Problem 1. Develop a very simple representation of the Hubble telescope.

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#########################################################################################
#                                         Hubble                                        #
#     ^V2                                                                               #
#     |                          +----------------------+                               #
#  <--+                          |                      |                               #
#  V1                            |         SA1          |                               #
#                                |                      |                               #
#                                +-----------+----------+                               #
#                                            |                                          #
#                                            |    +-------+                             #
#                            +--------------++---+       |                             #
#                            |               |   |       |                             #
#                            |       1       | 2 |   3   |                             #
#                            |               |   |       |                             #
#                            |               |   |       |                             #
#                            +--------------++---+       |                             #
#                                            |    +-------+                             #
#                                            |                                          #
#                                +-----------+----------+                               #
#                                |                      |                               #
#                                |         SA1          |                               #
#                                |                      |                               #
#                                +----------------------+                               #
#                                                                                       #
#########################################################################################
#                                                                                       #
#     ^V3                                                                               #
#     |                                                                                 #
#  <--+                                           +-------+                             #
#  V1                        +---------------+---+       |                             #
#                            |               |   |       |                             #
#                            |       1       | 2 |   3   |                             #
#                            |  +-----------+----------+ |                             #
#                            |               |   |       |                             #
#                            +---------------+---+       |                             #
#                                                 +-------+                             #
#                                                                                       #
#                                                                                       #
#                                                                                       #
#########################################################################################
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Diagram 1: Hubble ASCII Diagram. Solar panel distance from HST is exaggerated. One character is ≈ 20 inches.

We model both the body (3 sections) and the solar panels (2 sections) of the Hubble Space Telescope (HST). The body sections are connected as such: Section 1 is connected to Section 2, and Section 2 is connected to Section 3. The solar arrays are connected on Section 1, along the centerline, 20.75 inches V_1 away from the connection point with Section 2, and the near edge of the SA is 129 inches from center of Section 1. These sections are modelled with thin walled cylinders (TWC), solid cylinders (SC), and flat plates (FP). The rough

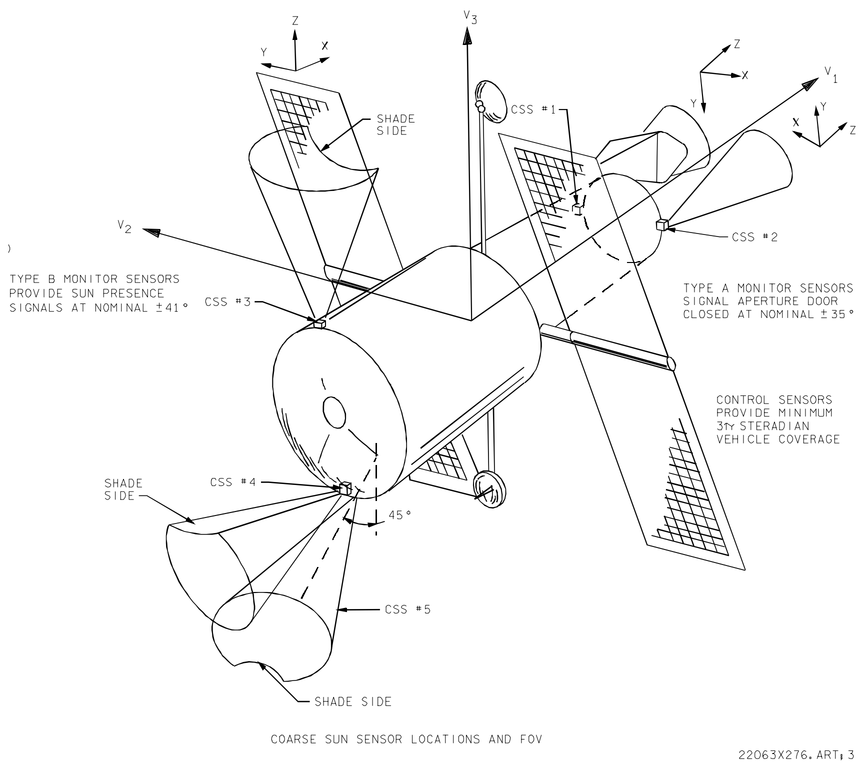

Figure 1: HST Axes Definition for V_1, V_2, V_3, CG is located at axis origin

layout of the sections is shown on the previous page, and the mass and length properties of each section are listed in Table 1.

Section	Model	V_1 (in)	V_2 (in)	Weight (lb)
Section 1				
Light Shield (LS)	-	153.2	120	-
Forward Shell (FS)	-	156.05	121.2	-
Total	TWC	309.25	121.2	9033
Section 2				
SSM Equipment Section (SSM-ES)	TWC	61.25	121.2	10593
Section 3				
Aft Shroud (AS)	SC	138.00	168.16	3363
Section 4				
Solar Arrays (SA)	FP	476.8[1]	113.5	735[2]

Table 1: [1]: This length can be fully rotated into V_3. [2]: Weight of both solar arrays. V_1 and V_2 indicate the measurements of the parts. All lengths taken from Hubble technical drawings, NASA, "Cargo Systems Manual (CSM): Hubble Space Telescope," February 13, 2002; all masses from Mattice, J., "Hubble Space Telescope Systems Engineering Case Study."

Problem 2. Use this model as a basis to write a function(s) to determine the Mass Center and Inertia Matrix for any location.

Using the radial-center of the farthest tip of Section 1 as our zero point , the center of mass is located at $V = [282, 0, 0]$ inches. This makes since, as the model is symmetric about the V_2 and V_3 axes, and the center of mass of the solar arrays is calculated to be ≈ 288 inches along V_1.

The HST inertia matrix[1], was at one point measured as:

$$I = \begin{bmatrix} 36046 & -706 & 1491 \\ -706 & 86868 & 449 \\ 1491 & 449 & 93848 \end{bmatrix} kg \cdot m^2.$$

The Python script in Appendix gives the result of:

$$I = \begin{bmatrix} 43535 & 0 & 0 \\ 0 & 117651 & 0 \\ 0 & 0 & 135519 \end{bmatrix} kg \cdot m^2,$$

which has a relative error of:

$$I = \begin{bmatrix} -20, 100, 100 \\ 100, -35, 100 \\ 100, 100, -44 \end{bmatrix} \%.$$

Note that while our simple, 5 part model does a very good job of predicting the I_{V_1} component ($\approx 20\%$ error), the I_{V_2} and I_{V_3} components are not represented very well. This is likely due to leaving out the antenna booms, which should have the largest effect in the V_2 and V_3 directions. It should also be noted that, due to the symmetric nature of our model, all of the off-axis terms are missing.

[1] Queen, S., "HRV GNC Peer Review, Flight Performance Analysis," Tech. rep., NASA Goddard Space Flight Center, 2004.

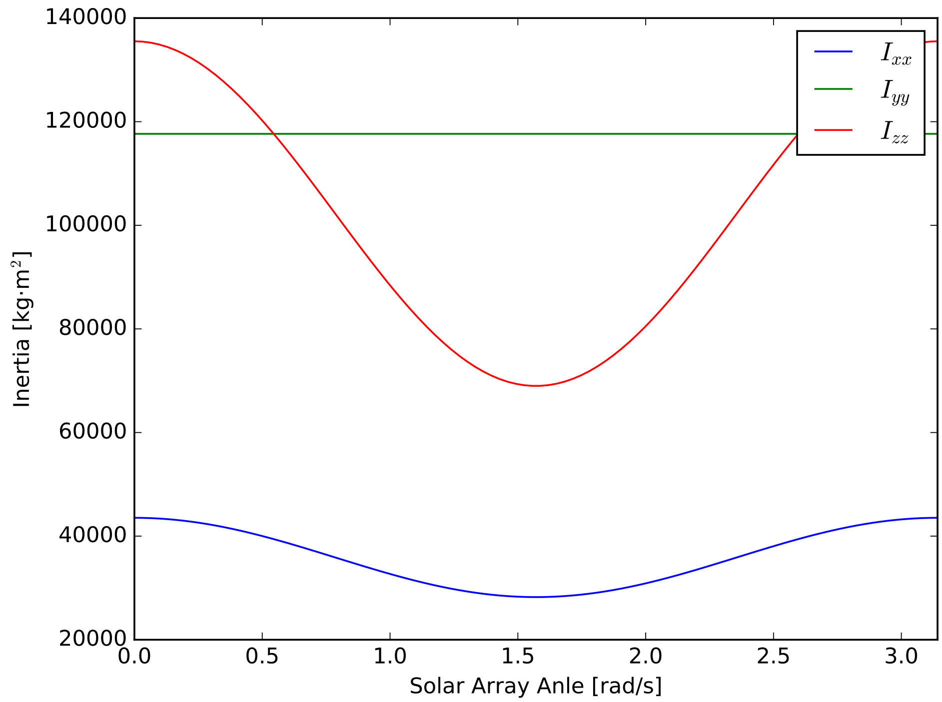

Figure 2: Inertias for principal axes for different solar array configurations

Problem 3. Write a function to find the current angular momentum relative to the mass center.

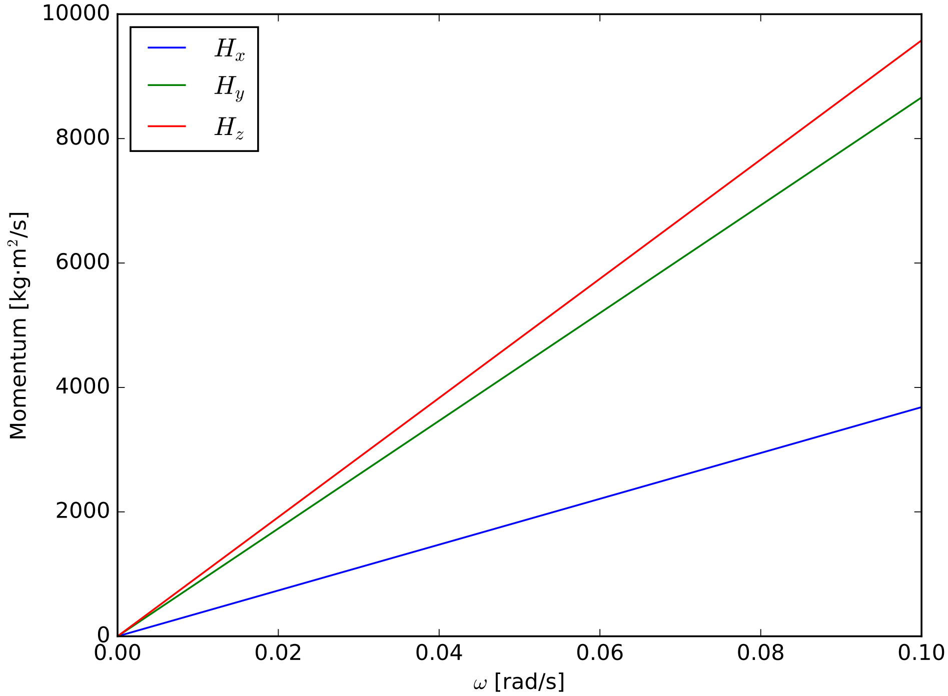

Figure 3: Effects of spin on each axis

Problem 4. Choose the optimal location for a torque producing system and explain why you think is the best location.

Problem 5. Using your previous functions, write a program to find the resulting angular acceleration produced from a given torque.

Problem 6. Write what next steps you would take to develop a controller that keeps the craft pointed in a specific direction.