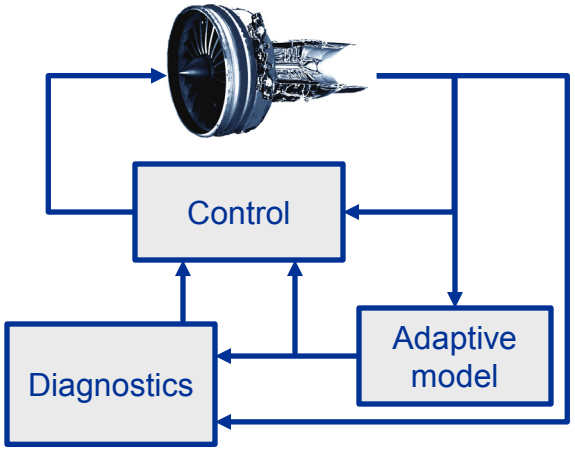
3rd NASA Glenn Propulsion Control and Diagnostics Research Workshop

Model-Based Control and Diagnostics

Time	Presentation Title	Presenter
1:30	Model-Based Control and Diagnostics Session Overview	Don Simon (NASA)
1:40	Model-Based Aircraft Engine Performance Estimation	Don Simon (NASA)
2:10	Model-Based Diagnostic Architecture	Jeff Armstrong (ASRC)
2:35	Vehicle Integrated Propulsion Research (VIPR)	Don Simon (NASA)
2:55	Model-Based Engine Control	Sanjay Garg (NASA)
3:15	Discussion	All

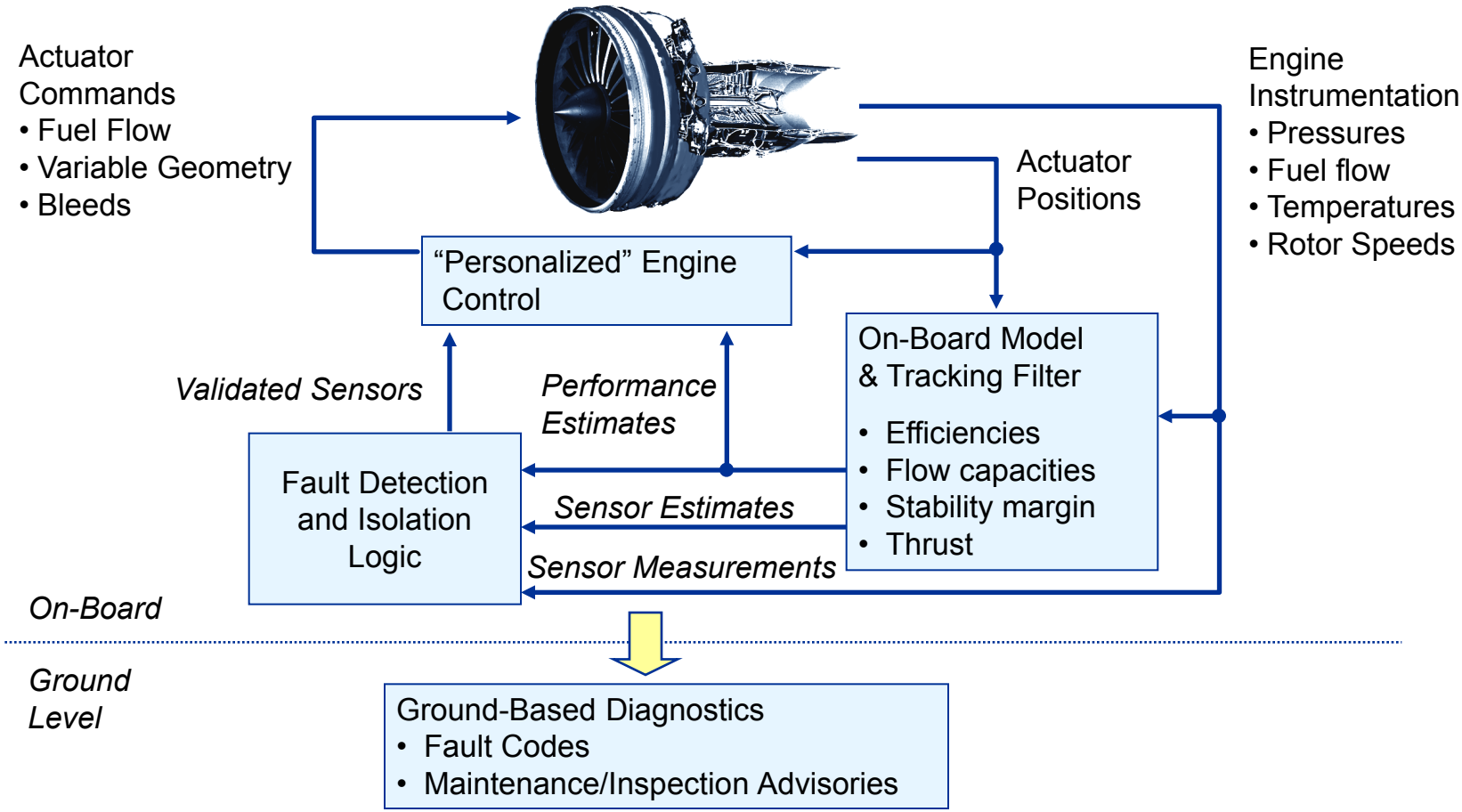
Model-Based Control and Diagnostics Session Overview



Donald L. Simon
NASA Glenn Research Center

3rd NASA Glenn Propulsion Control and Diagnostics Research Workshop
February 28-March 1, 2012
Cleveland, OH

Model-Based Control and Diagnostics



- ***Real-time performance estimation***
- ***Enhanced gas path diagnostics***
- ***Performance enhancing engine control***

NASA Mission / Program / Project Structure

Aeronautics Research Mission Directorate
- Works to solve the challenges that still exist in our nation's air transportation system: air traffic congestion, safety and environmental impacts

Aviation Safety Program
- Improving overall aircraft safety of new and legacy vehicles operating in NextGen

Vehicle Systems Safety Technologies (VSST) Project
- Maintain and improve vehicle safety

Maintain Vehicle Safety Between Major Inspections – Technical Challenge
- Identify and proactively mitigate critical airframe, engine and avionics failures

Model-Based Gas Path Diagnostics

Fundamental Aero Program
- Overcome national challenges in air transportation including

Subsonic Fixed Wing (SFW) Project
- Reduce subsonic/transonic emissions & noise

Efficient Propulsion and Power – Sub-Project
- Technologies to reduce thrust specific energy consumption and increase performance

Model-Based Engine Control

Aircraft Engine Performance Trend Monitoring and Gas Path Fault Diagnostics

Goal: Through the interpretation of measured aircraft engine gas path parameters…..

- Accurately assess engine component performance deterioration over an engine's lifetime of use

  - and -

- Accurately detect and isolate any engine system and/or instrumentation malfunctions that occur

Benefits: Inherently tied to …

- Safety

  - and -

- Affordability

Reduced in-flight malfunctions

Reduced maintenance-related delays and cancellations

Reduced fuel burn and operating costs

Aircraft Engine Gas Path Deterioration and Fault Examples

Turbomachinery Deterioration

- Fouling
- Corrosion
- Erosion

Turbomachinery Faults

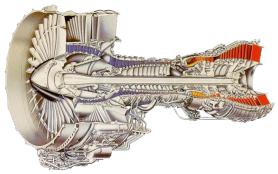
- Foreign object damage
- Blade/Vane failure

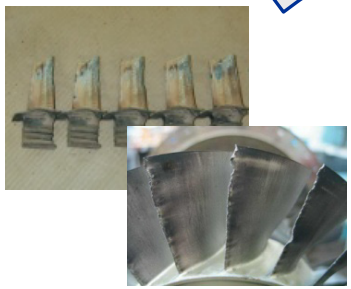
Controls and Accessories Faults

- Sensor faults
- Actuator faults
- Wiring harness faults

Gas Path Diagnostics Engine Fault Isolation Approach *

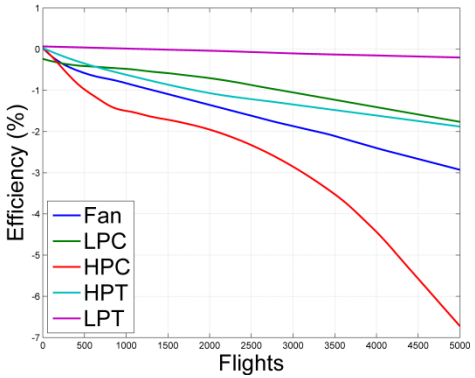
Deteriorated Turbomachinery and Gas Path Faults





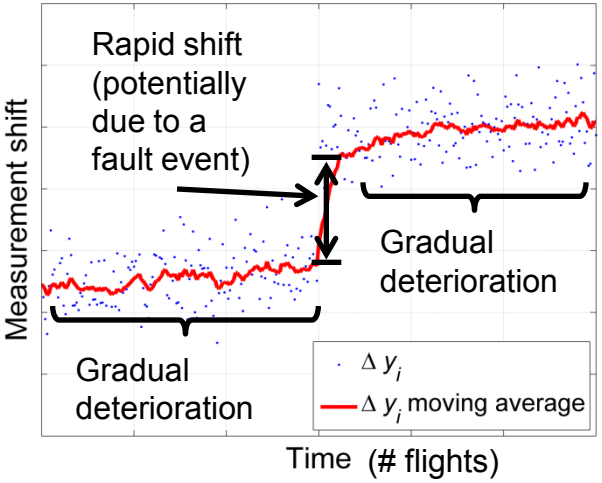
Resulting in

Degraded module performance



Producing

Changes in measured parameters



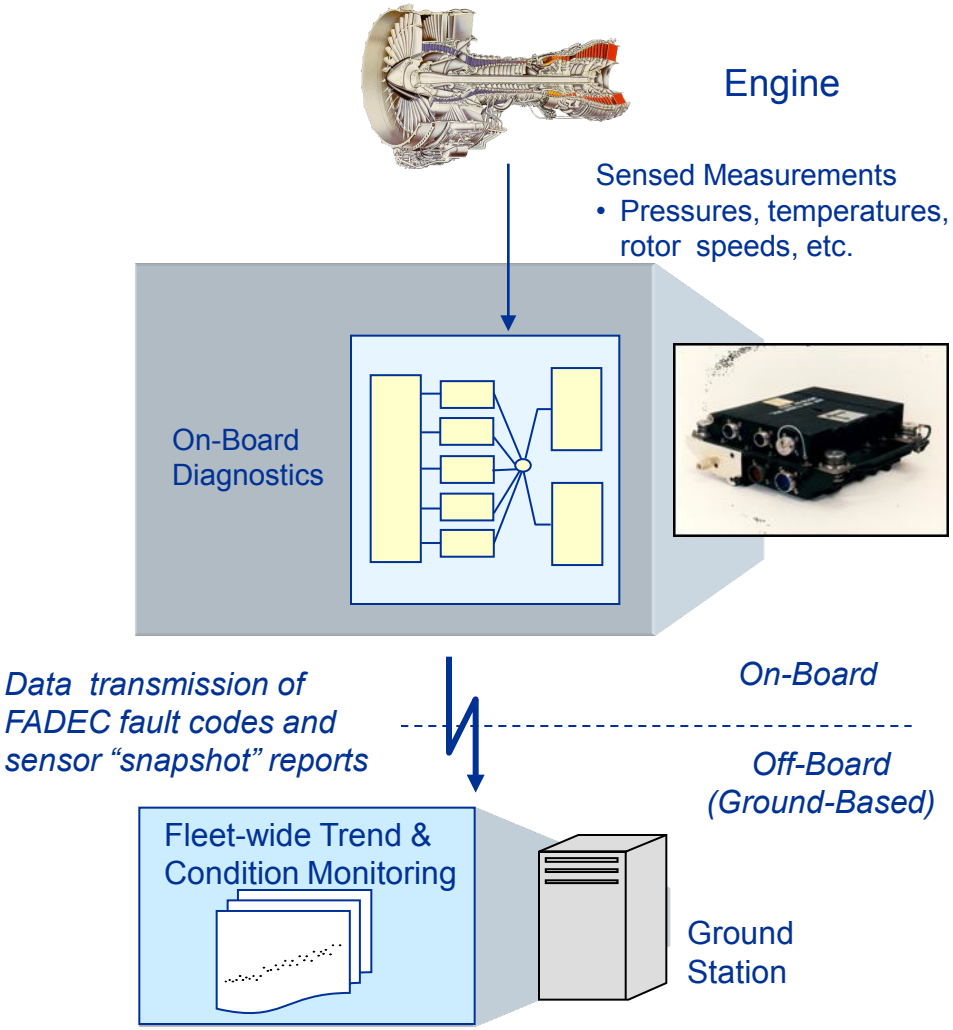
Allowing isolation of

Permitting correction of

* Adapted From "Parameter Selection for Multiple Fault Diagnostics of Gas Turbine Engines" by Louis A. Urban, 1974.

Conventional Aircraft Engine Gas Path Diagnostic Architecture

- Enabled by digital engine controls and data acquisition systems
- Includes both on-board and off-board functionality



Adaptive Self-Tuning Engine Model Technology

Background:

- Inclusion of on-board adaptive engine model technology is an emerging approach enabled by advances in avionics processing capabilities
- A Kalman filter-based tracking filter adjusts model tuning parameters to enable the model to match physical engine performance

Challenges:

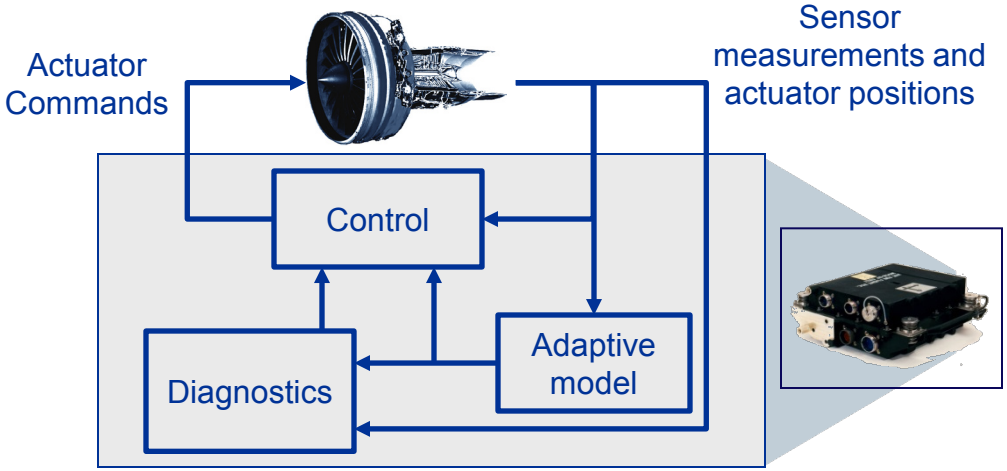
- Underdetermined estimation problem – more unknowns than available sensor measurements

On-board Benefits:

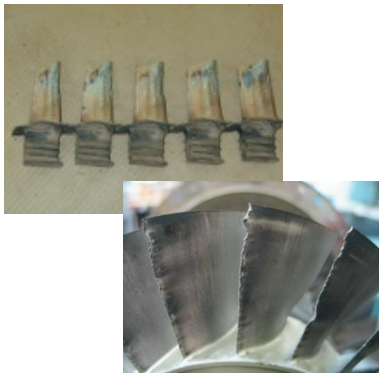
- Continuous, real-time engine condition monitoring
- Estimation of unmeasured engine parameters for control applications

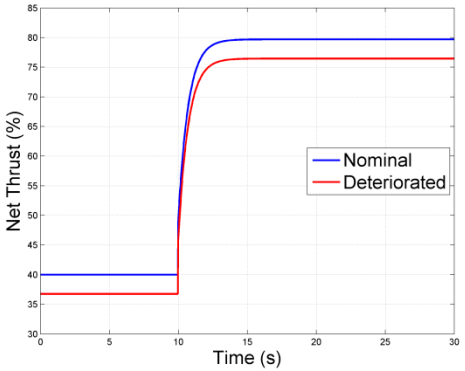
Off-board Benefits:

- Applicable for analyzing acquired full-flight engine data (e.g., FOQA data)
- Enhanced diagnostics and the estimation of unmeasured parameters for prognostics and performance trend monitoring applications



Model-Based Controls and Diagnostics Architecture

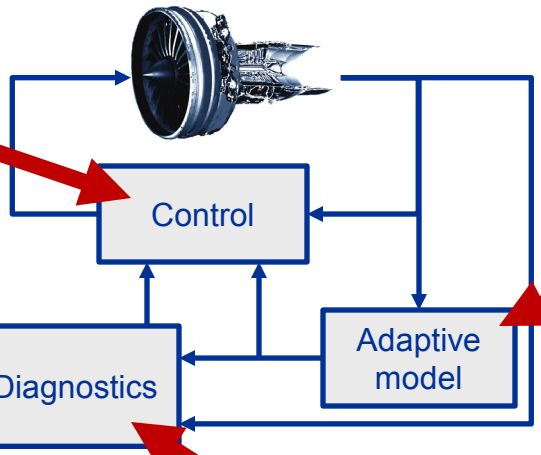




Deteriorated turbomachinery → Deteriorated engine performance

Model-Based Control and Diagnostics (*PCD Workshop Presentations*)

4) Model-Based Engine Control (Sanjay Garg)
- Control adapts to the condition of the engine, enabling more efficient engine operation



1) Model-Based Aircraft Engine Performance Estimation (Don Simon)
- Optimal model tuning parameter selection methodology enables minimization of estimation error in the parameters of interest

3) Vehicle Integrated Propulsion Research – VIPR (Don Simon)
- On-wing demonstration and data acquisition for evaluation of advanced engine health management sensors and algorithms
- Maturation of engine health management technology

2) Model-Based Diagnostic Architecture (Jeff Armstrong)
- Gains access to expanded quantity of measurement data
- Enables early diagnosis of incipient gas path fault conditions

Model-Based Control and Diagnostics (*Additional Related Activities*)

A Unified Nonlinear Adaptive Approach for Detection and Isolation of Engine Sensor, Actuator and Component Faults (*Phase II SBIR*)

Impact Technologies
A Sikorsky Innovations Company
WRIGHT STATE UNIVERSITY

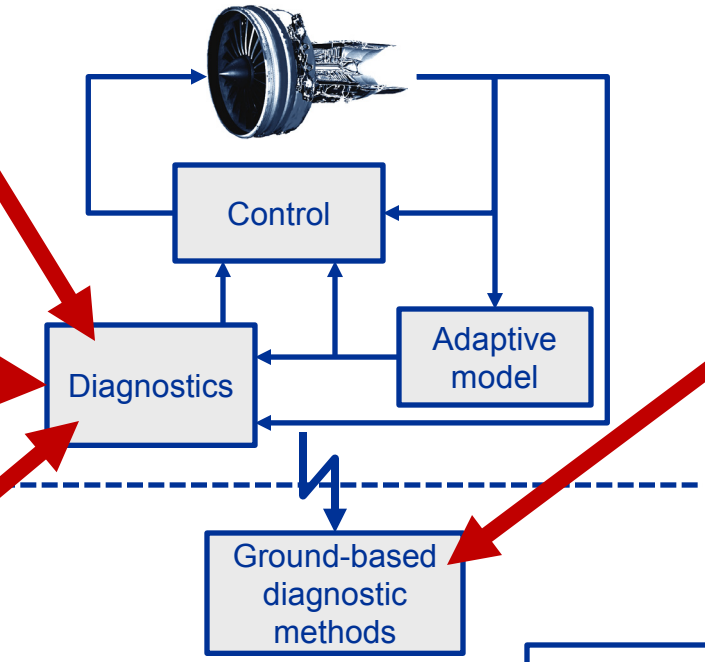
Health State Assessment and Failure Prognosis of Integrated Aircraft Propulsion Systems (*NRA*)

PENNSTATE 1855

Systematic Sensor Selection Strategy

Sensor Data Qualification

Included in PCD Workshop Reception Poster Session



Propulsion Diagnostic Method Evaluation Strategy (ProDiMES) – *A public approach for benchmarking gas path diagnostic methods*

Aircraft Engine Gas Path Modeling and Diagnostic Methods (Space Act Agreement)

- *NASA-industry collaboration in engine health management research*

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