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Create a MATLAB code, similar to the one you wrote for Exercise Set V, to treat lateral-directional motions. First, compute the dimensional stability derivatives from the following dimensionless variables for $\mathbf{M} = 0.25$ flight for the Boeing 747 aircraft at standard sea level conditions:

$$\begin{aligned} \mathbf{C}_{y_\beta} &= -0.96\,, & \mathbf{C}_{l_\beta} &= -0.221\,, & \mathbf{C}_{n_\beta} &= +0.15 \\ \mathbf{C}_{y_p} &= 0.0\,, & \mathbf{C}_{l_p} &= -0.45\,, & \mathbf{C}_{n_p} &= -0.121 \\ \mathbf{C}_{y_r} &= 0.0\,, & \mathbf{C}_{l_r} &= +0.101\,, & \mathbf{C}_{n_r} &= -0.30 \end{aligned} \tag{1}$$

and the dimensional properties

$$\begin{aligned} &W = 564,032.\ \text{lbf}\,, & &b = 195.7\ \text{ft} \\ &I_x = 14.3 \times 10^6\ \text{slug-ft}^2\,, & &I_z = 45.3 \times 10^6\ \text{slug-ft}^2\,, & &I_{xz} = -2.23 \times 10^6\ \text{slug-ft}^2 \end{aligned}$$

(These are the same values as specified in Section 5.4.2 of the class notes.) Verify that the times-to-damp to half amplitude of the exponential modes and the period and damping ratio of the oscillatory mode are the same as those given in class for this case.

For the remainder of this exercise, we will study the *high-speed transonic* flight condition of the Boeing 747 aircraft at $\mathbf{M} = 0.90$ and 40,000 ft. Compute the dimensional stability derivatives from the following dimensionless variables:

$$\begin{aligned} \mathbf{C}_{y_\beta} &= -0.92\,, & \mathbf{C}_{l_\beta} &= -0.095\,, & \mathbf{C}_{n_\beta} &= +0.207 \\ \mathbf{C}_{y_p} &= 0.0\,, & \mathbf{C}_{l_p} &= -0.296\,, & \mathbf{C}_{n_p} &= +0.023 \\ \mathbf{C}_{y_r} &= 0.0\,, & \mathbf{C}_{l_r} &= +0.193\,, & \mathbf{C}_{n_r} &= -0.333 \end{aligned} \tag{2}$$

and the dimensional parameters

$$\begin{aligned} &W = 636,636.\ \text{lbf}\,, & &b = 195.7\ \text{ft} \\ &I_x = 18.2 \times 10^6\ \text{slug-ft}^2\,, & &I_z = 49.7 \times 10^6\ \text{slug-ft}^2\,, & &I_{xz} = -0.35 \times 10^6\ \text{slug-ft}^2 \end{aligned}$$

(These are the same as specified in Section 5.4.2 of the class notes.)

1. Determine the characteristic response times for the rolling, spiral, and Dutch Roll modes. Compare the times to damp to half amplitude (or double[1]) for the real roots, and the period and damping ratio of the oscillatory root, with the values given in class (or the course notes) for the Mach 0.25 powered approach condition. Relate any differences to the effects of changes in values of the stability derivatives, if possible.

2. Determine the value of the dihedral effect $\mathbf{C}_{l\beta}$ for which the spiral mode becomes stable (while keeping all other variables fixed). How does this change affect the period and damping ratio of the Dutch Roll mode?

3. Determine the value of the weathercock stability $\mathbf{C}_{n\beta}$ for which the spiral mode becomes stable (while keeping all other variables fixed). Be sure you set the dihedral effect back to its default value after changing it for question **2**. How does this change affect the period and damping ratio of the Dutch Roll mode?

4. Determine and display the time histories of all state variables for a unit perturbation in roll rate for each of the three cases: the original data; the modified dihedral effect $\mathbf{C}_{l_\beta}$; and the modified weathercock $\mathbf{C}_{n_\beta}$. You will want to plot $\beta = v/u_0$, rather than v, so that all variables are on comparable scales. Plot the response for 20 seconds of flight time.

5. In order to see what is happening in the spiral mode more clearly, it is useful to plot the heading angle ψ. Do this by adding ψ to the state vector and modifying the plant matrix accordingly (using the fact that $\dot{\psi} = r$). Repeat the plots of Problem 4, including the heading angle.

[1] You should find that the spiral mode is unstable for this flight condition.