Perspective on Controls & Diagnostics

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Model-Based Controls

Recommended Focus on Control-Oriented Modeling

Industry Moving Towards Model-Based Controls
• Separates “Control Laws” from Plant (Engine) Characteristics
• Simplifies Upgrades and Re-Use

Need: Improved Control-Oriented Model Methods
• Increased Model Fidelity, Capture of Secondary Effects, etc.
• Better Exploitation of “Self-Tuning” / “Adaptation”
• Creation of Control Models “On The Fly”

IRAC Fast-response Engine Research (FastER)
• Exploring Leverage of Aircraft Adaptive Flight Controls Laws
Verification and Validation

Recommended Focus On Automation of Methods

Verification / Validation Huge Cost / Schedule Driver
• Increasing Control Sophistication Making Bad Problem Worse
• Learning / Adaptation Next Big Challenge

Need: V&V Tools / Methods To Reduce Workload
• Design for Validation - Design Methods Leading to Easier Validation
• Automated Validation Tools - Automation of Traditional V&V Tools
• Software Health Management - On-Board Monitoring of Software

New Av Safety Verification and Validation Project
• Opportunity for a DECWG-Like Collaboration (V&VWG)
• Joint Development of FAA Certifiable Tools & Methods?
Distributed Engine Control

Recommended Focus on High Temperature Electronics

Distributed Engine Controls Are Needed
• Addresses Obsolescence Robustness / Future-Proofing
• Opportunities for System-Level Cost / Weight Reduction
• Emerging Fit / Form / Packaging Issues

Need: Robust Control Hardware Building Blocks
• Key Enabler: High Temperature Electronic Components
• Plus: Power Distribution, Communication Network, Certification, …

Distributed Engine Controls Working Group (DECWG)
• Pre-Competitive Collaboration Looks To Be Effective
• Pursuing Commonality at “Building Block” Level
Active Controls

Recommended Focus on Enabling Practical Solutions

Slow General Trend Towards “Active”

• “Active” Is Promising - But Design Trades Challenging
• Latest Fuel Burn / Emissions Goals Need New Solutions
• Driving Fresh Look at Active Clearance, Combustion, etc.

Need: Viable “Active” Implementation Solutions

• Hardware: Small Size, Light Weight and Low Cost
• Software: Hierarchical Control Structures

Distributed Engine Controls Working Group

• Distributed Architectures Can Support Active Controls
• Opportunity For DECWG To Establish Strategy
Wire-Less Controls

Recommended Focus on High Temp Devices & Self-Powering

**Significant Wiring Harnesses Weight / Cost Impact**
- Wires, As Well As Shielding, Sheathing, Connectors, …
- *Wiring Source of Many “Control Faults” - Especially Connectors!*

**Need: Smaller Diameters / Less Wires / Shorter Runs**
- Robust (Thermal, EMI, Dropout, Security) Wireless Communication
- Self-Powered Wireless Sensors Could Eliminate Wires

**NASA Wireless Sensor Research**
- Good Opportunity to Address Concerns & Questions Like:
  – Does Wireless Make Sense If Power Wires Still Needed?
  – Is Self-Powering Feasible?
  – Trade Points Between “Wireless” and “Less Wires”?
Advanced Sensors

Recommended Focus on Reliability / Cost / Weight

“New & Improved” Sensors Always of Interest
• For Engine Control and Health Management
• Program Managers / Chief Engineers Don’t Share Enthusiasm

Need: Address Sensor Reliability / Robustness
• New Sensors Must Overcome Generally Poor Sensor Rep
• Fears That Sensors Actually Reduce System-Level Reliability

NASA High Temperature Sensor Research
• Good That High Temperature Concerns Being Addressed
• Need NASA Support for Transition From Research to Product
• Manufacturing Readiness Level?
Manufacturing Readiness Levels

Need To Address During Tech Maturation

Relationship To System Milestones

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<tr>
<th>Concept Refinement</th>
<th>Technology Development</th>
<th>System Development &amp; Demonstration</th>
<th>Production &amp; Deployment</th>
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Manufacturing Readiness Levels:
- NRL 3: Mfg Concepts Identified
- MRL 4: Mfg Processes Identified
- MRL 5: Mfg Processes Developed
- MRL 6: Critical Mfg Processes Demonstrated
- MRL 7: Prototype Mfg System
- MRL 8: Process Maturity Demonstration
- MRL 9: Mfg Processes Proven
- MRL 10: Lean System Production

Relationship To Technology Readiness Levels:
- TRL 1: Basic Principles Observed
- TRL 2: Concept Formulated
- TRL 3: Proof of Concept
- TRL 4: Breadboard in Lab
- TRL 5: Breadboard in Relevant Environment
- TRL 6: Prototype in Relevant Environment
- TRL 7: System Qual
- TRL 8: Mission Proven

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Recommended Focus on “Bringing Home Value” To Customers

IVHM / PHM Losing “Rising Star” Status
- Have Been Some Success Stories
- Difficulty of Implementing Good IVHM/PHM Underestimated
- Poor Implementations Tarnish Reputation of Health Mgmt

Need: Tools to Achieve / Ensure High Quality PHM
- Design: Complete Coverage, No False Calls, Timely Prediction
- Validation: Quality of Implementation

NASA Av Safety IVHM Research
- Balance of “New Technology” and “Making Existing PHM Work”
- “Level A” Certifiable IVHM/PHM?
Closing Thoughts

DECWG Showing Collaboration Is Possible
• Requires Clear, Pre-Competitive Objectives
• Top-Down *Steering* of Effort Seems To Work Best

Concerns About Research-to-Product Gap
• Research Extending Lead Over Technology Maturation
• Gov’t / Industry *Technology Development Plans*?

Regularly Reassess Research Alignment
• Aeronautics Is Very Dynamic Industry
• Regular Reviews of Areas of Research Focus/Timing Beneficial