Engine Control Research under NASA Aviation Safety Program
Overview

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RHC
February 28, 2012
Enhanced Engine Control Session

Session 1: Enhanced Engine Control

10:00 Overview - OA Guo
10:10 C-MAPSS40k Overview and Update - James Liu
10:30 Fast Engine Response Research - Ryan May
10:50 Piloted Evaluation of Fast Engine Response Mode - Jonathan Litt
11:10 Engine Icing Effects Simulation and Detection - Ryan May
11:30 Integrated Flight Propulsion Control Applications - James Urnes, SR. (Boeing)
11:50 Discussion - All
Enhanced Engine Research Overview

- Vehicle Systems Safety Technologies (VSST) project under Aviation Safety
- Lost of Control (LOC) Theme Problem under VSST
- Enhanced Engine Research for LOC
- Research Tool Development
- List of Research Activities
VSST Goal
(Aligned With National Policy & Priorities)

Develop technologies to reduce accidents and incidents through enhanced vehicle design, structure, systems, and operating concepts\(^1\)

\(^1\) U. S. National Aeronautics R&D Plan, Safety Goals 1 and 2, OSTP, 2010
Vehicle Systems Safety Technologies Overview

Improve Vehicle Safety by Proactively Mitigating Current and Future Risks

Improve Crew Decision-Making and Response in Complex Situations

Assure Safe and Effective Aircraft Control under Hazardous Conditions

Maintain Vehicle Safety between Major Inspections

Reduce current risks; Identify and proactively mitigate new risks
Assure Safe and Effective Aircraft Control under Hazardous Conditions (ASC)

**Today**

**Aircraft Dynamics and Control Limitations under Hazardous Conditions** can lead to **Loss of Control (LOC)**
- Current crew training under LOC conditions is limited due to model limitations for full stall conditions, failures and damage, and environmental hazards
- Information currently provided to the crew does not clearly inform of impending LOC
- Current autopilot systems are designed for nominal operations and often disengage under off-nominal conditions
- Current envelope protection systems provide limited capabilities

**Tomorrow**

**Potential Increase in LOC Accidents Resulting from**
- Increasing demand on the National airspace requiring high-density operations
- Increased demand on crew & automated systems
- Increased external hazard encounters (wakes, weather)
- New materials and vehicle configurations

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**Enhanced Vehicle Simulation under Hazardous Conditions**
- Aerodynamics
- Structures
- Propulsion

**Safe & Effective Vehicle Control under Multiple LOC Hazards**
- LOC Risk Prediction & Dynamic Envelope Estimation
- Upset Prevention & Recovery
- Multiple Hazards Mitigation

**LOC Working Group to Identify Emergent Risks, Define Test Scenarios, & Develop Evaluation Requirements**
Enhanced Propulsion Research

• Past research and experience have shown that propulsion systems can be very effective in helping airplanes recover from adverse conditions:
  – TOC (Throttle-Only-Control) research experience
  – PCA (Propulsion Controlled Aircraft)

• However, preliminary studies show that there are many other potentially catastrophic scenarios in which airplanes could be saved if the engines could:
  – Better integrate with flight control system
  – Respond faster
  – Generate more thrust for a short period of time

Enhanced Engine Operation
Engine dynamic simulation development

- And, we need an engine simulation that is capable of predicting the engine dynamics and controller reactions/limits

In 2006:
- No engine dynamic simulation available (government or industry)
- Information on stall margin over the flight and operation was not available
- No realistic engine controller that was comparable to the FADEC
Creating A New High Fidelity Engine / Control Simulation

1Numerical Propulsion System Simulation, co-winner of the NASA Software of the Year Award for 2001
2Scientific Monitoring, Inc.
Commercial Modular Aero Propulsion System Simulation 40,000 (C-MAPSS40k)

- 40,000 Lb Thrust Class High Bypass Turbofan Engine Simulation
- MATLAB/Simulink Environment
- Publicly available
- Representative dynamic performance
- Realistic controller
- Realistic surge margin calculations

2011 GRC Software of the Year Award nomination, and Exceptional Achievement Award
Enhanced Engine Research Activities

• In-House Research:
  ➢ Faster Response Engine Research
    ✓ Control gain modification
    ✓ Control limit modification
    ✓ Risk management modeling
    ✓ High speed idle
  ➢ Off-Nominal Operation Modeling
    ✓ Off-schedule VSV, VBV operation
    ✓ High inlet angle operation simulation
    ✓ Engine icing accretion simulation, detection, and control

• NRA:

• RTAPS:

• SBIR:
Thank you