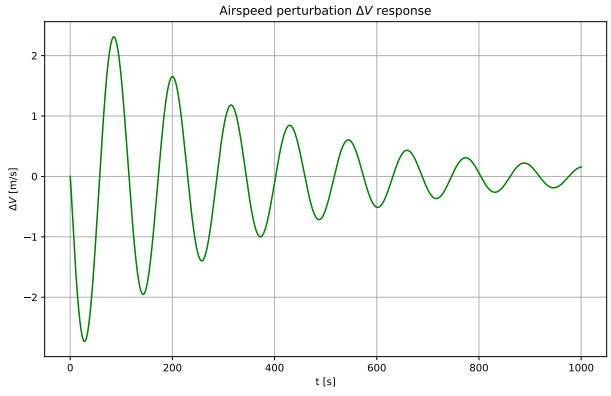
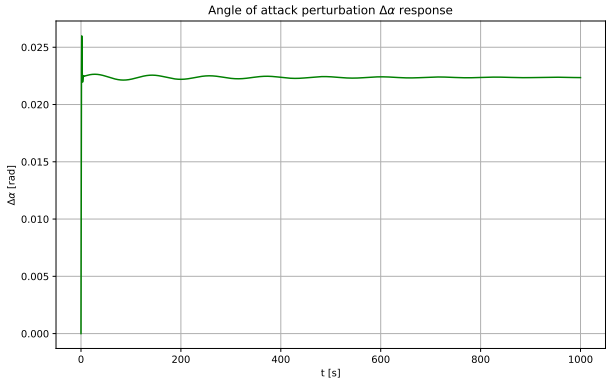
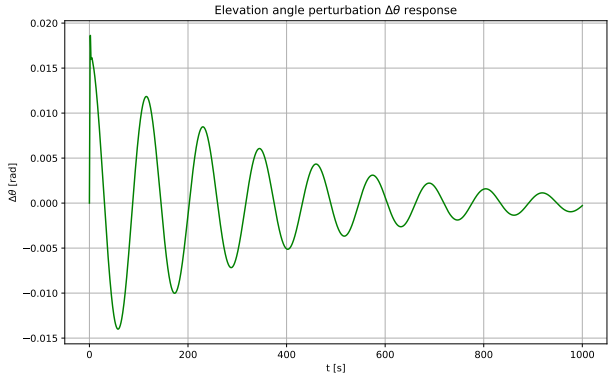
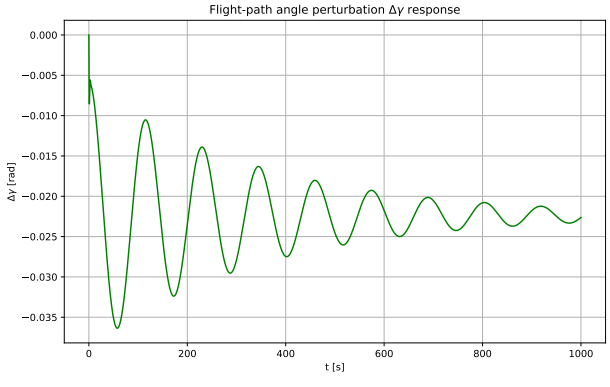
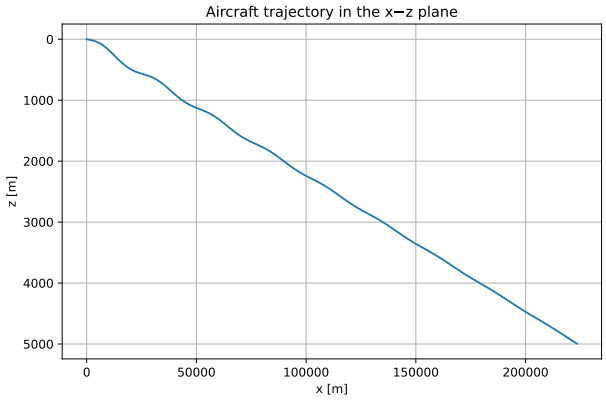
Longitudinal response to vertical wind step











The evolution of ΔV is characterized by a small-amplitude oscillation, slowly damped, associated with the phugoid mode. For long times, ΔV tends to zero and the airspeed returns to its initial equilibrium value.
The variation of the angle of attack $\Delta\alpha$ exhibits a much faster evolution, reaching its steady-state value after approximately 10 s. Oscillations associated with the short-period mode are damped extremely rapidly, while those related to the phugoid mode are almost imperceptible due to their small amplitude. The steady-state value of $\Delta\alpha$ is positive, since an upward vertical gust, when combined with the forward velocity, increases the angle of attack.
The elevation angle ϑ shows an initial peak associated with the short-period mode, followed by a weakly damped oscillation characteristic of the phugoid mode. At steady state, $\Delta\vartheta$ vanishes and the elevation angle returns to its equilibrium value, which coincides with the equilibrium angle of attack since $\gamma_e = 0$. This implies that the steady-state variation of α is compensated by the flight-path angle γ,

$$\Delta\vartheta_{ss} = \Delta\alpha_{ss} + \Delta\gamma_{ss} = 0 \qquad \Delta\gamma_{ss} = -\Delta\alpha_{ss}.$$

This behavior is confirmed by the evolution of $\Delta\gamma$, which reaches a negative steady-state value equal in magnitude to $\Delta\alpha_{ss}$. An upward vertical gust, therefore, results in a decrease in the flight-path angle.
In the trajectory plot, the vertical axis has been inverted to represent the altitude z as positive downward. Consistent with the negative steady-state flight-path angle, the trajectory shows a progressive loss of altitude. The small oscillations visible in the initial phase are due to the oscillations of the flight-path angle. Airspeed variations are negligible, allowing the motion along the x-axis to be approximated as uniform rectilinear motion with constant equilibrium velocity.