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AER408
Aerospace Guidance & Control Systems

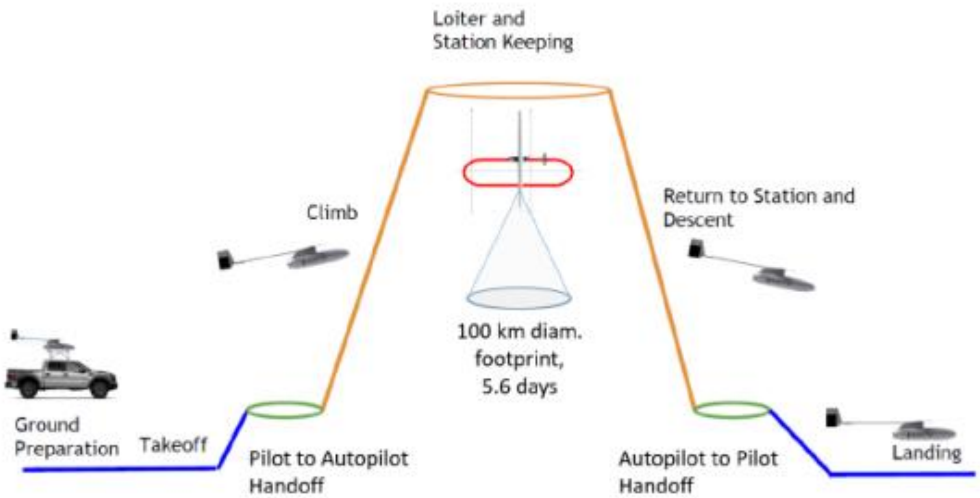
Task (7)
Autopilot Testing on Non-Linear Simulation

Introduction:

The objective in this part of our project is to test our controllers ***"The lateral + longitudinal Autopilots"*** for a conventional fixed wing airplane on a more realistic model of the airplane dynamics, which is the 6DOF nonlinear airplane equations of motion.

The nonlinear model of the airplane dynamics is more accurate than the linearized state space model of the airplane and it inherits the ***"coupling"*** between the longitudinal & lateral dynamics of the airplane, so the testing the controllers with the nonlinear model will get both the "longitudinal & lateral" controllers in action simultaneously, controlling the 4 control actions ***"aileron, rudder, elevator & thrust"*** to maintain the required attitude & altitude of the airplane performing ***"coordinated-level turns"*** and ***"climb/descent"*** commands.

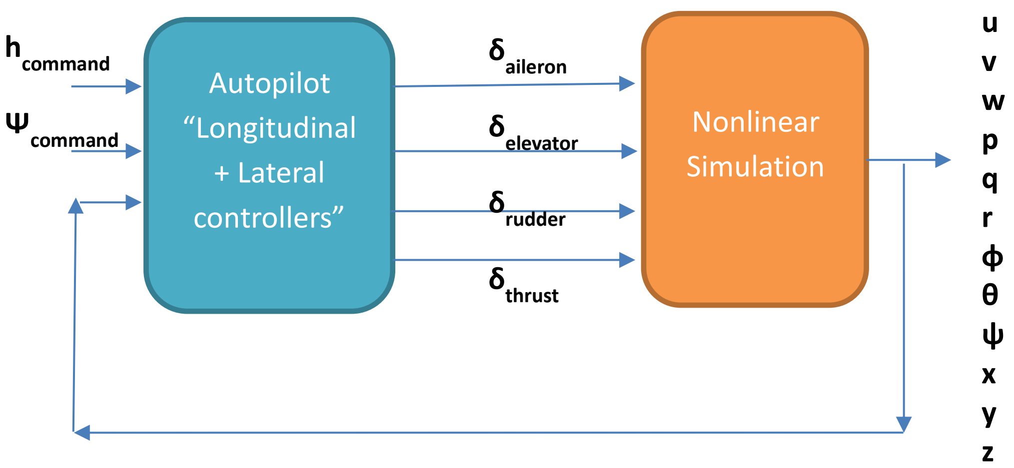
A specific set of tests will be performed one by one in order to test each part of the Autopilot separately, and finally a complete mission that includes "climb, cruise, turn, descent" will be performed to check all the functionalities of the Autopilot at the same time



<u>Task Statement:</u>

a) Develop the testing loop Containing the "Controller + Simulator"

It is required to test the designed controllers with the simulator, the Autopilot has 4 outputs that represent the ***commanded control actions "aileron, rudder, elevator, thrust"*** at each time step. These 4 control actions are the inputs to the nonlinear simulator that calculates the new states of the airplane due to these inputs, the calculated states are considered as the ***"sensor signals"*** that are fed back to the Autopilot as the ***"feedback signal"*** which are required to implement the control law and calculate the ***new commanded control actions*** that are fed to the simulator as input and so on



b) Test the "Pitch controller" and compare the response with the same test on the State space model

Give a commanded input signal of pitch angle and observe the response and control action (θ, u, γ, h, δe)

Perform the same test on the Linear Longitudinal state space model and observe the response and control action (θ, u, γ, h, δe)

Plot the results against each other

Note: in this test all the control actions are set to zero except the (δe) which will by the Autopilot, this test validate the pitch controller and express the necessity of velocity controller

Please watch the tutorial video it will help you keep the work organized

c) Test the “Pitch controller + Velocity controller” and compare the response with the same test on the State space model

Give a commanded input signal of pitch angle and observe the response and control action (θ, u, γ, h, δe. δth)

Perform the same test on the Linear Longitudinal state space model and observe the response and control action (θ, u, γ, h, δe. δth)

Plot the results against each other

Note: in this test all the control actions are set to zero except the (δe , δth) which are calculated by the Autopilot, this test shows the effect of the velocity controller and validate the operation of both the pitch and velocity controllers

d) Test the “Altitude Hold” controller and compare the response with the same test on the State space model

Give a commanded input signal of altitude (h) and observe the response and control action (θ, u, γ, h, δe. δth)

Perform the same test on the Linear Longitudinal state space model and observe the response and control action (θ, u, γ, h, δe. δth)

Plot the results against each other

Note: in this test all the control actions are set to zero except the (δe , δth) which are calculated by the Autopilot, this test shows the effect of the velocity controller and validate the operation of both the pitch and velocity controllers

e) Test the “Lateral controller” and compare the response with the same test on the State space model

Give a commanded input signal of Heading (ψ) and observe the response and control action (β, φ, ψ, h, δr. δa)

Perform the same test on the Linear Lateral state space model and observe the response and control action (β, φ, ψ, h, δr. δa)

Plot the results against each other

Note: in this test all the control actions are set to zero except the (δa , δr) this test validate the operation of "Yaw damper & Heading" controllers. Check the coordination of the turn by observing the sideslip angle.

Check the response of the altitude (h) during turn in both the cases of linear & nonlinear tests, and comment

Is this a "Coordinated level turn" ?????

f) Test the "Lateral controller + Altitude Hold controller" and compare the response with the same test on the State space model

Give a commanded input signal of Heading (ψ) and observe the response and control action (β, φ, ψ, h, δr. δa, δe, δth)

Perform the same test on the Linear Lateral state space model and observe the response and control action (β, φ, ψ, h, δr. δa, δe, δth)

Plot the results against each other

Note: this test validates the operation of "lateral & longitudinal" controllers simultaneously. Check the rule of the lateral controller to achieve coordination of the turn by observing the sideslip angle, and the rule of the longitudinal controller to maintain the altitude by observing the altitude (h)

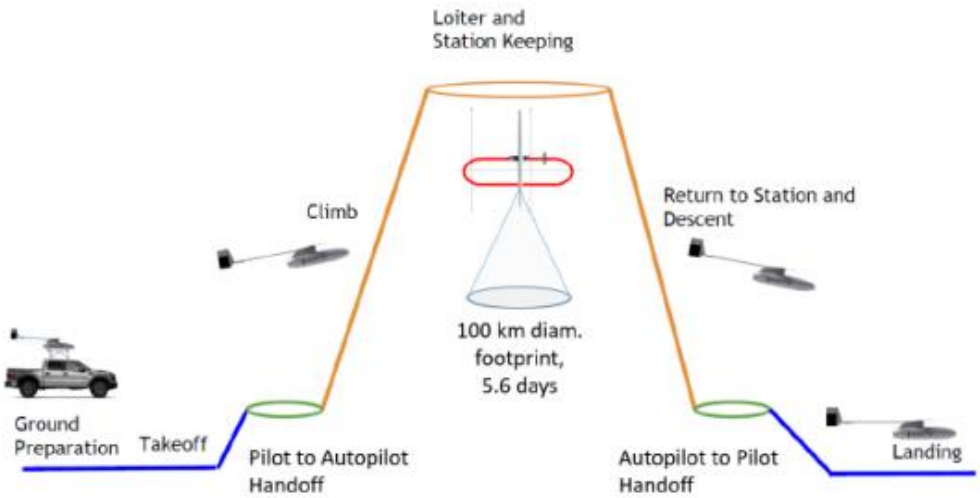
Check the response of the altitude (h) during turn in both the cases of linear & nonlinear tests, and comment

Is this a "Coordinated level turn" ?????

g) Perform a complete autonomous mission including "climb, cruise, turn, descent"

Having checked the correctness of the flight control system, it can be used to pilot the airplane autonomously to perform a required mission commanded to the flight control system in the form of "commanded altitude & commanded heading"

It is required to use the Autopilot to perform a segment from the mission shown in the figure starting from the (Pilot to Autopilot Handoff → Autopilot to pilot Handoff)



Mission:

- Climb
  climb to altitude of 10,000 ft at 1500 ft/min climb rate

- Cruise
  cruise at constant velocity and heading angle for 2 minutes

- Complete turn
  make a circle by commanding a change in the heading angle with 360^o

- Cruise
  cruise at constant velocity and heading angle for 2 minutes

- Climbing turn
  command a change in the heading angle with 30^o along with a step input of 100 ft in altitude

- Descent
  descend down to the initial altitude by reducing the altitude by 10,000 ft at 1500 ft/min descent rate