

NASA Glenn Research Center
2012 Propulsion Control and Diagnostics Workshop

February 28 – March 1, 2012
Ohio Aerospace Institute
Cleveland, OH

Perspective on Controls & Diagnostics

Bruce Wood
Kurt Sobanski
Pratt & Whitney
East Hartford, Ct

P&W Engine Product Markets



Large
Commercial



Military



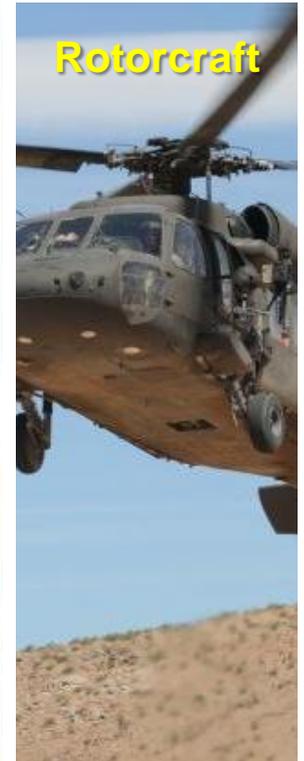
Small
Commercial



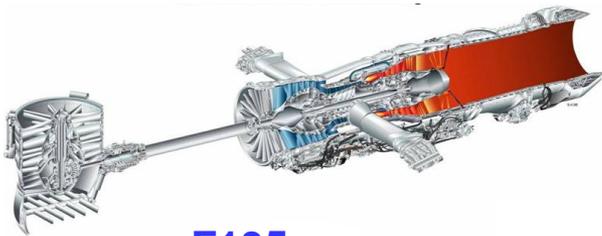
Industrial
Power



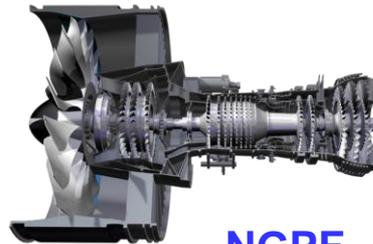
Space



Rotorcraft



F135



NGPF



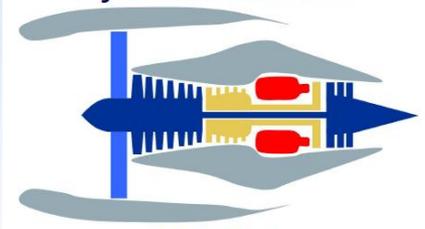
HPW3000



Model-Based Controls & Diagnostics

Modeling Methods and Tools

MAPSS/CMAPSS
Commercial Modular Aero-Propulsion
System Simulation



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Glenn Research Center
Controls and Dynamics Technology Branch

at Lewis Field



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DRIVERS

More Pervasive Use of Engine Models

OPPORTUNITIES

Modeling Methods for ...

- Increased Fidelity
- Computational Efficiency
- Capture of Secondary Effects, etc.
- Integrated Aircraft Systems (Generators/Bleeds)
- Real-Time Model “Adaptation”

ACTIVITIES

NASA IRAC Fast-response Engine Research (FastER)

- Investigation of Adaptive Engine Controls Laws

NASA VSST Integrated Flight Propulsion Control (IFPC)

- Exploration of Integration of Adaptive Engine and Flight Controls Laws

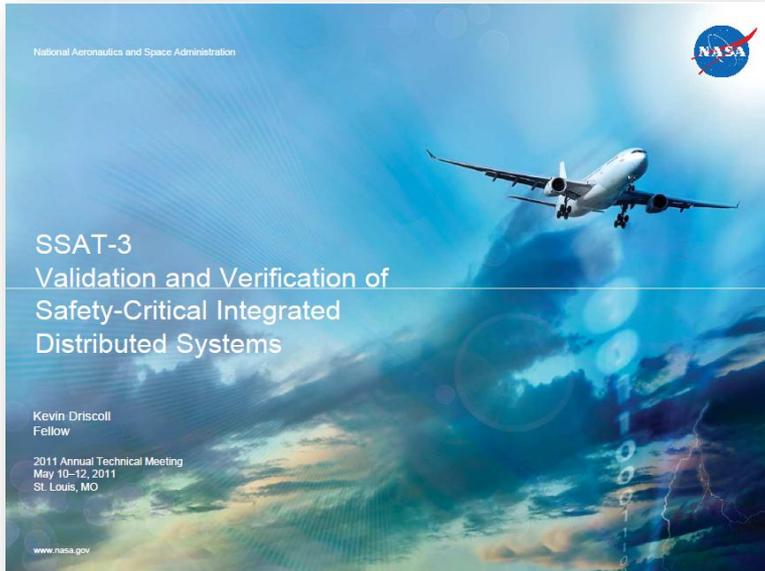
NASA Turbofan Engine Simulation Tools (C-MAPSS, C-MAPSS40K, etc.)

- Non-Proprietary Generic Models That Support Tool Development



Verification, Validation and Certification

Automation of Methods



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DRIVERS

- Increasing Software Size/Complexity
- Use of *Open Source* 3rd Party Algorithms
- Coming: Adaptive Systems

OPPORTUNITIES

- Software Design Methods for Easier Validation
- Automation of Traditional V&V Tools
- On-Board Software Health Management

NASA Verification and Validation of Flight Critical Systems (VVFCs)

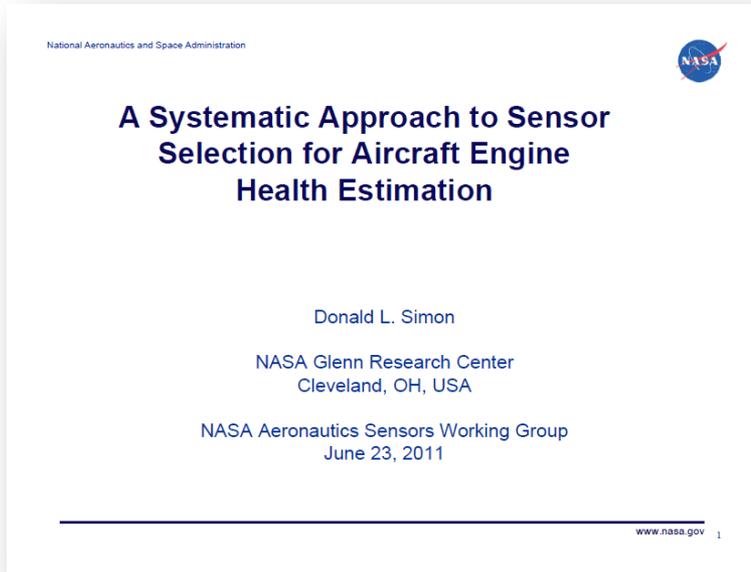
- Long Promised NASA Funded Effort Has Not Materialized
- Run-time Methods To Enable Safety Assurance For On-board Adaptive Engine Models
- Industry Wide Collaboration Opportunity – maybe a Working Group?
- Joint Development of Standards, Tools and Methods?

ACTIVITIES



Diagnostics and Health Management

Tools, Methods and Validation



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DRIVERS

More Complete Coverage of Engine Condition
Fleet-Wide Health Management
Possibility of “Level A” Certifiable PHM

OPPORTUNITIES

- Sensor Suite Selection
- Very Large Data Set Handling / Analysis
- Open Source Algorithm Assessment

ACTIVITIES

NASA Aviation Safety System-Wide Safety & Assurance Technologies

NASA Vehicle Systems Safety Technologies

- Blending of On-Board and Off-Board Health Management
- Intelligent Decision Making

NASA Propulsion Diagnostic Method Evaluation Strategy (ProDiMES)

- Gaspath Diagnostic Systems Design Optimization Tools



PHM System Validation

Sensor, Algorithm, Tool Maturation Test Opportunities



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Challenges In Implementing “Quality” PHM

OPPORTUNITIES

- Sensor Evaluation
- Algorithm Validation
- Bench / Rig Tests
- Seeded Fault Engine Tests

NASA Vehicle Integrated Propulsion Research (VIPR)

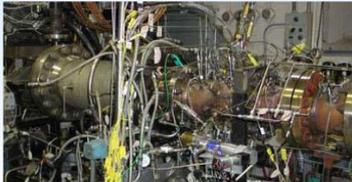
- Run To Structural Limits, Run To Failure Tests
- Use and Evaluate Advanced Instrumentation/Sensing
- Characterization of Engine Condition During Progression to Failure
- Low Concentration Volcanic Ash Ingestion

ACTIVITIES

Active Controls

Active Controls Research

NASA Overview: Combustion Dynamics and Control for Ultra Low Emissions in Aircraft Gas-Turbine Engines



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Interest In Fuel Burn / Emission Solutions
Variable Adaptive Engines
Weight / Size / Cost Packaging

OPPORTUNITIES

- Distributed Controls Collaboration
- High Temp, Low Cost. Compact Actuation
- Robust, High Sample Rate Sensing

NASA N + 2 Low NO_x Combustor Research

- Fundamental Enabling Research
- Novel Concepts for Ultra Low Emissions Active Combustion

Sensors for Intelligent Engines

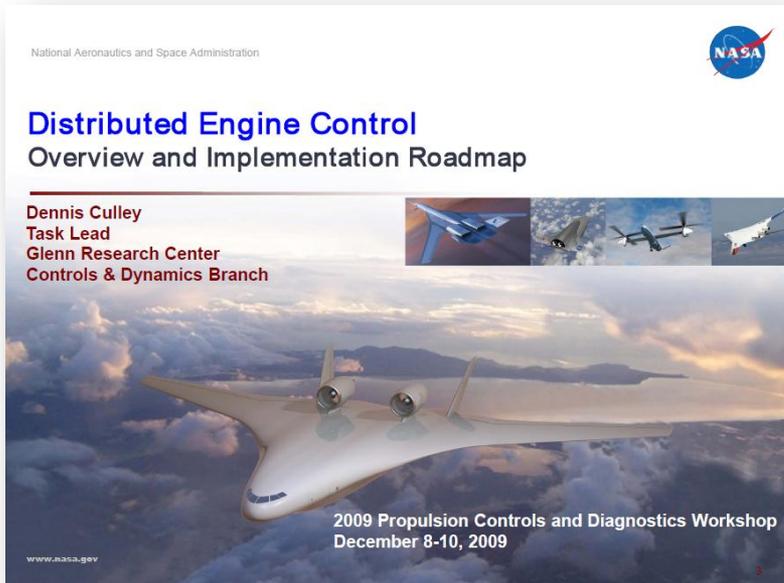
- Microwave Sensing for Active Clearance Control
- Emissions Sensing

ACTIVITIES



Distributed Engine Controls

Toolbox of High Temp Capable Control Elements



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DRIVERS

Thermally Challenging Engine Environment
Perennial Weight / Size / Cost Concerns
Reuse / Upgradability / Future Proofing
Variable Adaptive Engines (Actuators/Sensors)

OPPORTUNITIES

- High Temp Electronic Components
- Power Distribution / Communication Networks
- Certification

Distributed Engine Controls Working Group (DECWG)

- Pre-Competitive Collaboration Looks To Be Effective
- Defining Requirements for Commonality at “Building Block” Level

 **NASA High Temperature Electronics Development**

 **NASA Common Environment Hardware-in-the-Loop Test Facility**

ACTIVITIES

Advanced Sensors

Product-Ready Sensors

High Temperature Wireless Sensor Systems

Gary W. Hunter

Aviation Safety Program Technical Conference
November 17-19, 2009
Washington D.C.

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Always Interested In New Sensors, But ...
Poor Reputation – Perceived Reliability Issues
Benefit vs. Weight / Packaging Size / Cost

OPPORTUNITIES

- High Temperature Sensor Research
- In-Product Optics
- Manufacturing Readiness → Product Transition

NASA Aero Sensors Working Group (ASWG)

- Extend From Education to Collaboration – Similar to PIWG

SBIR Partners

- Need to Establish Business Strategies for Commercialization

Major Sensor Supplier Partners

- Bring In Early To Work with OEM and Small Businesses

ACTIVITIES



Wireless and Wire-Less

High Temp Hardware, Standards and Certification

Intelligent Wireless Sensor Networks for System Health Monitoring

Aeronautics Sensors Working Group
(ASWG)

Teleconference Presentation

December 8, 2011

Rick Alena

Discovery and Systems Health Group
Intelligent Systems Division
NASA Ames Research Center



Rev B 12/6/11

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DRIVERS

- Reduce Control System Weight / Size / Cost
- Rapid Low Cost Control Upgrade
- Decrease Wiring / Connector Faults

OPPORTUNITIES

- Thermally Robust Wireless for On-Engine Use
- Address EMI, Dropout and Security Issues
- Self-Powering/Batteries To Truly Eliminate Wires

NASA Intelligent Wireless Sensor Networks

- Standards/Protocols for Wireless for In-Flight Controls Applications

NASA Aero Sensors Working Group (ASWG)

- Industry Requirements for Passive Surface Acoustic Wave Sensors

ACTIVITIES



In Closing ...

Exciting Times for Controls & Diagnostics

- Variable, Adaptive, Active, High-Response ...
- Diagnostics, Prognostics, Condition-Based Maintenance ...

Opportunities for Pre-Competitive Collaboration

- Fundamental Building Blocks Benefit Everyone
- Distributed Engine Controls Working Group Example

NASA / DoD Are Leading Cutting-Edge Research

- Small Business and University Contracts
- Industry Contracts and Space Act Agreements
- Facilitating Industry Collaboration

