Technical Challenges

The primary technical challenges were to tune and integrate the separate adaptive control technologies for a handling qualities evaluation. For this purpose it was necessary to mature each technology to handle a full-flight envelope. Tuning of the various controllers then required developing a simple but intuitive tuning methodology based on design requirements and simulation studies.

Technical Approach

- Integrate each adaptive control technology into a common baseline control architecture (robust dynamic inversion controller).
- Define each adaptive control technology for a common set of basis functions (used for parameterizing the model uncertainty).
- Tune each adaptive technology to achieve a 50 ms time-delay margin.
- Require that the design parameters for each controller remain constant.
- Tune using evaluations of simulated aircraft performing a lateral, longitudinal, directional doublet maneuver at 10,000 ft./140 Kts. and 10,000 ft./250 Kts.

Objectives

The objective of this work is to assess the strengths, weaknesses, and robustness characteristics of several MRAC (Model-Reference Adaptive Control) based adaptive control technologies garnering interest from the community as a whole. To facilitate this, a control study using piloted and unpiloted simulations to evaluate sensitivities and handling qualities was conducted. The adaptive control technologies under consideration were ALR (Adaptive Loop Recovery), BLS (Bounded Linear Stability), Hybrid Adaptive Control, L∞, OCM (Optimal Control Modification), PMRAC (Predictor-based MRAC), and traditional MRAC.

Experiment for Cooper-Harper (CH) Handling Qualities Evaluations

- Two tasks: Flight director capture task for large amplitude maneuvers and an approach and landing task with a side-step maneuver.
- Adequate/Satisfactory rating for capture task based on number of captures. Rating for landing based on sink rate, crab angle, bank angle, centerline offset, and touchdown distance (all measured at touchdown).
- Capture task for two flight conditions: 1) 10,000 ft., 140 Kts. and fully configured for landing (full flaps and gear); and 2) 10,000 ft. and 250 Kts.
- Failures include lose of 50% of left horizontal tail, artificial aileron/elevator cross-coupling, baseline controller inversion errors, and combination cross-coupling/inversion errors.

Results

- ALR, OCM, and PMRAC provided improved ratings over the baseline controller in all instances.
- L∞ implementation exhibited marginal directional stability at high airspeeds for the inversion and combined failures and was generally unstable at lower airspeeds. This is reflected in the CH ratings as further tuning and investigation is required.
- Hybrid, BLS, and MRAC gave mixed ratings of improved, degraded, and unaffected performance.
- Hybrid, BLS, and MRAC performed better with the inversion failure and the combined failure then with the cross-coupling failure alone.