ASE 389P.4: Methods of Orbit Determination
Term Project

Assigned:	Thursday, April 6, 2023
Due:	Friday, April 28 @ 5:30pm

This is the final project for the course and all relevant information has been uploaded on the canvas website for (**JahSat1**). Please provide a write-up with the deliverables given below.

Please keep in mind that "*Knowledge*" statistics are for intervals where there are fit data (i.e. trajectory reconstruction) and "*Delivery*" statistics are for assessing the predicted trajectory performance.

Deliverables

1. Prefit residuals for all data and all sensors
2. Postfit residuals (bounded by 3-σ bounds of the innovations covariance) for all data and all sensors
3. A plot in each of the following frames: Radial-Crosstrack (spacecraft motion is going into the page). Radial-Intrack (looking face-on to the orbital plane), and Crosstrack-Intrack (looking edge-on to the orbital plane) with all of the following ellipses simultaneously. Label each ellipse with the case number from below so we know what is being plotted. Be mindful of your units. Show things in an adequate scale.
   (a) fit range only for all sensors
   (b) fit range-rate only for all sensors
   (c) fit Kwajalein only for all data types
   (d) fit Diego Garcia only for all data types
   (e) fit Arecibo only for all data types
   (f) fit the long-arc (all data and all sensors)
   (g) fit the short arc (only the last day of data for all sensors)

Plotting residuals MUST always have an associated covariance (3-σ bounds).

For the first phase of this final project, you are given one day's worth of data so at first, there is no case (f) and (g).

Propagate your estimated states and covariances to the time of ΔV_1 (30 March 2018, 08:55:03 UTC). These are called Delivery statistics. Select your best estimated trajectory as the basis for the Radial-Intrack-Crosstrack frame with which you will compare ALL other cases.

Provide a detailed narrative of your analyses and your interpretation of the results. What are these cases indicating to you? How does each sensor and data type contribute to the overall uncertainty (knowledge and delivery)? Did you have to compensate for unmodeled dynamics? If so, how? How well are you predicting future measurements? Did you infer the presence of any biases? If so, which? What do you seem most sensitive to in your solutions? How observable are your states and parameters? What did you estimate? Did you "consider' any parameters? Did you smooth the trajectory? If so, how did this help? What was your strategy for getting your results and making it all "work?"

Be explicit in listing all of your assumptions as these should always caveat your analyses. Some of them follow (i.e. initial conditions, *a priori* uncertainty, observation model(s) used, dynamic model(s) used, spacecraft model(s) used, states and parameters estimated and/or considered, process noise model(s) used, estimation strategy used [e.g. EKF, batch, UKF, etc.]). Provide a rationale for why you chose what you did and not something else, for instance. Orbit Determination and Prediction is a science and also an art with its own "tradecraft." Part of your evaluation is based upon this tradecraft that you developed over the course.

Initial Satellite State: GCRF Reference Frame

The epoch for your initial conditions is 23 March 2018, 08:55:03 UTC. Approximate initial conditions for the satellite are (note that the state is in kilometers!)

	Position (km)	**Velocity (km/s)**
i	6984.45711518852	-1.67667852227336
j	1612.2547582643	7.26143715396544
k	13.0925904314402	0.259889857225218

Station Position in Body-Fixed Coordinate System: ITRF Reference Frame

The station coordinates are

Number	Description	X_s (m)	Y_s **(m)**	Z_s **(m)**
1	Kwajalein	-6143584	1364250	1033743
2	Diego Garcia	1907295	6030810	-817119
3	Arecibo	2390310	-5564341	1994578

where the coordinates for each tracking station approximately known to say 1 meter.

Atmospheric Drag Model

The satellite cross-sectional area should be computed from a box-wing model including the solar panel orientation. An approximate value for C_D is 1.88. The exponential density model is given by

$$\begin{aligned}
\rho &= \rho_0 e^{-(r-r_0)/H} \\
\rho_0 &= 3.614 \times 10^{-13} \text{ kg/m}^3 \\
r_0 &= (700000.0 + R_{\text{Earth}}) \text{ m} \\
H &= 88667.0 \text{ m} \\
r &= \text{magnitude of the satellite radius vector}
\end{aligned}$$

Spacecraft Model Properties

The spacecraft has a mass of 2000 kg. The solar-panel is double gimbaled and always Sun-Pointed, and the -Z axis of the spacecraft bus is always NADIR pointed.

Component	Area	Coating
+X/-X Face	$6m^2$	MLI Kapton
+Y/-Y Face	$8m^2$	MLI Kapton
+Z/-Z Face	$12m^2$	White Paint/Germanium Kapton
Solar Panel	$15m^2$	Solar Cells

Material	C_d	C_s
Bulk S/C MLI Kapton	0.04	0.59
White Paint	0.80	0.04
Germanium Kapton	0.28	0.18
Solar Cells	0.04	0.04

Note: +Z is all white paint and -Z is all germanium kapton

Observations

The observation data file has been uploaded to canvas. The columns of the data file have been populated as follows:

1. Observation Station ID
2. Observation time in seconds past epoch
3. Apparent range in kilometers
4. Apparent range rate in kilometers/second

The apparent range and range rate data were simulated with noise. The standard deviations of the noise for each data type for all stations are provided in the table below. <u>DO NOT</u> assume that the data are unbiased.

Number	Description	Range σ (m)	Range Rate σ (mm/s)
1	Kwajalein	10	0.5
2	Diego Garcia	5	1
3	Arecibo	10	0.5

Astrodynamics Constants

Earth Gravitational Parameter, $\mu = 398600.4415\ km^3/s^2$
Earth Radius, $R_{Earth} = 6378.1363\ km$
Sun's Gravitational Parameter, $\mu_{Sun} = 132712440018\ km^3/s^2$
1 Astronomical Unit $= 149597870.7\ km$
Moon's Gravitational Parameter, $\mu_{Moon} = 4902.800066\ km^3/s^2$
Earth's eccentricity, $e_{Earth} = 0.081819221456$
Earth's rotational velocity, $\omega_{Earth} = 7.292115146706979e-5\ rad/s;$