically, multiple direct mentions of satellite altitude and inclination in order to define the orbital plane. Additionally, there is discussion of circular orbits hinting at eccentricity and the assumption of circular keplerian orbits.

I did not see a specific item that is impacted by drag and secular precession. However, if these variables are not accounted for they are bound to impact overall satellite performance and coverage. Secular Precession should affect the mega-constellations with fewer satellites as they are prone to variation.

b) **Identify the HW problem where you did calculations relative to this concern.**

In HW#3 problems 1 and 2 involve secular precession, and HW#4 Problem 1 concerns drag.

In HW#8 problem 3 we did calculations concerning the elevation angle and zenith to determine the satellite relation to ground stations, specifically analysis of the satellite passing.

(Optional Problem) Why is the onboard processing regarded as an "important innovation" on the bent-pipe architecture?

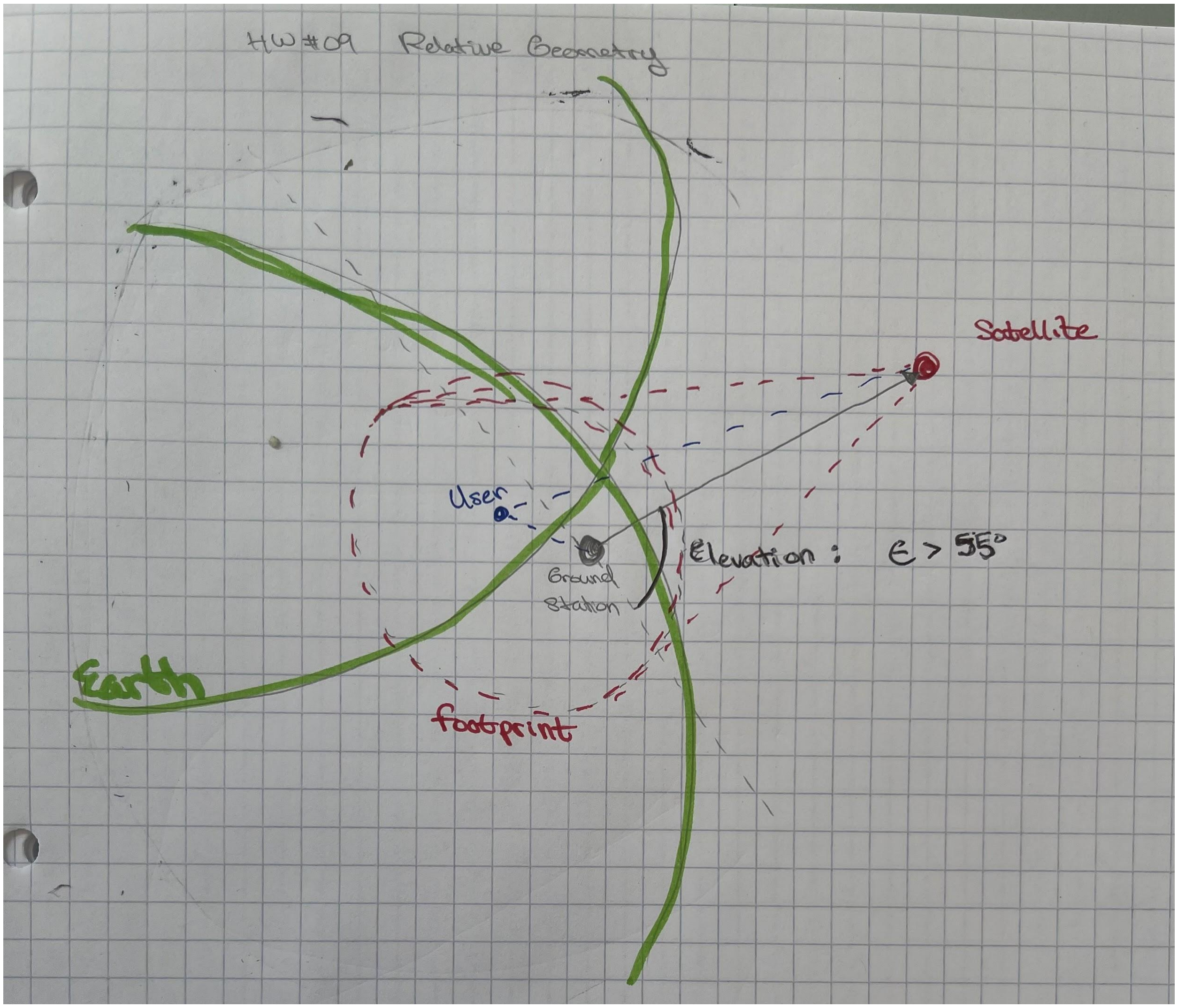
The onboard processing module has the capability of demodulation, routing, and remodulation. This allows for decoupling up and downlink so it is an important bent pipe architecture innovation.

Problem 4. Write down the conditions that must be met by the orbit (number of planes and number of satellites) and the footprint before you can be assured of the "guarantee".

For OneWeb's constellation 720 satellites in 18 circular orbital planes are used. The orbital planes have an altitude of 1200 km and an inclination of 87 degrees. When the elevation is greater than 55 degrees the highly elliptical user beams effectively "guarantee" that any user will be within the line of sight.

- Must be enough orbital planes to cover all areas of the Earth or areas that need coverage
- Inclined planes of orbit can focus upon areas with high population density
- Number of satellites should be sufficient so that all points along the orbital plane are covered.
  - This goes hand in hand with the size of the satellite footprint covering the surface

Problem 5. Draw a sketch of the relative geometry between the satellite, ground station, and the user; write down the mathematical condition that ensures when "service can be offered".



Problem 5. Are any of these sun-synchronous orbits?

Assuming e = 0 for the given altitudes and inclinations.

Using code from HW#6 I found that satellite #7 Telesat's first satellite (1000km, 99.5 deg) was the closest to the sun synchronous orbit with the difference in Node Precession rate and 360/365.25 deg/day being near zero.

```
%constants
mu = 3.986004415*10^14;
ae = 6378136.3;
we = 7.292115*10^-5;
g=9.81;
j2=1.082*10^-3;
```

```
%%Preallocations
n = zeros(1,4);
bigWbar = zeros(1,4);
wbar = zeros(1,4);
Mbar = zeros(1,4);
T_kepler = zeros(1,4);
T_anomalistic = zeros(1,4);
u = zeros(1,4);
T_nodal = zeros(1,4);
bigW = zeros(4,361);
beta = zeros(4,361);

%% Problem 1
% a. Calculate Precession rates in units of degrees/day
%       1       2       3       4
%   [Topex   Grace   ERS-1   Lageos]
a = ([1200    1150    1110 1130 1275 1325 1000 1248]*1000)+ae; % m
e = 0; %
i = [87.9 53 53.8 74 81 70 99.5 37.4]*pi/180; % rad

for j=1:8
n(j) = sqrt(mu/a(j)^3);
bigWbar(j) = -1.5*n(j)*(ae/a(j))^2*j2/sqrt(1-e^2)*cos(i(j));
end
%convert from rad/s to deg/day
Node_Precession_Rate = (bigWbar)*180/pi*60*60*24

% b. Calculate the Kepler, Anomalistic, and Draconitic/Nodal Periods


% c.Calculate the Sun-Cycle Duration in units of days
bigWs = (360/365.2426); %deg/day
for j=1:8
Cs(j) = 360/(Node_Precession_Rate(j) - bigWs);
end
SunCycle_Duration = Cs

% d. Identify if Satellite is in sun-synchronous orbit
SunSyncTest = Node_Precession_Rate - bigWs
```

Problem 6. Guess which classes teach you the material needed to carry out the analysis shown in section 3.4 using the course schedule.

ASE 374K SPACE SYSTEMS ENGR DESIGN-WB

ASE 374L SPACECRAFT/MISSION DESIGN-WB

Another potential class could be Satellite Based Navigation but I did not see it available in Spring 2021 or Fall 2021

(Optional Problem) the text is cut off in the pdf