**AFOSR Grant F49620-96-1-0207** [CIT 61063]

# Robust Nonlinear Control Theory with Applications to Aerospace Vehicles

## AASERT Grant

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Progress Report
**1 August 1997 to 31 July 1998**

# 1 Objectives

This grant is a subcontract to the University of Minnesota, under the supervision of Prof. Gary Balas. This AASERT subcontract augments the parent subcontract to UMN and is focused on the application of Linear Parameter Varying (LPV) Control to Aerospace Systems.

# 2 Status of Effort

UMN has continued work on application of LPV to flight control systems, partially funded by this augmentation award and the parent PRET grant. This AASERT award is being used to fund a student who is applying these techniques to control of flutter and the ICE aircraft.

# 3 Accomplishments

The past year our research at the University of Minnesota under the AFOSR PRET program has focused on applying linear-parameter varying (LPV) control design methods to flight control, active flutter attenuation and turbofan engines. We are working closely with researchers at the Air Force Research Laboratory, Wright Patterson AFB to apply LPV techniques to a tailless fighter aircraft model developed under the Innovative Control Effectors (ICE) program.

Flutter suppression is an area that we have also successfully applied $\mu$-synthesis and LPV control design techniques. An experimental comparison of $H_2$ and $\mu$-synthesized flutter suppression control systems was performed on a NACA 0012 test model of a typical section mounted in a low-speed wind tunnel. The pitching angle, flap angle, and plunge deflection of the airfoil are measured with sensors and fed back through the control compensator to generate a single control signal commanding the trailing edge flap of the airfoil. It was found that when compared to the $H_2$ control system, the $\mu$-synthesis controller provided better disturbance rejection in the bandwidth of the unsteady aeroelastic dynamics across the range of operating dynamic pressures. In addition, the $\mu$ controller required less control energy than the $H_2$ control system.

A gain-scheduled, LPV controller for active flutter suppression of the NASA Langley Research Center's Benchmark Active Controls Technology wing section was designed. The wing section changes significantly as a function of Mach and dynamic pressure and is modeled as a linear system whose parameters depend in a linear fractional manner on Mach and dynamic pressure. The resulting gain-scheduled controller also depends in a linear fractional manner on Mach and dynamic pressure. Closed-loop stability is demonstrated via time simulations in which both Mach and dynamic pressure are allowed to vary in the presence of input disturbances. The linear fractional gain-scheduled controller and an optimized linear controller (designed for comparison) both achieve closed-loop stability, but the gain-scheduled controller outperforms the linear controller throughout the operating region.

## 4 Personnel Supported

Jeff Barker, UMN graduate student (4th year).

## 5 Publications

- J.M. Barker, G.J. Balas, and P. Blue, “”Gain-Scheduled Linear Fractional Control for Active Flutter Suppression, ” submitted to *AIAA Journal of Guidance, Dynamics and Control*, March, 1998 and the *1999 American Control Conference*, San Diego, June, 1999.
- J.S. Vipperman, J.M. Barker, R.L. Clark, G.J. Balas, “Comparison of $\mu$ and $H_2$ -Synthesized Controllers on an Experimental Typical Section,” accepted with modifications *AIAA Journal of Guidance, Dynamics and Control*, June, 1998.