Semester Project

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1 Part 1

For the first part of the semester project, you are required to design both longitudinal and lateral autopilots for an F-16. You are free to use frequency domain **or** state-space analysis to design your controller. For all tasks, analysis of robustness/margins are **required**. Actuator dynamics should always be included. **Be sure to include a Mach-hold autopilot that maintains the velocity of the aircraft. Choose one and follow carefully the steps provided below:**

1.1 Frequency Domain

For this part you will be using frequency domain analysis to design and build autopilots that control both the lateral and longitudinal dynamics of the F-16. Follow the steps below and provide a block diagram of your final control system.

1.1.1 Longitudinal Autopilot

Design a longitudinal autopilot that satisfies the following requirements:

- Design a pitch-damper with a washout filter. Check the functionality of the damper with Bode, Nyquist, and time response plots. **How does the inclusion of a pitch-damper and washout filter affect the short period dynamics of the F-16 model?**
- Design a pitch-attitude hold controller by closing the loop around the pitch damper **Show the location of your poles and zeros in your Bode plot and plot the pitch angle command, pitch angle, pitch rate, and elevator deflection versus time.**

1.1.2 Lateral Autopilot

Design a lateral autopilot that satisfies the following requirements:

- Design a yaw damper with a washout filter. Check the functionality of the damper with Bode, Nyquist, and time response plots.
- Design a sideslip angle select controller. Check your work with a 2 deg three second pulse. **How does air speed affect the yaw response? Show the location of your poles and zeros in your Bode plot and plot yaw command, yaw angle, yaw rate, and rudder deflection versus time.**
- Design a roll angle controller complete with a roll rate damper. Start by designing a roll damper. Then close the loop around the damper with a roll controller. Check the functionality of the damper with frequency domain, pole diagram, and time response plots. **Show the location of your poles and zeros in your Bode plot and plot roll command, roll angle, roll rate, and aileron deflection versus time.**

1.2 State-Space Methods

For this part you will be using state-space methods to design an LQ feedback controller for both the lateral and longitudinal dynamics of the F-16. Follow the steps below and provide a block diagram of your final control system.

1.2.1 Longitudinal Autopilot

Design a pitch attitude hold using pole placement or the lqr command in MATLAB. If you use an integrator augmentation in your controller, show it. **Show the location of your poles and zeros in your Bode plot and plot the pitch angle command, pitch angle, pitch rate, and elevator deflection versus time.**

1.2.2 Lateral Autopilot

Design a combined roll/yaw angle controller using pole placement or lqr command in MATLAB. If you use an integrator augmentation in your controller, show it. **How does this method differ from a lateral autopilot designed using frequency methods? Show the location of your poles and zeros in your Bode plot and plot roll/yaw command, roll/yaw angle, roll/yaw rate, and aileron/rudder deflection versus time.**

2 Part 2

For the second part of the semester project, you are free to choose **two out of the three** challenges:

2.1 Heading/VOR/LOC Autopilot

- Design a heading select controller. Make a 90 deg heading change and limit the roll angle to 70 deg as shown in figure 1. Maintain airspeed at 400 ft/s. **Record your results and plot heading, roll angle, rudder, and aileron deflection versus time.**

- Include VOR/LOC hold into the lateral autopilot of the aircraft as shown in figure 1. Start with an initial heading of 60 deg at 10000 ft and 400 $\frac{\text{ft}}{\text{s}}$. Acquire a VOR transmitter beam $\gamma_{\text{VOR}} = 100$ deg located at $\begin{bmatrix} 36 & 1 \end{bmatrix}$. Maintain constant speed and pitch angle. Now acquire a beam from the LOC transmitter with $\gamma_{\text{LOC}} = 150$ deg located at $\begin{bmatrix} 42 & -2 \end{bmatrix}$ with a signal radius of 1.3 mi. **Include plots of heading, roll angle, roll-rate. yaw angle, yaw rate, aileron and rudder deflections, and heading-path deviations for both transmitters in your plots!**

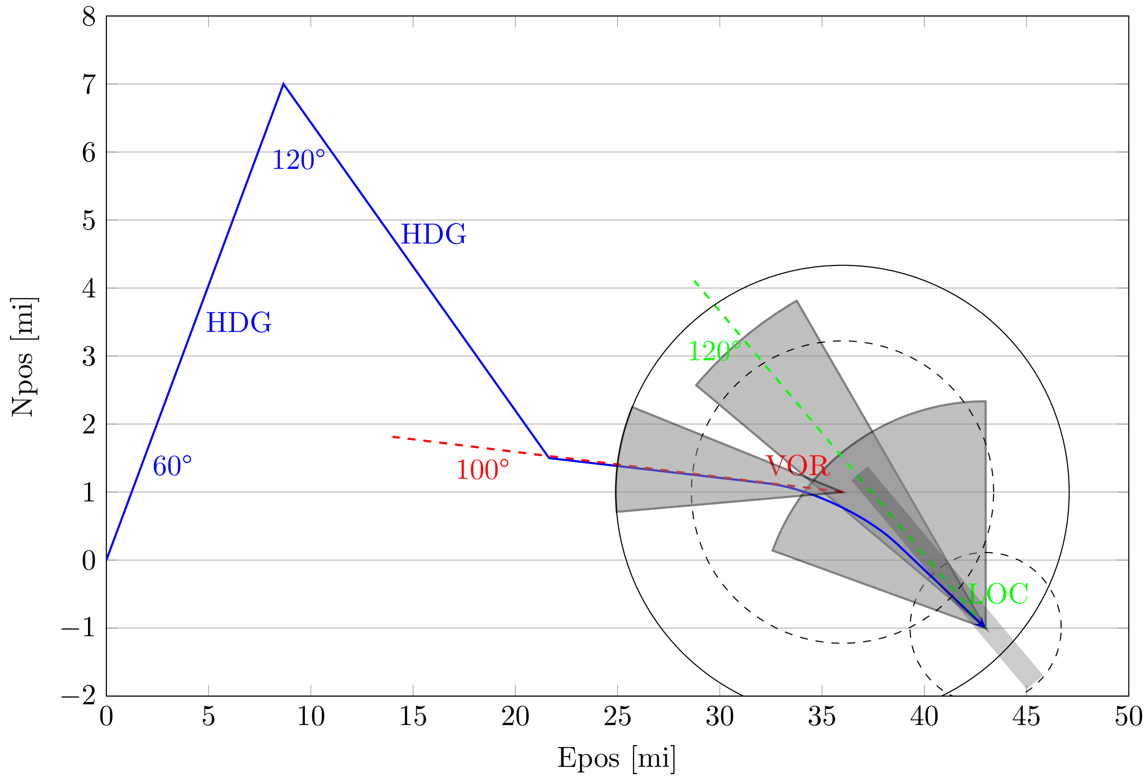

Figure 1: Lateral Autopilot

2.2 Altitude/ILS/GS

- Include an altitude select to your longitudinal autopilot as shown in figure 2. Start from an initial altitude of 0 ft and make a steady climb to 20000ft with a pitch angle limit of 20 deg. Maintain airspeed at 400 $\frac{\text{ft}}{\text{s}}$. Fly for 20 mi. **Record your results and plot altitude, angle of attack, and elevator deflection versus time.**

- Include an automatic landing system with GS/ILS into the longitudinal autopilot of the aircraft as shown in figure 2. Start the descent from an altitude of 1500 ft and an airspeed of $250\frac{\text{ft}}{\text{s}}$. Maintain constant airspeed and a pitch angle between -5 deg to 5 deg. Choose $\gamma_{\text{ILS}} = -2.5$ deg. Include an autoflare such that, at an altitude of 70 ft above the ground, the rate of descent of the aircraft is reduced to less than 2 $\frac{\text{ft}}{\text{s}}$. **Be sure to include altitude, pitch, pitch rate, angle of attack, descent rate, elevator deflection, and glide-path deviation in your plots!**

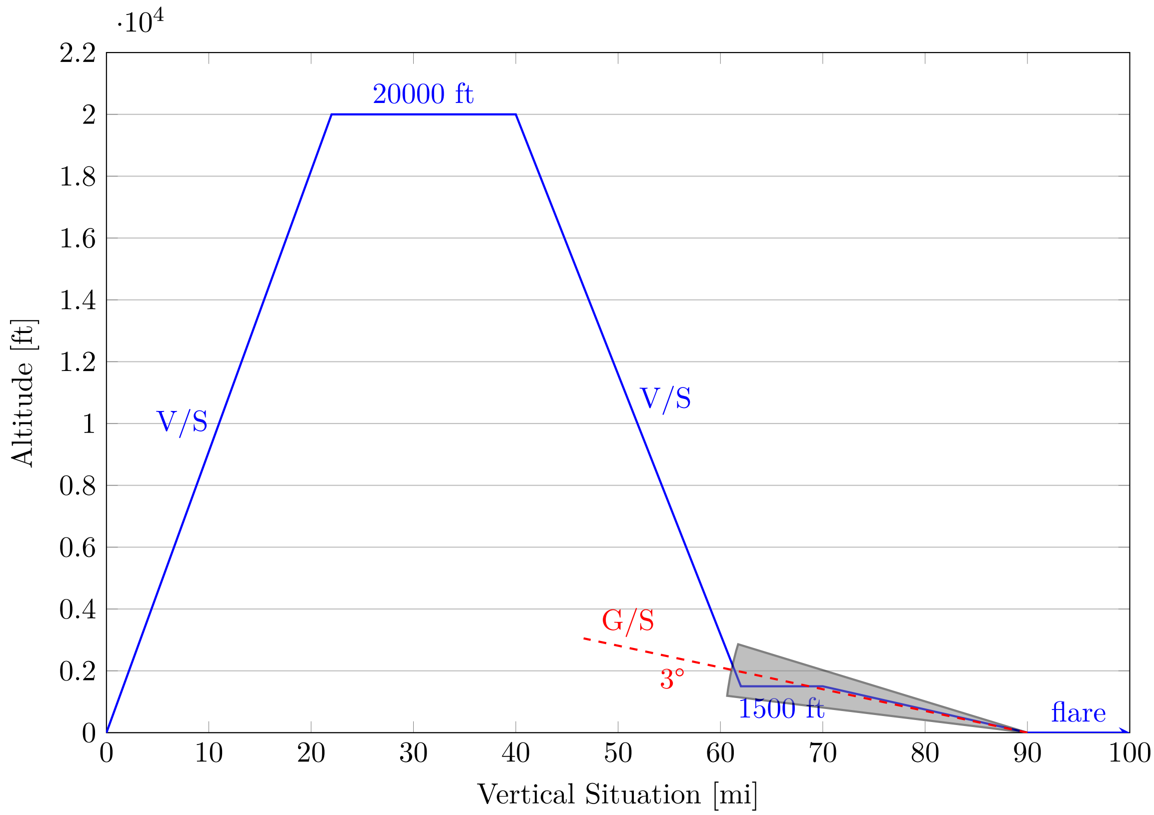

Figure 2: Longitudinal Autopilot

2.3 Full 6DOF Flight Simulator Demonstration

The task of this project is to integrate **Part 1** and the 6DOF flight model into FlightGear for MATLAB/Simulink and integrate it with a joystick and flight instruments in the simulator located in lab s109.

3 Deliverables

At the end of the semester you will be expected to deliver a presentation and turn in any m-code used for your projects.