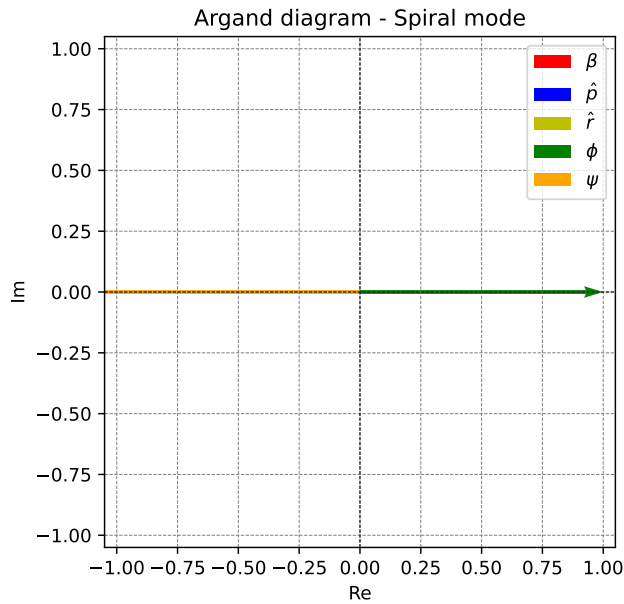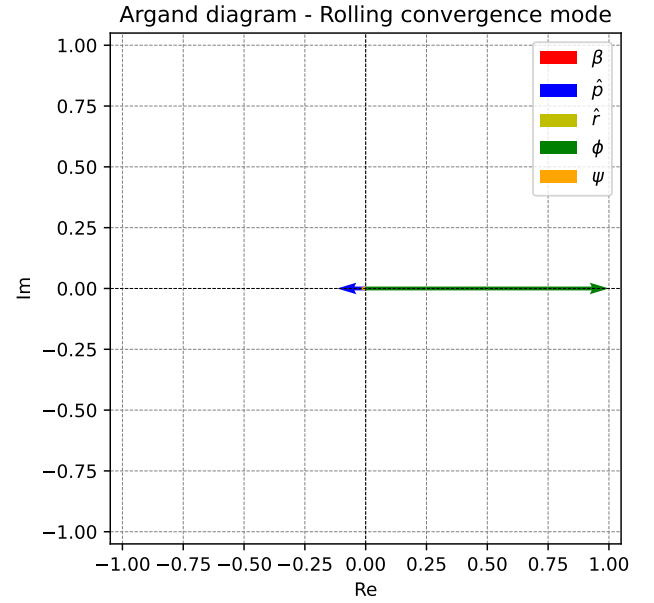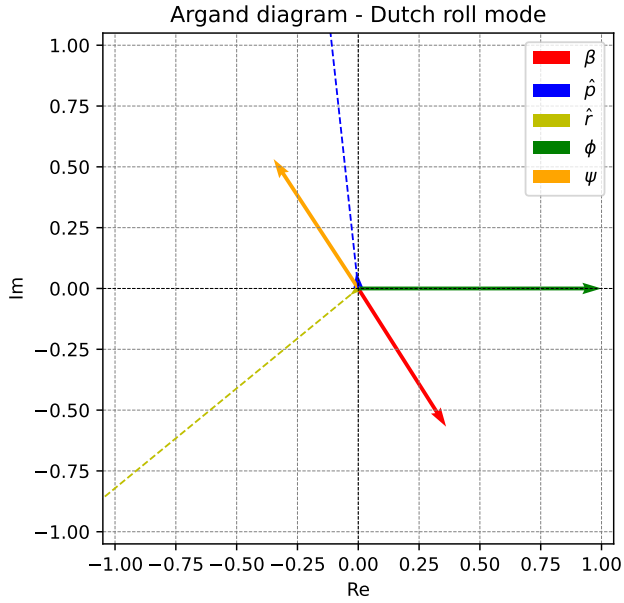# Argand diagrams of aircraft lateral-directional modes

Equilibrium conditions: $V_e = 500\,\mathrm{mph}$, $\gamma_e = 0°$, $\rho_e = 0.458\,\mathrm{kg/m^3}$, $SM = 0.15$

In the Dutch roll mode, the state variables that change most are the sideslip angle β, the bank angle Φ, and the azimuth angle Ψ, with Ψ leading Φ by approximately 130° in phase. β and Ψ are almost equal and opposite. This mode is characterized by a lateral oscillation combined with a yawing motion, as the aircraft swings like a pendulum while rotating around the z-axis.

In the rolling convergence mode, the motion can be approximated as a single-degree-of-freedom rotation around the x-axis. The bank angle Φ and the roll angular velocity p are the primary variables showing significant changes.

In the spiral mode, the bank angle Φ and the azimuth angle Ψ change most, with opposite signs, and Ψ dominates, being more than six times greater than Φ. The mode consists mainly of a yaw with almost zero sideslip and some roll. It is a banked turn with a variable radius of curvature, which increases if the mode is stable. Once the transient has ended, the aircraft returns to its initial direction with the wings level.