# Integration of MSC.EASY5 Software with Multibody Dynamics Software to Investigate and Create a Solution for the G450 Autopilot Limit Cycle Oscillation Problem

Brian Lojko

Lead Engineer, Flight Controls – New Product Development

Gulfstream Aerospace Corporation

# Autopilot Limit Cycle Oscillation

Problem Statement

- Aircraft will not hold altitude or pitch while under control of autopilot for H ≥ FL350 and M ≥ .80.
- At the altitudes and Mach #s stated above, a constant frequency and constant amplitude oscillation occurred. Changes in altitude of ±150 ft and vertical speeds of ±1000 fpm with a period of 20 sec. were noted during flight testing.
- Excessive phase lag in the power boost mechanism loop induces limit cycle oscillation of the AFCS system.

# General Problem Solving Method

Define the Situation
- Problem statement
- Request data
- Verify problem existence
  - Simulate event
  - Conduct production inspections
  - Take corrective action

Find Paths of Influence
- Gather documentation
- Identify functions
  - Aircraft
  - System
  - Subsystem
  - Assemblies
  - Subassemblies
  - Components
- Create diagrams/truth tables/visual aids

Test & Simulate
- Develop test & simulation plan
- Instrument
- Inspect/test function input and output
- Identify critical path of influence

Take Corrective Action
- Repair/replace as necessary
- Verify effectiveness of solution

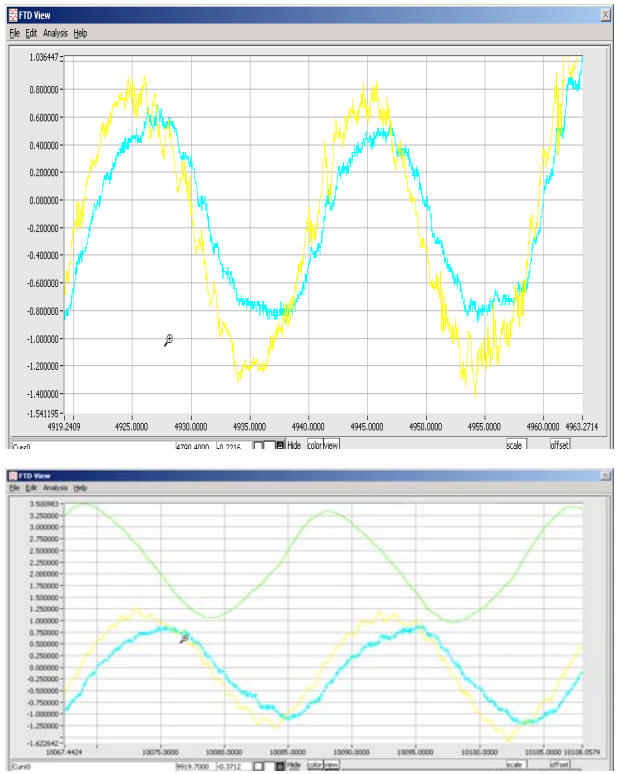
# Task-Specific Problem Solving Activities

Gulfstream

Define the Situation

- Problem statement – as defined on slide 1
- Request flight test data
  - Inputs and outputs throughout servo loop
  - Look for phase lag
- Verify problem existence
  - Participated in flight test and ground test activities
  - Create analytical model

Flight Test Data



# Task-Specific Problem Solving Activities

Gulfstream

## Find Paths of Influence

- Gather documentation
- Identify functions
  - Autoflight system
  - Air data
  - Smart servos
  - Power boost mechanism
  - Hydraulic actuator

# Task-Specific Problem Solving Activities

Gulfstream

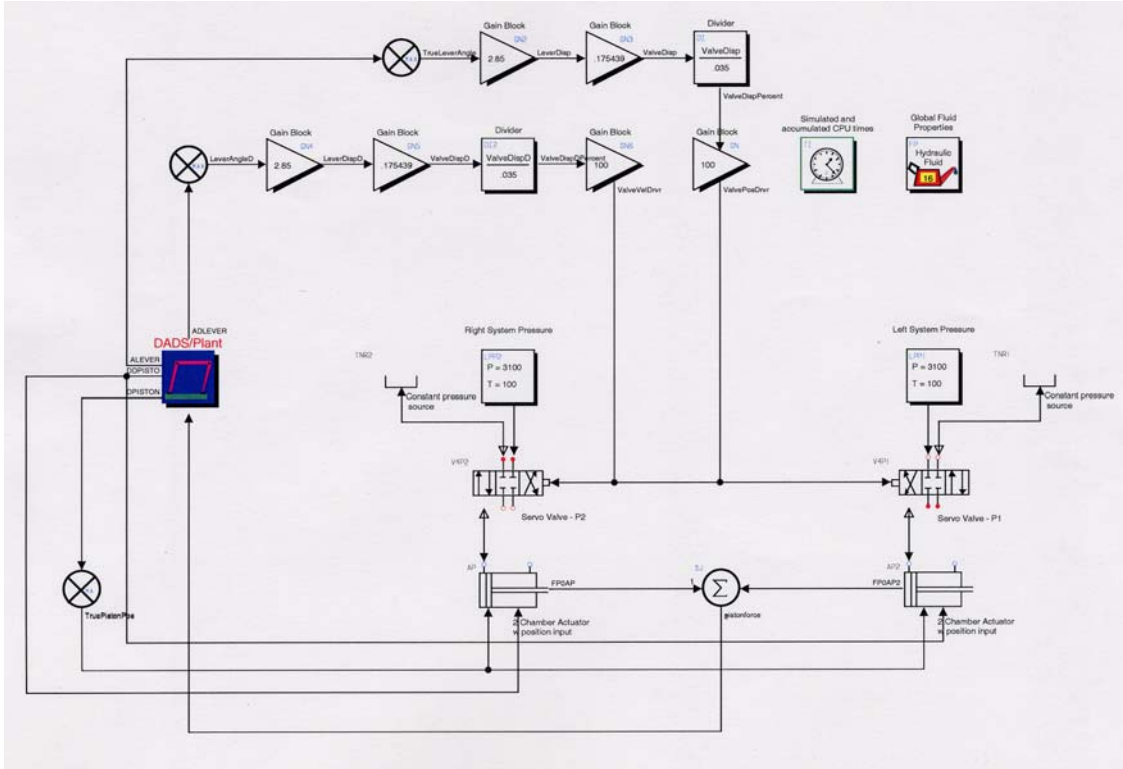
Test & Simulate

- Develop test & simulation plan
  - Examine inputs and outputs for each path of influence
  - Develop MSC.EASY5/Plant model
- Instrument
  - Install instrumentation to support test plan
- Inspect/test function input and output
  - Conduct ground test
  - Conduct flight test
  - Inspect ATPs
  - Conduct simulations
  - Validate simulations to test data
- Identify critical path of influence

# Hydraulic Actuation Model

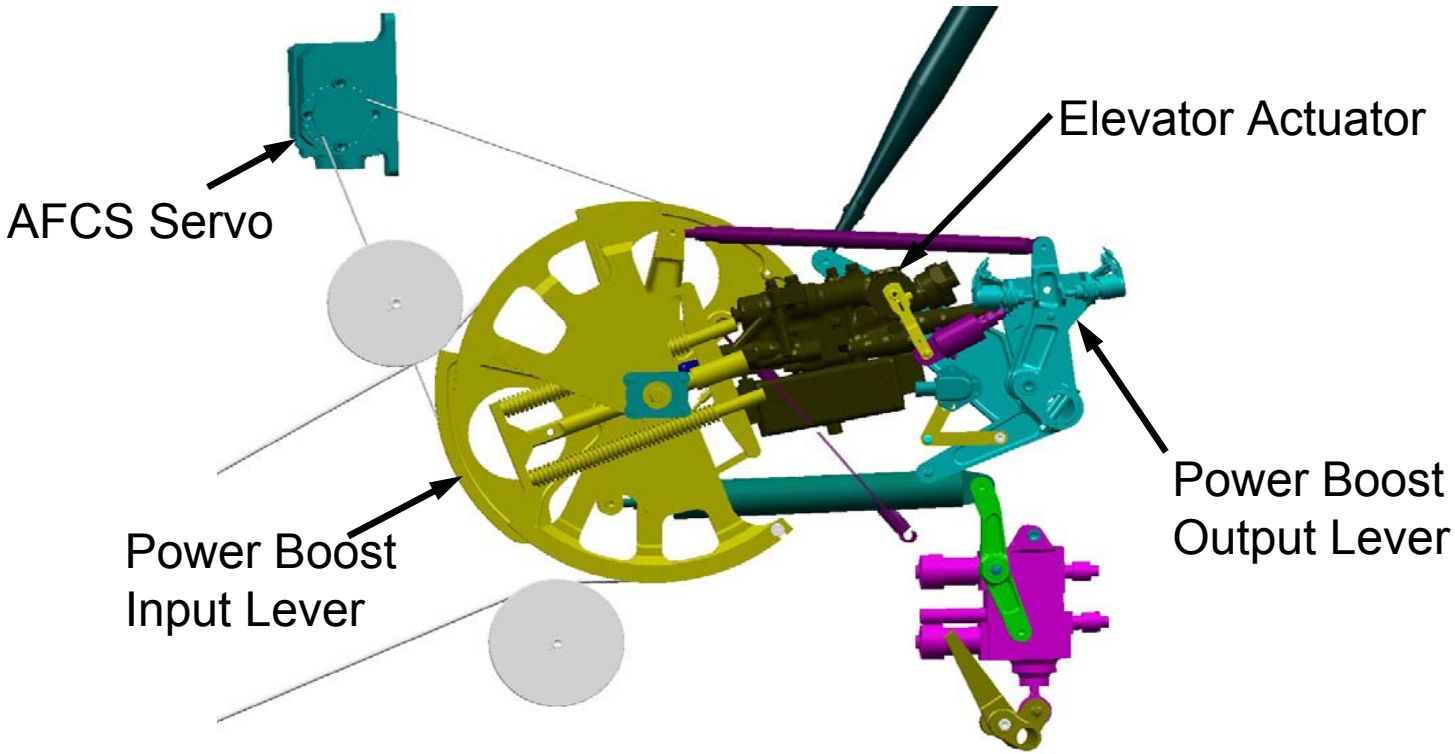
MSC.EASY5 w/ Thermal Hydraulic Library

& Plant Extensions

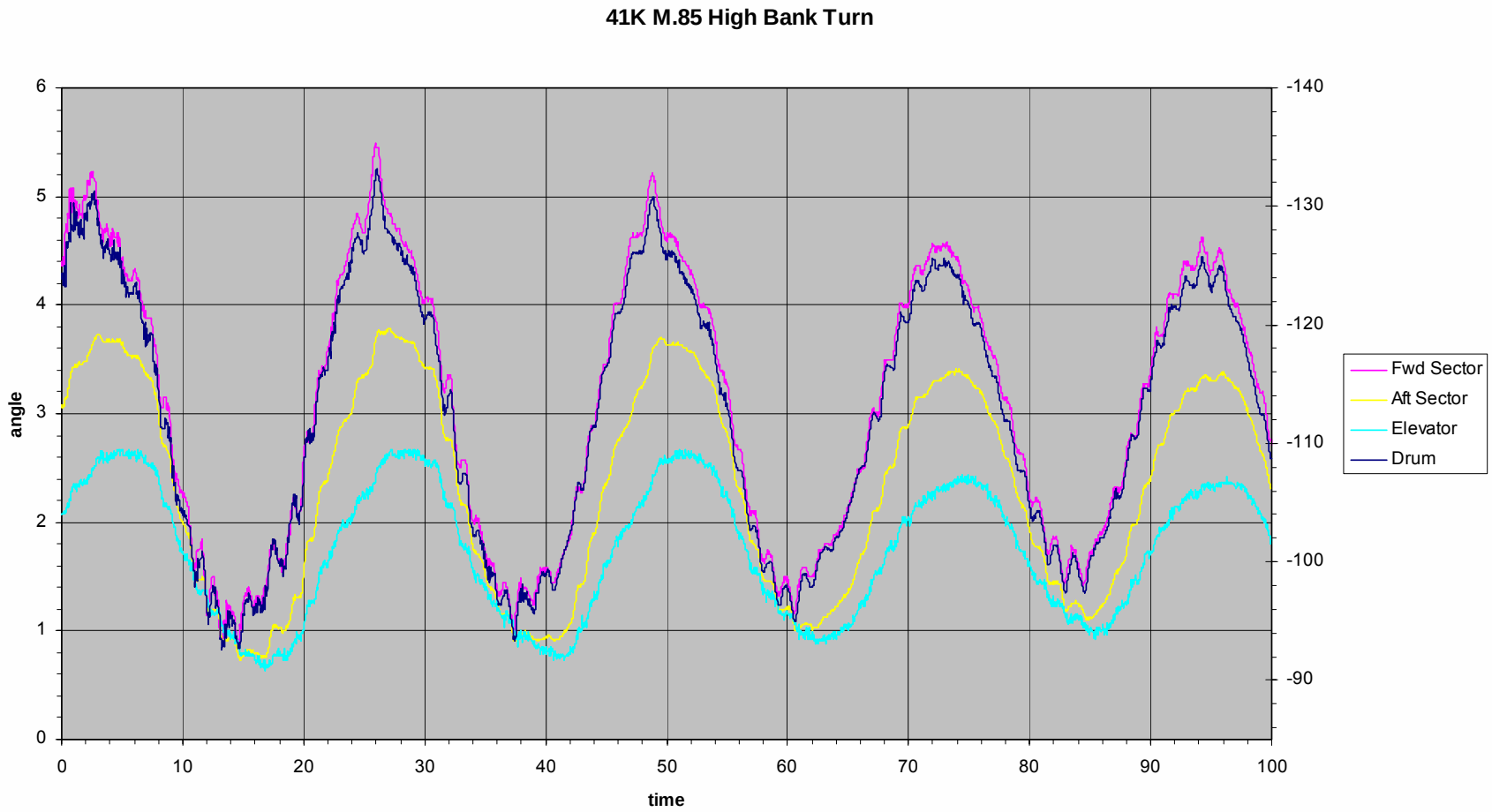


# Multi-Body Dynamics Model

Power Boost Mechanism – Generated from CATIA Model

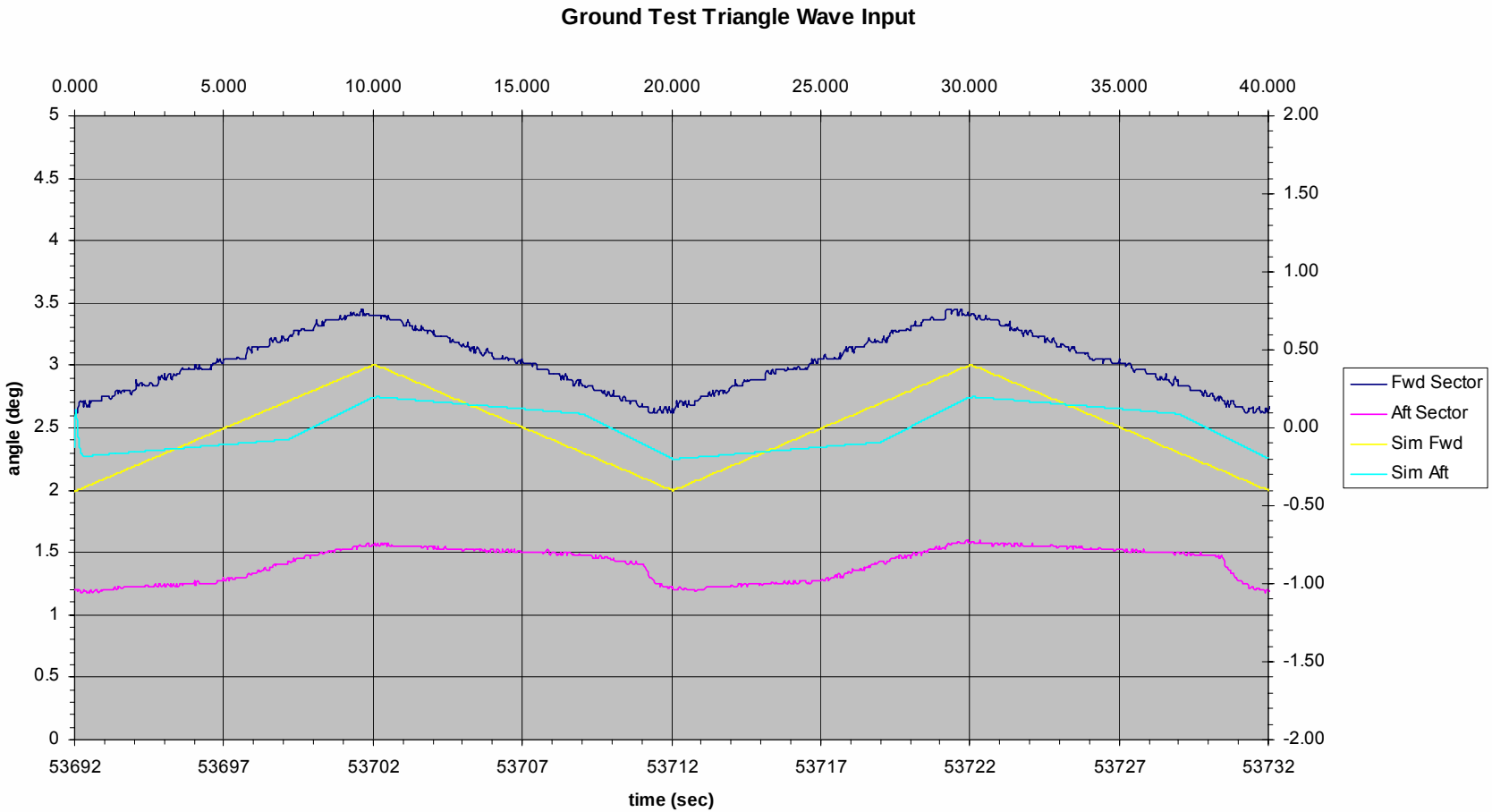


# Flight Test Data – Phase Lag



# Validation of Simulation to Test Data

Gulfstream



# Identification of Critical Path of Influence

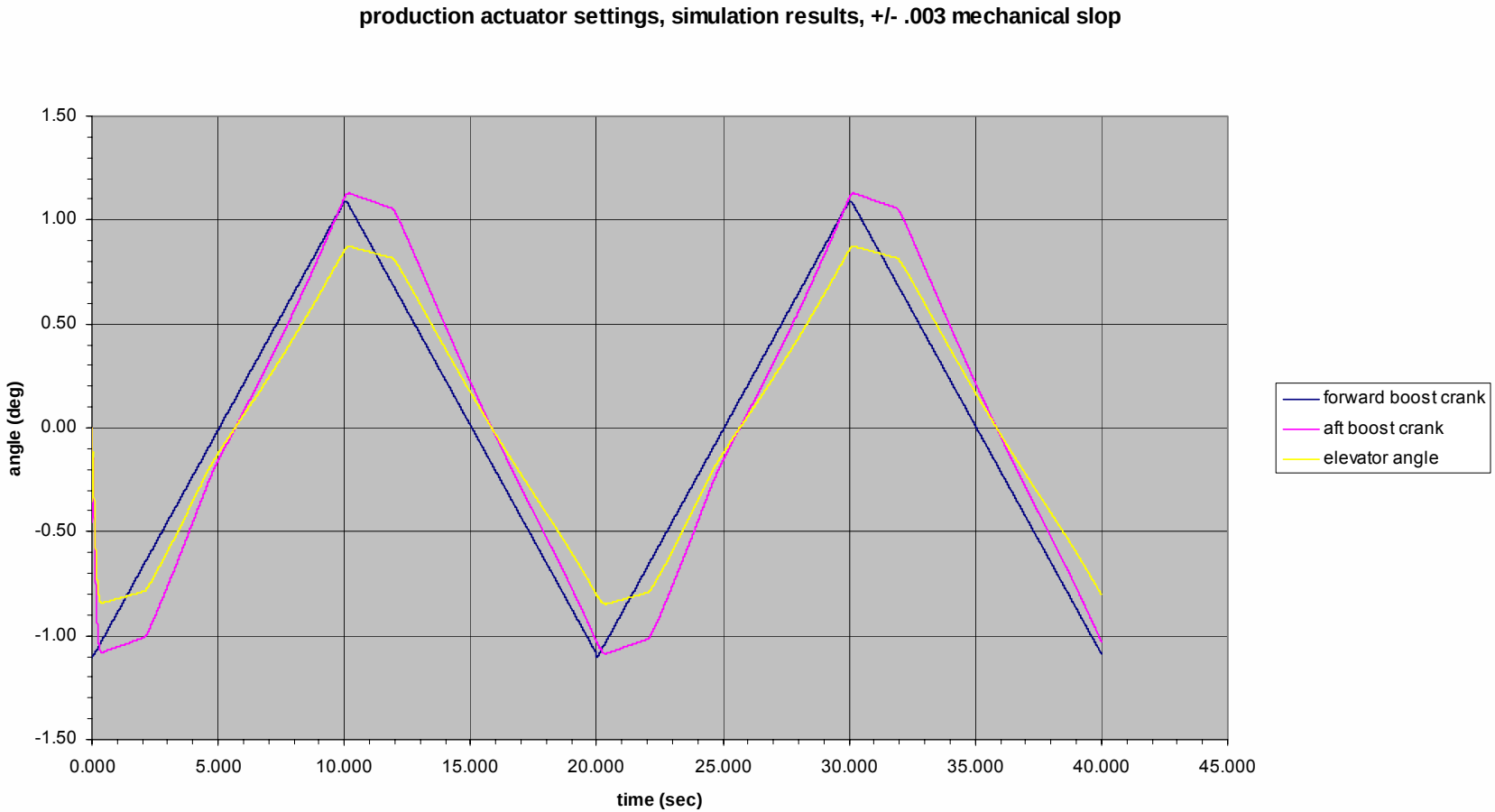
Gulfstream

## Test & Simulation

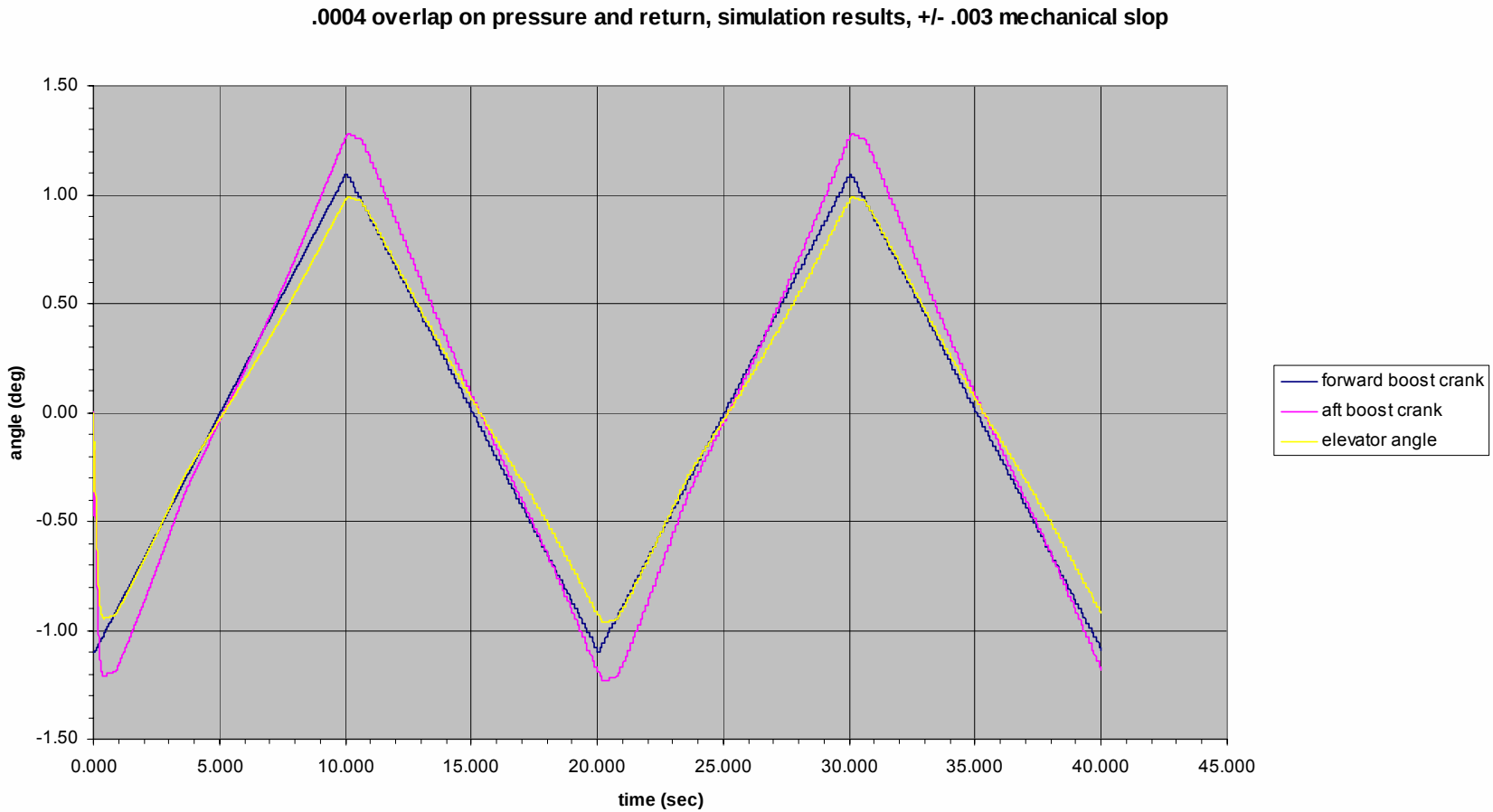
- Identify Critical Path of Influence
  - The power boost mechanism was found to contain the critical path of influence.
  - Reduction in the overlap of the actuator servovalve reduced phase lag to acceptable levels.

# Identify of Critical Path of Influence

Gulfstream



# Identify of Critical Path of Influence



# Problem Solution

System Design Verification

- Ground Testing
  - Improvement in phase lag noted.
- Company Flight Testing
  - AFCS held altitude within ± 15 FT for altitude hold (worst case)
  - AFCS achieved altitude captures within ± 15 FT (worst case)

# Conclusion

MSC.EASY5/Plant allowed the Flight Controls Design Team to iterate on simulation models during the search for the critical path of influence.

Items without an effect were ruled out and the search was continued until the offending design parameter was identified.

Potential solutions were investigated to gain a level of confidence and choose the best alternative.

Proof of solution required one design revision and one flight test.

Gulfstream saved $$$ in flight testing money

Certification flight testing continued without a significant delay in the test schedule.