**Homework Assignment #4** **AE-3521**
Date: 1/26/04 Due: 2/02/04

1. Estimate $C_{m_{\dot{\alpha}}}$ and $C_{m_q}$ in Problem 3.5.
2. Problem 3.6
3. Estimate $C_{n_r}$ in Problem 3.9, and compare to the value in Appendix B.
4. Problem 3.12
5. A reentry vehicle is entering the Earth's atmosphere at a latitude of 38 degrees. It's inertial velocity is 20,000 ft/s at a heading of 45 degrees, The flight path angle nearly tangential to the Earth's surface, so for this problem you can approximate it as zero.
   a) Calculate the vehicle's speed and heading relative to the Earth's surface.
   b) The on-board accelerometers read [1.5; 0; 0] g's. Calculate the acceleration relative to the Earth's surface. *Note* that this result is needed to navigate relative to the Earth's surface using on-board sensors. That is, given accelerometer and gyro readings, we can calculate $\ddot{\vec{r}}(t)$, and then integrate twice to obtain $\vec{r}(t)$. The same idea can be used to navigate relative to any planetary body.

**Hints and answers:**

1. Use the expressions in Table 3.3. Assume η=1. Note that $\bar{c} = S/b$, and use (2.22) to estimate dε/dα, where $AR_w = b/\bar{c} = b^2/S$. The theoretical value of $C_{l_{\alpha_w}} = 0.1$ needs to be corrected for a wing with finite aspect ratio using the expression on page 57 (note the units are /rad). The same goes for the tail surfaces. The tail volume ratio, $V_H$, is defined on page 48, where $S_t$ is the reference area for the horizontal tail. Ans: -10.4 and –19.7.

2. Use the expressions in Table 3.4, again correcting $C_{l_{\alpha_w}}$ for finite aspect ratio. The wing tip chord and root chord have to be estimated from the figure. Use $c_t = 4.4$ ft. and $c_r = 9$ ft. The aspect ratio for the vertical fin needs to be estimated from the figure. To do this, visualize the vertical fin as a wing, whose span ($b_v$) is twice the height of the fin. Use 6.5 ft for the height. Then $AR_v = \dfrac{b_v^2}{2S_v}$. Assume $\eta_v = 1$. Ans: -0.6 and 0.27
3. From the drawing and the data given on page 417, use the following estimates: $S=5500$ ft$^2$, $S_v = 900$ ft$^2$, $b_v/2 = 32.6$ ft and $l_v = 105$ ft to get $V_v$ and $AR_v$, and estimate $C_{L_{\alpha_v}}$ using the expression on page 57. Assume $\eta_v$=1. Ans: -0.3

5. Solve this problem in a rotating Earth fixed frame, with the x and y axes in the equator, the z axis passing through the North pole, and the entry condition located in the x,z plane. In part a) use $V = \dot{\vec{r}} + \vec{\omega} x \vec{r}$. From the entry conditions given, you should be able to express the inertial velocity ($\vec{V}$) and position ($\vec{r}$) in the Earth fixed frame, and then solve for $\dot{\vec{r}}$. In part b) use $\vec{a} = \ddot{\vec{r}} + 2\vec{\omega} x \dot{\vec{r}} + \vec{\omega} x \vec{\omega} x \vec{r} = \vec{F}/m$ and solve for $\ddot{\vec{r}}$, using $\dot{\vec{r}}$ from part a) and calculating $\vec{F}/m$ from the accelerometer readings. Remember that accelerometers sense

only the specific force, (aero + propulsive force)/mass, so you need to add in the gravity term.

**Answers for problems 1 to 3 are from the solutions manual, and are not guaranteed. Let me know if your answer is different. Be careful of units. Your result should be dimensionless, or equivalently, /rad.**