Real Time Simulation of Flexible Aerospace Vehicles Using Simulink and RT-Lab

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Agenda

• Flexible aerospace vehicles
• Controller design
• Challenges
• Strategy
• Simulation and results
• Conclusion
Flexible Aerospace Vehicles

- **Definition**: Vehicles that undergo structural deformation during flight
- High length to diameter ratio
- Aerodynamically more efficient
- Lower radar visibility
Effects of Flexibility

• Corrupts the feedback signals from sensors
• Vibration frequencies can interfere with control frequencies.
• May lead to self excited divergent oscillations

Proper controller design and simulation of vehicle flight dynamics is necessary to ensure stability
Controller Design

• Gain stabilization for high frequency modes
• Phase stabilization for lower frequency modes
Non-Real Time vs Real Time Simulation

• Non-real time:
  – Generally used for validation of algorithms

• Real time:
  – Essential for validation of controllers which are designed using phase stabilization.
  – Can simulate effects of computational delays
  – Enables testing of hardware components
Challenges

• Complexity and order of the model is large
• High computational load
• Model compatibility with real time simulator
• Support for IO cards / communication interfaces in hardware-in-loop simulation
• Monitoring and debugging
Strategy

• MATLAB and Simulink
• RT LAB
• Distributed architecture
• Multi-rate simulation
Tactical Aerospace Vehicle and its Model in MATLAB®/Simulink

Advantages:
- Conversion from Non Real-time to Real-Time is very easy
- Easy to Implement Communication interfaces (MIL std 1553B, SharedMemNet, ADC/DAC etc.)
- Easy to trace the signal, Introduction of disturbance
- Validation of model developed by external Agencies (Academic institution/Collaborating Org) has become easier (Plug & Play).
Flexibility Model

Mode shape & slope Computation

Force Coef. Computation

Flexibility Rate & Lateral Acc. Computation in Pitch/Yaw plane
Simulation Scenario

• Scenario of a flight test which failed due to excessive bending oscillations was reproduced
• Flight response of the launch vehicle with rigid body model and flexible body model was analysed
• Updated controller was validated
Vehicle Response with Rigid-Body Model
Vehicle Response with Flexible-Body Model
Vehicle Response with Flexible-Body Model and Updated Controller
Conclusion

• MATLAB and Simulink tools enabled to develop a complete model of the dynamics of a flexible aerospace vehicle
• RT LAB helped in real time simulation of the vehicle using Simulink models, with hardware in loop
• Block based modelling technique eased the process of debugging, monitoring and modifying the model, and allowed for flexible degrees of freedom to be added to the existing rigid body model
Thank you!