Overview – AeroPropulsoServoElasticity Task

Fundamental Aeronautics – Supersonics Project
AeroPropulsoServoElasticity Task

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Overview of APSE Propulsion Team/Task

- **Team:** All NASA GRC (2FTE’s)
  - George Kopasakis (3Y)
  - Joseph Connolly (3Y)
  - Nulie Theofilaktos (1Y)
  - Richard Blech (1Y)

- **NRAs**
  - No NRA’s
  - Possibility of NRAs in FY 2011

- **Type of Studies Conducted**
  - So far Analytical Studies (TRL 1-3)
  - Possibility of involvement with Demonstration Projects starting in 2011
Project Challenges

-- The Supersonics Project aims to conduct fundamental research necessary to develop the technologies for supersonic transports

-- As such the project identified several technical challenges
  -- Among these challenges are also

    ➢ **Performance challenges**, including Aero-Propulso-Servo-Elasticity (APSE) analysis and design

    ➢ **Efficiency challenges**, including supersonic cruise efficiency
Task Objectives

- Study integrated vehicle dynamics (i.e. AeroServoElastic w/Propulsion) for **vehicle stability** and **ride quality**

  -- Thrust dynamics to ASE modes to upstream flow disturbances to thrust dynamics

  -- Develop dynamic propulsion system models and control designs

- Study propulsion system efficiency
Aero-Propulso-Servo-Elastic (APSE)

Propulsion

Integrated APSE Model

Thrust Dynamics

Structural Modes

Flutter

External Flow Disturbances

APSE Flow Disturbances

Integrated Modeling & Controls Design

Vehicle Stability

Ride quality

Cruise Efficiency

Design and Analysis

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Modeling Approach/Propulsion

- **1D Gas Dynamics (Volume Dynamics) & Component Performance Characteristics**

\[
\frac{\partial}{\partial t} (\rho_s A) + \frac{\partial}{\partial x} (\rho_s Av) = 0
\]

\[
\frac{\partial}{\partial t} (\rho_s Av) + \frac{\partial}{\partial x} (\rho_s Av^2) = -Ag \frac{\partial P_s}{\partial x}
\]

\[
\frac{\partial}{\partial t} (\rho_s Au_t) + \frac{\partial}{\partial x} (\rho_s AvH) = 0
\]

- **Controls Systems Design Approach**

  -- Based on Loop Shaping Design Approach Developed at GRC

  -- Relates hardware performance to control requirements

  -- Maximizes Control System performance
APSE Task Accomplishments

- Modeled turbojet & turbofan engine w/ lump volume dynamics
- Developed loop shaping feedback controls design approach
- Developed atmospheric turbulence models
- Designed shock position controls for internal compression inlets
- Developed engine controls and linear integrated propulsion system model
- Developed dynamic compressor and turbine stage-by-stage models
- Derived compressor bleed schedules
- Started developing dynamic engine component design GUI library
- Started on parallel component modeling for flow distortion and rotating stall
Future Plans (FY10)

• Continue enhancing propulsion system component models and control designs
• Integrate Propulsion and AeroServoElastic models
• Initiate study of integrated vehicle control designs
• Initiate analysis of vehicle ride quality and stability

Publications:

• Kopasakis - Feedback Control Systems Loop Shaping Approach with Practical Considerations, NASA/TM-2007-215007
• Kopasakis et al. – Shock Positioning Controls Design for a Supersonic Inlet, AIAA-2009-5117
• Kopasakis – Atmospheric Turbulence Modeling for Aero Vehicles- Fractional Order Fits, to be published
• Kopasakis – Modeling of Atmospheric Turbulence as Disturbance for Control Design and Evaluation of High Speed Propulsion, ASME TurboExpo 2010, to be published