"Pain" Compensating Control for Structural Overload Prevention

The Problem

Current aircraft designs utilize high structural margins and fixed control allocation schemes to prevent structural overload for a priori operating conditions and maneuvers, resulting in:

- Higher vehicle weight (more fuel burn)
- Lack of adaptability to damage
- Lack of robustness to flight outside of the design flight envelope (stall/spin)
- No explicit guarantee of prevention of structural overload

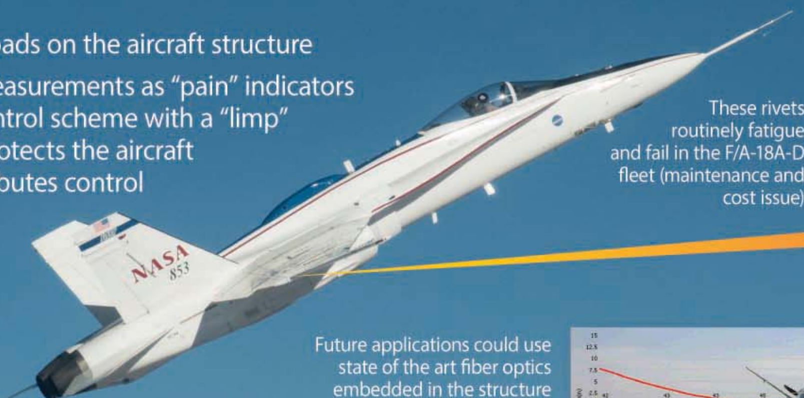
American Airlines Flight 587, Nov. 12 2001, "the probable cause of this accident was the in-flight separation of the vertical stabilizer as a result of the loads beyond ultimate design that were created by the first officer's unnecessary and excessive rudder pedal inputs."

NTSB Number AAR-04/04

Next Gen concepts will require reduced structural margins to achieve desired performance improvements

The Idea

- Measure the critical loads on the aircraft structure
- Utilize these strain measurements as "pain" indicators within an optimal control scheme with a "limp" reflex that actively protects the aircraft structure and redistributes control commands to other control surfaces and structure with available margin
- Conduct a simple flight experiment on the FAST aircraft limiting aileron hinge moment while maintaining flying qualities



These rivets routinely fatigue and fail in the F/A-18A-D fleet (maintenance and cost issue)

Future applications could use state of the art fiber optics embedded in the structure to yield high quality strain data at thousands of load points with minimal weight

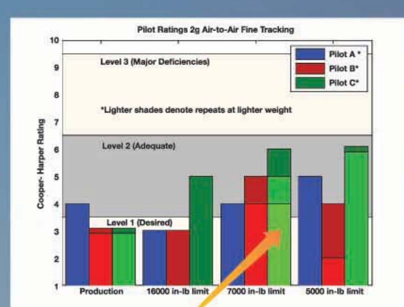
The Results

The Good

- The experiment successfully demonstrated the use of strain feedback as a means to actively limit the aileron loads
- The allocator redistributed roll control to other surfaces and achieved the desired roll rate
- Adequate handing qualities were maintained even with very restrictive load limits

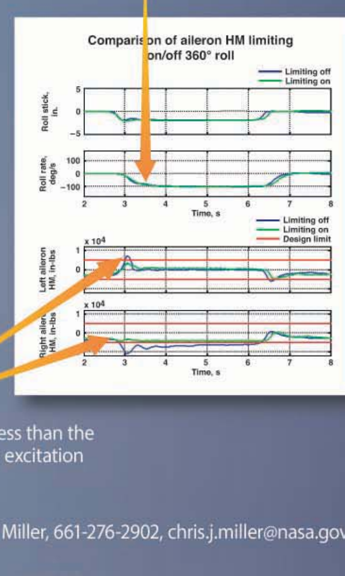
The Questions

- Changes in the pitch trim characteristics of the aircraft for load relief, resulted in oscillatory prone configurations
- Control/structural modal interactions need further exploration based on the flight results
- Accounting for multiple critical loads requires additional investigation leveraging the experience from these flights



Lighter shaded ratings are at lighter weights resulting in lower angles of attack . At higher AOA and restrictive load limits the research control law fairs the ailerons out to reduce the load, further increasing AOA resulting in a more oscillation prone trim configuration

Desired roll rate achieved with only a small decrease in the roll onset rate



Aileron hinge moment limited to less than the specified value but with some ASE excitation

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