



L1 Adaptive Control for AirSTAR GTM T2 Aircraft: Piloted Simulation and Preliminary Flight Test

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Objectives

Design, analyze and flight test an L1 adaptive control law as an inner-loop Control Augmentation System for α - p tracking on a dynamically scaled Generic Transport Model with a pilot in the loop.

- A **single design** for the **entire flight envelope** (including stall, post stall and high α conditions), **without gain scheduling**.
- Compensation for **structural damage** and **actuator failure**.

Demonstrate: desired stability, performance and flying qualities during adverse conditions.

- Adverse conditions considered are inoperative flight control surface, variable stability, and high-angle-of-attack flight conditions.

Piloted Simulation and Flight Test Control Evaluation

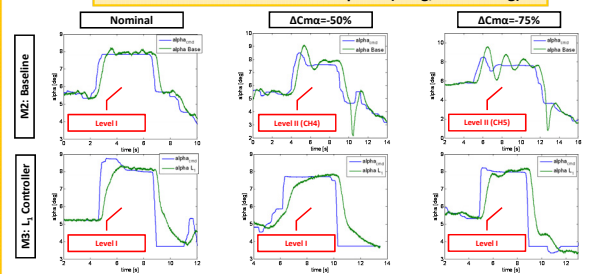
The flight control law evaluation test block consists of a set of maneuvers, emulated faults, and wavetrain inputs.

- Evaluation maneuvers consisted of angle-of-attack captures, bank angle captures, and offset landing tasks

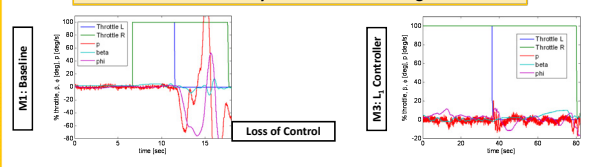
Research Pilot Control Laws:

- Mode2: baseline - a closed loop control law (pitch: α CAS; roll & yaw: rate damping SAS)
- Mode3: L1 adaptive control law (pitch: α CAS; roll & yaw: p - β CAS)

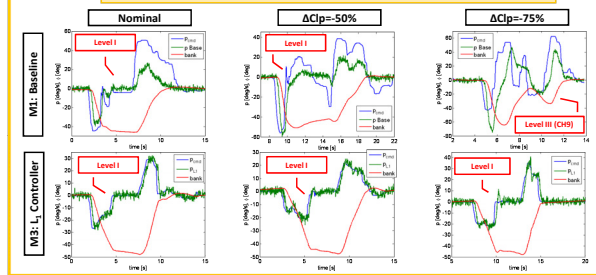
Piloted evaluation task – AoA capture (8deg; des= ± 1 deg)



Full throttle → Asymmetric thrust during climb



Piloted evaluation task – Bank capture (45deg; des= ± 5 deg)



Piloted Simulation Results & Observations [1,2]

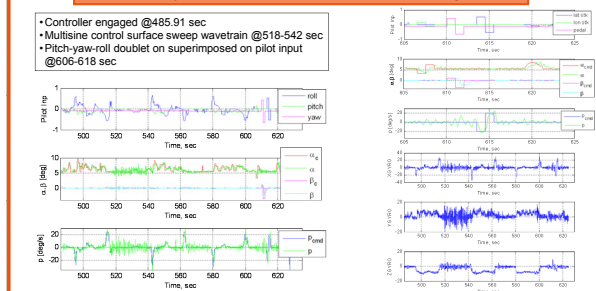
- L1 adaptive control **maintains stability and predictable performance** in the presence of unmodeled dynamics and control surface failures.
- This **predictability and consistency** was experienced over a **large flight envelope** that included linear, stall, post-stall and high angle of attack regions, as well as wide a range of aircraft stability
- **Graceful degradation** when can no longer maintain desired performance or stability

Preliminary Flight Test Evaluation

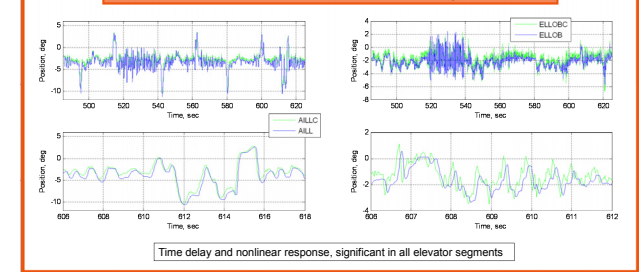
Flight Control Law Buildup Block : partially completed

- Adaptive Control law & Wavetrains – functional check out
- Vref + 5; Wavetrains – (i) multisine control surface sweep, (ii) stick/pedal input: pitch-yaw-roll doublet sequence

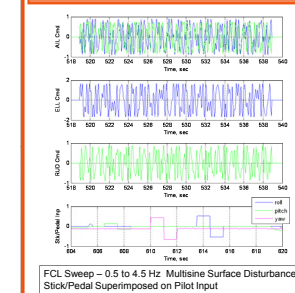
L1 Adaptive Controller Functional Checkout Flight



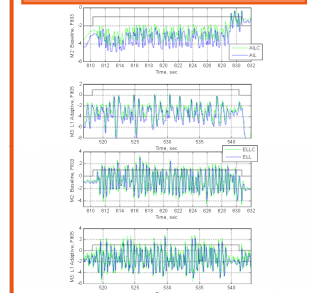
Actuator Commanded and Measured Responses



Actuator & Stick/Pedal Wavetrains



Actuator Response Comparison



Preliminary Flight Test Results & Observations

Flight Control Law Buildup Block : partially completed

- Adaptive Control law & Wavetrains – functional check

Actuators: Significant mismatch between model and actual hardware

- Appears to be nonlinear even for small deflections
- Significantly larger apparent latency from actuator command to actuator response
- In addition to normal piloted flight, the L1 adaptive control law was subjected to control surfaces disturbances and doublets in stick/pedal.
- Control law stable with nominal flying qualities performance as reported by the pilot

References:
[1] Xargay, Hovakimyan, and Cao. Piecewise Constant Adaptive Laws for L1 Adaptive Controller in the Presence of Uncertain Nonlinear Cross-Coupling. Submitted to ACC, Baltimore, MD, 2010.
[2] Gregory, Cao, Xargay, Hovakimyan, Zou. L1 Adaptive Control Design for NASA AirSTAR Flight Test Vehicle. AIAA GNC Conference, Chicago, IL, 2009.