ROLL PERFORMANCE IMPROVEMENTS

STEADY STATE ROLL RATE

5,000 FT

MACH NUMBER

BASELINE - AILERONS/DIFFERENTIAL TAILS/RUDDERS
ROLL MOD I - ADDED DIFFERENTIAL FLAPERONS AND MODIFIED AILERON MACH/DYNAMIC PRESSURE SCHEDULES
ROLL MOD II - ADDED DIFFERENTIAL LEADING EDGE FLAPS FOR WING WARping
DIFFERENTIAL LEADING EDGE FLAPS
ROLL POWER

\[ C_l \Delta \delta_{LEF} \]

\[
\begin{array}{c}
\text{SEA LEVEL} \\
15,000 \text{ FT} \\
\text{WIND TUNNEL (RIGID)}
\end{array}
\]

MACH NUMBER

AILERON ROLL FORCE
FORCE DUE TO
TWIST FROM LEF
EFFECT OF INERTIAL COUPLING COMPENSATION
360° FULL STICK ROLL

ANGLE-OF-ATTACK DEG

SIDESLIP DEG

With inertial coupling compensation
Without inertial coupling compensation

AVERAGE STABILATOR POSITION, δ_H DEG

RUDDER DEFLECTION, δ_r DEG

TIME

TIME
WING-FOLD AND WING-ROOT BENDING MOMENTS

INCREASED TRAILING-EDGE-FLAP DEFLECTIONS REDUCE WING-FOLD AND WING-ROOT BENDING MOMENTS

BEFORE

AFTER

GP33-0509-10
Structural Loads Control

The Digital Flight Control is Very Effective in Controlling Structural Loads

- Control Wing/Pylon Loads With Heavy Stores
- Control Wing-Fold and Wing-Root Bending Loads
- Redistribute Loads by Scheduling Control Surfaces
- Limit Loads by Scheduling Maximum Control Deflection
- Limit Maximum Load Factor - Pilot Over-Ride
INERTIAL COUPLING EQUATIONS AND COMPENSATION

EQUATIONS:

\[ \dot{q} = \left( \frac{l_z - l_y}{l_y} \right) p r \]

\[ \dot{r} = \left( \frac{l_x - l_y}{l_z} \right) p q \]

WHERE:

- \( q \) = PITCH RATE
- \( p \) = ROLL RATE
- \( r \) = YAW RATE
- \( l_x \) = ROLL MOMENT OF INERTIA
- \( l_y \) = PITCH MOMENT OF INERTIA
- \( l_z \) = YAW MOMENT OF INERTIA

LONGITUDINAL COMPENSATION FEEDBACK:

![Diagram of longitudinal compensation feedback]

DIRECTIONAL COMPENSATION FEEDBACK:

![Diagram of directional compensation feedback]
DUTCH ROLL MODE CHARACTERISTICS
POWER APPROACH CONFIGURATION

DOMINANT ROOT CHARACTERISTICS

DAMPING RATIO

ESTIMATED SIDESLIP RATE FEEDBACK (PRODUCTION)

CANCELLED YAW RATE FEEDBACK (FIRST FLIGHT)

FREQUENCY - RAD PER SEC
Discussion of F/A-18 Flight Control System

Next Topic

• Systems Engineering
• Integrated Product Team
F/A-18E/F Development
A Brief Discussion on Systems Engineering From the Integrated Product Development Team Perspective

What is Systems Engineering?

“Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs”.

Reference: International Council On Systems Engineering

IPT TEAM LEADERS MUST MANAGE:
• SYSTEM DESIGN AND DEVELOPMENT
• COST AND SCHEDULE
Flight Controls and Flying Qualities Team
Example of Level 4 IPT
Multidiscipline Flight Controls Team
Before IPT - Functional Organizations

Program Manager

Engineering Manager

Level 1

Level 2

Engineering Technology

Aircraft Engineering

Avionics Engineering

Test & Evaluation

Level 3

Aerodynamics
Guidance & Cont.
Loads
Matl. & Processes
Propulsion
R & M
Thermodynamics
Strength
Structural Dyn.

Structures
Mechanics
Armament
Crew Station
Electrical
Fuel
Hydraulics
Landing Gear
Mfg. Engr.

Electronic Sys.
Radar
Communication
Navigation
Electronics Lab.
Ground Support

Ground Test
Flight Test
Flight Safety

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Before IPT - Functional Organizations

Engineering Technology
- Aerodynamics *
- Guidance & Cont. *
- Loads
- Matl. & Processes
- Propulsion
- R & M *
- Thermodynamics
- Strength
- Structural Dyn.

Aircraft Engineering
- Structures
- Mechanics
- Armament
- Crew Station
- Electrical
- Fuel
- Hydraulics *
- Landing Gear
- Mfg. Engr.

Avionics Engineering
- Electronic Sys. *
- Radar
- Communication
- Navigation *
- Electronics Lab.*
- Ground Support

Test & Evaluation
- Ground Test
- Flight Test
- Flight Safety *

Note:
• Before IPT Cost and Schedule Was Allocated to Functional Groups
• The ( * ) Indicates Groups Represented in the Flight Controls & Flying Qualities IPT

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Flight Controls and Flying Qualities IPT Major Products

- Flying Qualities Requirements
- Flight Control System Requirements
- System Design and Analysis Documents
- System/ Subsystem Interface Documents
- Flight Control Computer and Sensor Hardware
- System Software Design, Code, and Testing
- System Integration Test Requirements and Testing
- Coordination of FCS Integration Team
Flight Control System Integration Team

THIS IS NOT A FORMAL IPT!
Purpose - Horizontal Integration Across Program IPTs
- IPT Charters Included Support of FCS Integration Tasks
- All Teams Concur With FCS Development Plan
Integrated Product Team (IPT)

Responsibility
• Product Delivery
• Customer Supplier Relationship
• Processes
• Trades/Design Decisions

Accountability
• Technical Performance Measurands (TPM)
• Cost
• Schedule
• Risks

Authority
• Management of Multi-Disciplined Team
• Budget
• Performance Appraisals

Program Management Structure Needed to Support Systems Engineering and IPTs
F/A-18E/F
Management Processes to Support IPT

- Requirements Flow Down
- Budget
  - Allocated to IPT
  - Management Reserve - Held at Program Manager Level
- Integrate Schedules
- Weekly Earned Value
  - DOD Cost & Schedule Control Systems Criteria (C/SCSC)
- Weekly Program Managers Meeting
  - Cost
  - Schedule
  - TPM
  - Problems / Issues
  - Risk Management
    - Likelihood / Consequence
    - Mitigation - Plan of Action and Milestones
  - Help Needed

IPT Organization and Management Processes Are Critical to Completing a Program on Schedule and Cost
IPT Tasks for Development of a New System

What We Don’t Know
• Pop-Up Risks
• Management Reserve

What We Know
• Planned and Scheduled Tasks

What We Know
• Development Testing
  • Contractor
  • Suppliers
• Risk Reduction Tasks

IPT Budget Should Include Management Reserve Funds
Risk Management Status

- Assess Likelihood That Risk Will Happen (1=not Likely, 5=near Certainty)
- Assess Consequence of Risk Being Realized (1=min. Impact, 5=unacceptable)
- Determine Type of Risk: Schedule, Cost, or Technical

Place X in One Cell

Risk Type
(Check one)

- Schedule
- Cost
- Technical / Quality

Green = Low Risk
Yellow = Medium Risk
Red = High Risk

Each Risk Must Have a Mitigation Plan
- Statement of Risk
- Plan of Action
- Milestone Schedule
What is Earned Value Management?

BCWS = Budgeted Cost of Work Scheduled
ACWP = Actual Cost of Work Performed
BCWP = Budgeted Cost of Work Performed

Cost Variance = BCWP - ACWP
Schedule Variance = BCWP - BCWS

Reference: Office of the Under Secretary of Defense
Acquisition Resources & Analysis, www.acq.osd.mil/pm/