[6] The short period dynamics of a certain aircraft, and the transfer function of the elevator servo are given by :

$$\frac{\theta(s)}{\delta_e(s)} = \frac{-1.45(s+0.32)}{s(s^2+0.82s+1.62)} \qquad G_s(s) = \frac{-10}{s+10}$$

2021
2019
2017

Use Bode diagram to design a controller for the displacement autopilot in order to achieve phase margin of $50°$. Find the gain margin and bandwidth of the compensated system.

[7] A fighter aircraft, flying at 200 ms^{-1} and at a height of 10^4 m has the following short period equations of motion:

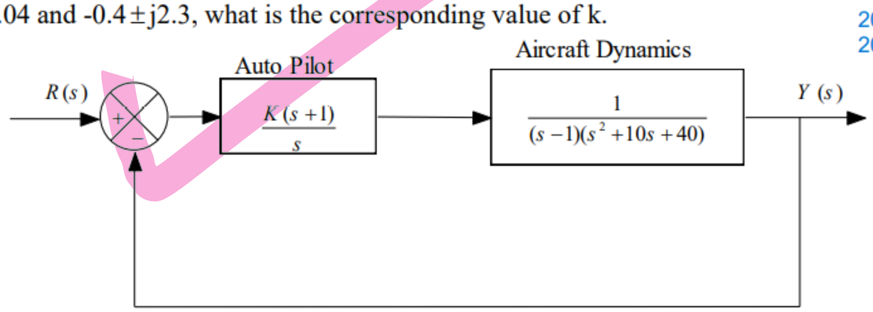
2018

$$\dot{\alpha} = -6\alpha + q \qquad \dot{q} = -5\alpha - 0.6q - 12\delta_e$$

(a) Derive the transfer function relating both angle of attack and pitch rate to the elevator deflection.
(b) Derive the transfer function relating acceleration in z-direction to the elevator deflection.
(c) With the aid of root locus method, design an acceleration autopilot such that, the poles of the inner loop are critically damped poles, while the outer loop must has a damping ratio of 0.707.
(d) Determine the overall transfer function of the system.
(e) Predict the nature of the response of the system to both step and impulse inputs.

[14] A high performance jet aircraft with an autopilot control system has a unity feedback and control system shown. Sketch the root locus by finding all the required information. Verify that the breakaway points are -4.07 and 0.444, find the corresponding gains. Find the range of k for stability. What is the best value of ξ that can be achieved. If the closed loop poles were chosen as -4.1 $\pm$j1.04 and -0.4$\pm$j2.3, what is the corresponding value of k.

2020
2019



[15] A wind tunnel model is mounted on a bearing system so that the model is free to pitch about its center of gravity. No other motion is possible. The equation of motion for the model is

$$\begin{bmatrix} \Delta\dot{\theta} \\ \Delta\dot{q} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ M_\alpha & M_q \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \Delta q \end{bmatrix} + \begin{bmatrix} 0 \\ M_\delta \end{bmatrix} [\Delta\delta_e]$$

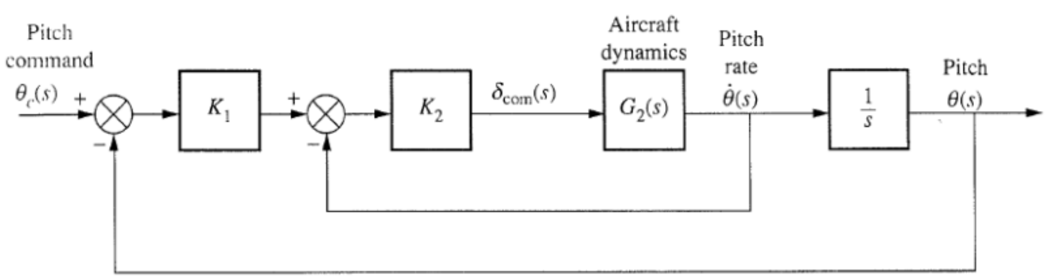
2021
2018

where $M_\alpha = -1$, $M_q = -2$, and $M_\delta = -3$.

Design a control system to maintain the model at some reference pitch attitude and the closed loop poles at $S_{1,2} = -2 \pm j$.

[18] The pitch stabilization loop for an F4-E military aircraft is shown, δ_{com} is the elevator and canard input deflection command to create a pitch rate. If $G_2(s) = \dfrac{-508(s+1.6)}{(s+14)(s-1.8)(s+4.9)}$ 2017

(a) Sketch the root locus of the inner loop.
(b) Find the range of K_2 to keep the inner loop stable with just pitch rate feedback.
(c) Find the value of K_2 that places the inner loop poles to yield a damping ratio of 0.5.
(d) For your answer to part (c), find the range of K_1 that keep the system stable.
(e) Find the value of K_1 that yields closed loop-poles with damping ratio of 0.45.
(f) What is the effect on the performance if the pitch rate sensor fails?



[22] The two degree of freedom approximation of a high speed aircraft has the following linearized equations of motion lateral motion:

2018

$$\dot{\beta} = -0.6\beta - 1.2r + 0.04\delta_R$$

$$\dot{r} = 28\beta + 0.8r - 20\delta_R$$

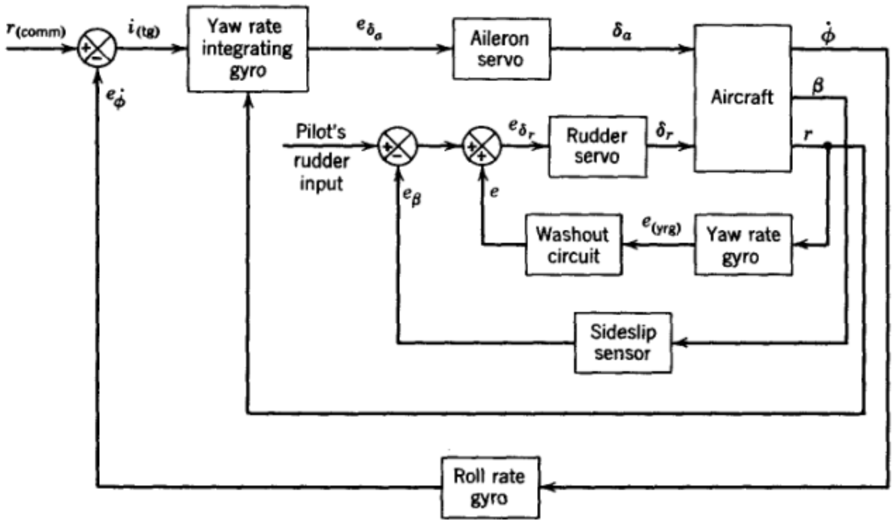
- Derive the transfer function relating the side slip angle and yaw rate to the rudder deflection.
- Design a yaw damper for the system.
- Use side slip sensor to achieve a coordinated aircraft.

[23] The block diagram of yaw orientation control system is shown in the figure. Derive the state space model of the closed loop system using the full state space model of the aircraft. The transfer function of different blocks are given by

$$G_{\substack{rudder\\servo}}(s)=\frac{10}{s+10},\quad G_{\substack{aileron\\servo}}(s)=\frac{4}{s+4},\quad G_{yrig}(s)=\frac{kyrig}{s},\quad G_{washout}(s)=\frac{s}{s+1/\tau},$$

$$G_{yrg}(s)=k_{rg},\quad G_{sss}(s)=k_{s},\ \text{and}\quad G_{rrg}(s)=k_{rrg}.$$

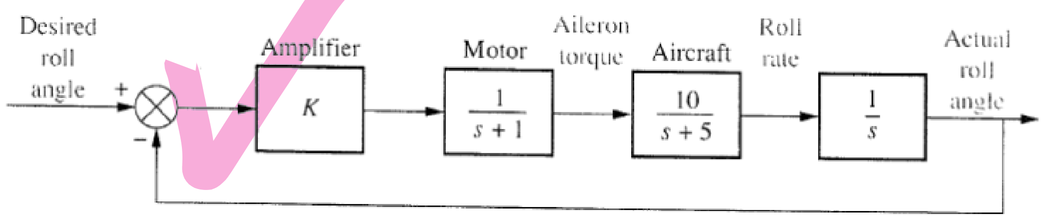
2021
2019
2017



Block diagram of yaw orientation control system.

[24] An aircraft control system is shown. The torque on the aileron generates a roll rate. The resulting roll angle is then controlled through a feedback system. Design a lead compensator for a 60° phase margin and $K_v = 5$.

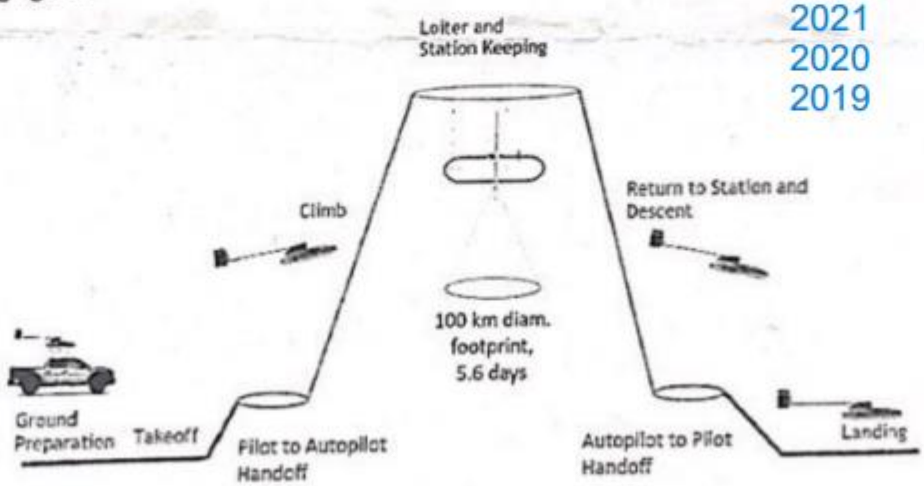
2020



Question (4): [32%]

It is required to design a complete autopilot for long-endurance communication support UAV to get the UAV autonomously operated in three flight phases (Climb, Loiter, and Descent) as shown in the following figure.

2021
2020
2019

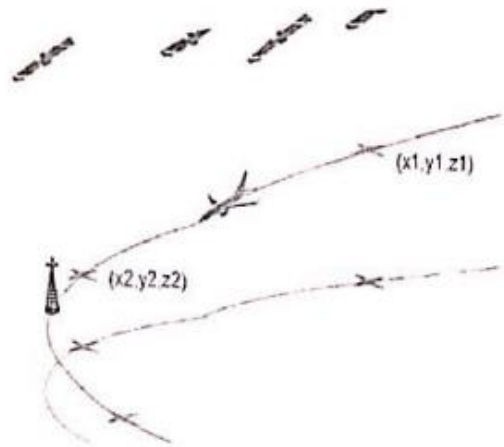


A. Sketch the program flow chart required to perform the mission.
B. State all of the necessary control loops required for each flight phase.
C. Draw the block diagrams of the required control loops and specify the sensors used for the feedback of each loop.
D. Starting from the state space model of the aircraft, derive the aircraft transfer functions required for each control loop.

Question (4): [24%]

It is required to design a complete autopilot to guide an aircraft between two way points (x1,y1,z1) and (x2,y2,z2)

2018
2017



A. Draw the block diagrams required to control the altitude, speed, and heading.
B. Specify the sensors used for the feedback of each loop.
C. Starting from the state space model of the aircraft, derive the longitudinal state space model of the closed loop system required to control the altitude and speed.
D. Starting from the state space model of the aircraft, derive the lateral state space model of the closed loop system required to coordinate the aircraft and control the heading.