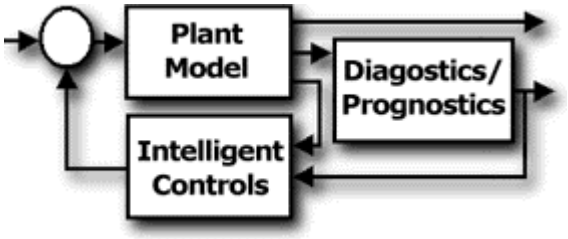
Diagnostics for Aerospace Propulsion Systems
GRC Vision and Current Activities

Turbine Power Systems Conference and
Condition Monitoring Workshop
Feb. 25-27, 2002, Galveston, TX



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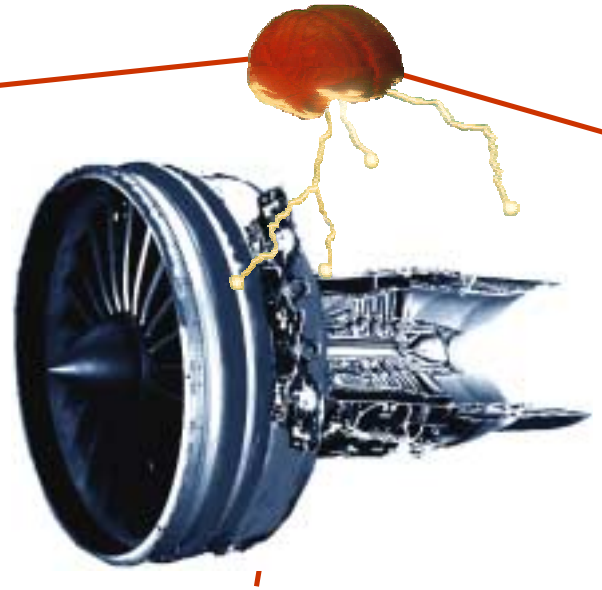
INTELLIGENT ENGINES
Multifold increase in propulsion system affordability, reliability, performance, capability and Safety

Active Control Technologies for enhanced performance and reliability, and reduced emissions
- active control of combustor, compressor, vibration etc.
- MEMS based control applications



Advanced Health Management technologies for self diagnostic and prognostic propulsion system
- Life usage monitoring and prediction
- Data fusion from multiple sensors and model based information

Distributed, Fault-Tolerant Engine Control for enhanced reliability, reduced weight and optimal performance with system deterioration
- Smart sensors and actuators
- Robust, adaptive control

General Engine Diagnostic Data / Information Fusion Architecture

(Applied to Pratt & Whitney F117 Engine – C17 Aircraft)

Combine Available Information/Data Sources and Diagnostic Modules….

….To Automate and Enhance Diagnostic System Inference Capabilities

Engine Instrumentation
- Gas Path
- Vibration
- Lubrication System
- Advanced Sensors
  - Electrostatics
  - Stress Wave

Not Used Under Current Research Effort
- Maintenance Information
- FADEC Fault Codes

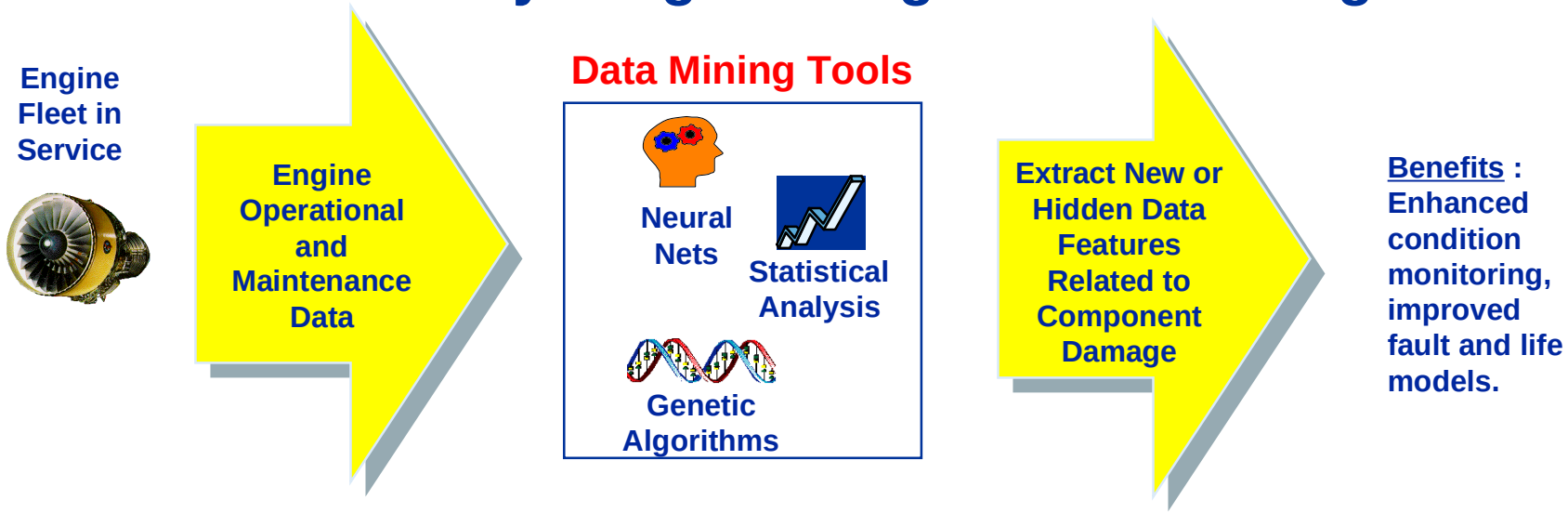
Data Alignment Module

Model / Analysis Module
- Gas-Path Analysis
- NN-Based Anomaly Detector
- Empirical Lubrication System Model
- Vibration Analysis

High Level Fusion Module (Bayesian Networks)

Fused Diagnostic Information
(List of candidate faults with confidence levels)

NASA Aviation Safety Program Engine Data Mining Tools

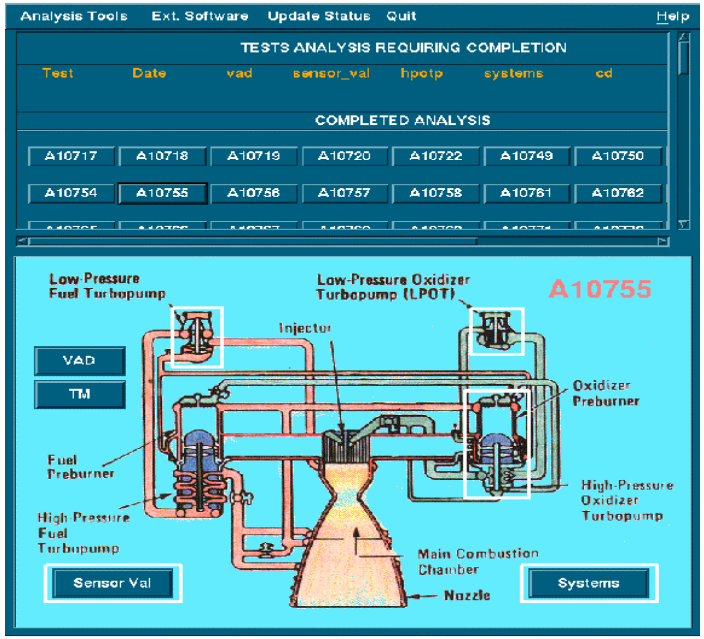


- Data mining tools provide new insights into wear and failure mechanisms in engine components
- In addition to the safety enhancement, benefits include:
  - Decreased maintenance costs through Intelligent Prognostics and to optimally schedule maintenance
  - Increased part life through usage modification.

Post-Test/Post-Flight Diagnostic System

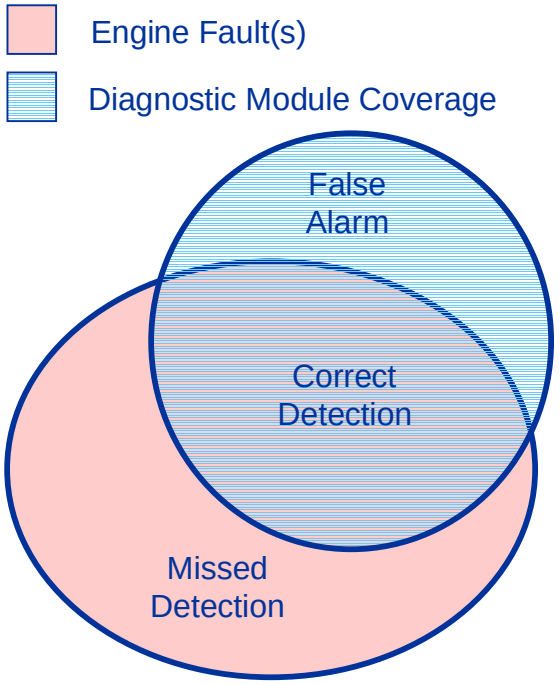
Objective: Develop and mature technologies that automate the analysis of rocket engine data to detect and isolate system and component failures

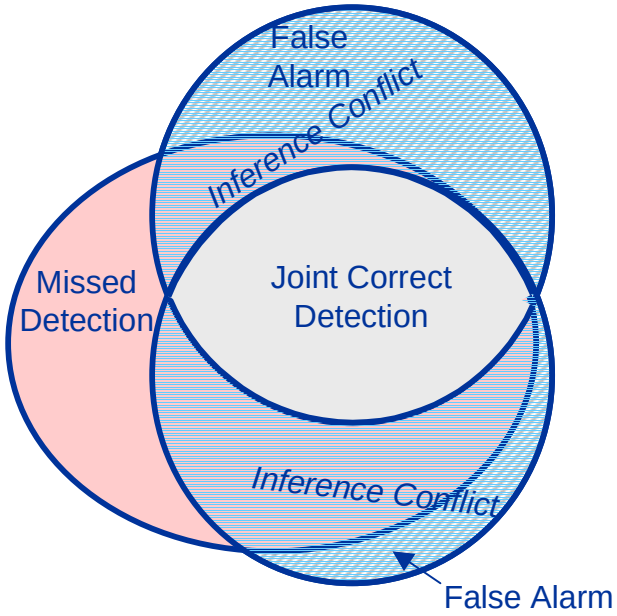
- Production version of system delivered to MSFC for integration into SSME data analysis process

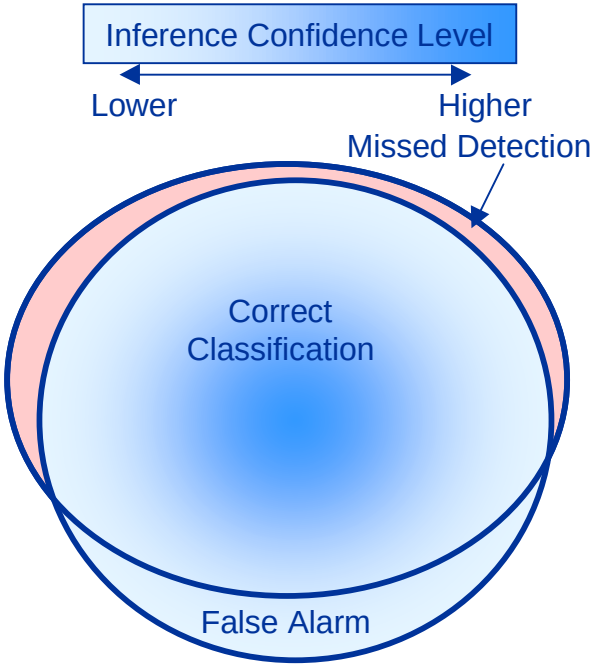


•System used for testing of the aerospike engine under the X-33 Reusable Launch Vehicle program.

Higher Level-Fusion Statistical Based Diagnostic Benefits







Single Diagnostic Approach

- Limited fault coverage
- Detection threshold tradeoffs between false alarms & missed detections (often established manually)
- Fault isolation often occurs manually

Multiple Independent Diagnostic Approach

- Additional fault coverage
- Detection threshold tradeoffs between false alarms & missed detections more challenging
- Fault isolation improved- but still requires manual effort
- Introduces problem of inference conflict between modules

Fused Diagnostic Approach
(Bayesian Inference, Dempster-Shafer)

- Optimal fault coverage
- Designer has statistical based means to assess false alarms & missed detections rates based on detection thresholds
- Inference confidence levels provided to aid in fault annunciation and isolation
- Automated resolution of inference conflict between modules