AE 554 Final

Constants:
\[
\begin{align*}
\mu &= 398600.5 \times 10^9 \text{m}^3/\text{s}^2 \\
R_E &= 6378.137 \text{ km} \\
J_2 &= 1.082 \times 10^3
\end{align*}
\]

Useful formulae:
\[
\begin{align*}
\dot{\Omega} &= \frac{-3 n R_E^2 J_2}{2 \left[ a \left(1-e^2\right)^{3/2}\right]} \cos(i) \\
\dot{\omega} &= \frac{3 n R_E^2 J_2}{4 \left[ a \left(1-e^2\right)^{3/2}\right]} \left[ 4 - 5 \sin^2(i) \right]
\end{align*}
\]

1. a) Briefly explain what an “orbit propagator” is. Compare and contrast with “batch filter” and “sequential filter”. (No figure, no formula) [13/100]
   b) Compare the advantages and disadvantages of analytical and numerical orbit propagators. [10/100]
   c) On 19 March 1990, the spacecraft Hiten approached the Moon to a range of 16,472 kilometers and then released a small 12-kilogram orbiter satellite named Hagomoro into lunar orbit. Initial orbital parameters were 22,000 x 9,000 kilometers. If you were designing an on-board numerical orbit propagator for Hagomoro, where the initial orbit parameters are updated from the Earth groundstation on a twice-a-week basis, which numerical integration scheme would you use? Justify your choice. [7/100]

2. a) What is the minimum condition that two satellites in close proximity will stay together after a couple of hundred orbits? (State any and all assumptions you make.) [5/100]
   b) Assume that, due to the difference in drag characteristics, the semi-major axis difference between the two satellites are increasing quadratically with time. Show that the mean distance between the satellites increase with \( t^3 \). [10/100]

3. You are in the design team of a small spacecraft for a tactical reconnaissance mission, operating in the visible spectrum. Initially the satellite is to be placed in a circular, near-polar, Sun-synchronous orbit, though it will be equipped with a thruster to allow it to be brought down to low altitude (180km) for short-term higher resolution imaging. Its planned lifetime is 3 years in nominal operations, but is considerably less if altitude decrease maneuver are to be executed. Due to launcher weight restrictions, the initial orbital altitude is limited to 500km.
   a) Calculate the orbital elements \( a \) (semimajor axis), \( e \) (eccentricity), \( i \) (inclination), \( T \) (period), \( n \) (mean motion - in revolutions/day) as well as the rate of change of Argument of Perigee (Apsidal Rotation) and rate of change of Right Ascension of the Ascending Node (Nodal Precession) [15/100]
   b) Choose a Local Time of Ascending Node (LTAN) value to maximize the image return for the mission. Justify your choice. [5/100]
   c) Assuming drag is constant during nominal operations and that it changes the mean motion by \( 10^{-4} \) revs/day\(^2\), calculate whether the satellite can stay within the +/-1.5 hour LTAN envelope throughout its lifetime. [10/100]
   d) There are two possible strategies to lower the altitude for high resolution imaging. The first is to drop to a circular orbit at 180km altitude; the second is to change the perigee altitude such that high resolution imaging of the target takes place at the 180km altitude perigee. Calculate the minimum DV required for both strategies, assuming all firings are impulsive. [15/100]
   e) As the drag will be extremely high for a circular orbit at 180km altitude, the more feasible option is the 500x180km orbit. Assuming the requirement is to keep this orbit for two weeks, calculate the argument of perigee drift during this period. Also calculate the nodal precession rate and comment on the “Sun-synchrononousity” at this orbit. [10/100]