VISION

BE THE MODEL ACQUISITION PROGRAM FOR JOINT SERVICE AND INTERNATIONAL COOPERATION

DEVELOP AND PRODUCE A FAMILY OF AFFORDABLE MULTI-MISSION FIGHTER AIRCRAFT USING MATURED/Demonstrated 21ST CENTURY TECHNOLOGY AND SUSTAIN IT WORLDWIDE

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.
Prognostics and Health Management

• Why Did We Choose This Technology?
  – Enable Autonomic Logistics
  – Enhance Flight Safety
    • Single Engine Aircraft, Must Have Dual Engine Reliability
  – Increase Sortie Generation Rate
  – Eliminate False Alarms
  – Eliminate CND’s and RTOK’s
  – Reduce Life Cycle Costs
  – Maximize PHM Benefit from Limited Specialized Sensors
  – Take Max Advantage of the “Smart” Digital Aircraft

Natural Evolution of Legacy Diagnostic Capabilities Coupled with the Added Functions, Capabilities, and Benefits offered by New Technologies
Prognostics and Health Management

What is it?

- **Enhanced Diagnostics** – the process of determining the state of a component to perform its function(s), high degree of fault detection and fault isolation capability with very low false alarm rate

- **Prognostics** – actual material condition assessment which includes predicting and determining the useful life and performance life remaining of components by modeling fault progression

- **Health Management** – is the capability to make intelligent, informed, appropriate decisions about maintenance and logistics actions based on diagnostics/prognostics information, available resources and operational demand.
PHM Constituent Functions and Processes

- Fault Detection
- Fault Isolation
- Advanced Diagnostics
- Predictive Prognostics
- Useful Life Remaining, Time-to-Failure Predictions
- Component Life Tracking
- Performance Degradation Trending
- Warranty Guarantee Tracking - Enabling New Business Practices
- Health Reporting
  - Only tells pilot what NEEDS to be known immediately
  - Informs Maintenance of the rest
- Aids in Decision Making & Resource Management
- Fault Accommodation
- Information Fusion and Reasoners
- Information Management
  - Right Info to Right People at Right Time
JSF CDP AVPHM/JDIS Demos Provided
Substantiation of Weapon System PHM

1. FD/FI and Confirmation
   - Failure Impact Assessment
   - In-flight Mission Replanning
   - Autonomic Triggering of AL
   - Prognostics
   - Cooperative Operations

2. FOD Detection/Classification
   - System Correlation/Confirmation
   - Shaft Misalignment Detection
   - Lift Fan Safe Operation
   - Condition Based Maint.
   - Elimination of Unnecessary Inspections

3. Improved FD/FI
   - Fault Confirmation
   - Post-Flight Data Analysis
   - Manufacturer Feedback
   - Reduction of OEM Trouble-Shooting Time
   - CND/RTOK Elimination

4. Improved FD/FI
   - FD/FI w/o Add’l Sensors
   - Failure Impact Assessment
   - Optimization of Supply Chain Management

5. Operational Loads Monitoring
   - Overload Analysis
   - Force Management
   - Elimination of Unnecessary Inspections
   - Usage Tracking / Life Projection

6. Assist Maintainer in Difficult Failure Analysis
   - Resolution Sharing for Fleet
   - Rapid/Effective Interface to Engineering
   - Knowledge Discovery

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PHM Is the Air Vehicle Enabler of the Autonomic Logistics Structure

Intelligent Air Vehicle

PHM

PHM Download

Operational Requirement

Repair Required

Replenishable Requirements

Repair Recommendation

Just-in-Time Training

Onboard Stock

Aircraft Turn-round & Repair

Return of Defective Item

Aircraft Available

Supply of AOG item/ Replenishment of Ship Stock

Reduced Log Footprint

High SGR

High MR

Supply of AOG item/ Replenishment of Ship Stock

Reduced Log Footprint

High SGR

High MR

Integrated Supply/Engineering Info systems

Lessons Learned/ Failure Rates

Maintenance Rehearsal

Audio

Graphical

Simulated World

Haptic

MX Training

Lessons Learned/ Failure Rates

Automated Logistics Update

Automatic/JIT Re-Supply

Govt/Industry/Depot Activities

PHM Is the Air Vehicle Enabler of the Autonomic Logistics Structure

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PHM Architecture and Enabling Technologies

**Air Vehicle On-Board Health Assessment**

- **ICAWS Manager**
  - Hosted in VMC
- **PHM Area Managers**
  - **Propulsion**
  - **FCS/Utility Subsystems**
  - **Structures**
  - **Mission Systems**
  - **MS Subsys**

**Health Management, Reporting & Recording**

- **NVM Crash Recorder**
- **Displays & Controls PVI**
- **PHM Data**
- **AMD/PMD**
- **PMA**

**Autonomic Logistics & Off-Board PHM**

- **AVPHM**
  - Hosted in ICP

**Methods Used:**
- Sensor Fusion
- Model-Based Reasoning
- Tailored Algorithms
- Systems Specific Logic / Rules
- Feature Extraction

**Provides:**
- AV-Level Info Management
- Intelligent FI
- Prognostics/Trends
- Auto. Logistics Enabling/Interface

**Results In:**
- Decision Support
- Troubleshooting and Repair
- Condition-Based Maintenance
- Efficient Logistics

- **AVPHM**
- **Maintenance Interface Panel**
- **PHM / Service Info**
- **IETMs Consumables On-Board Diagnostics**
- **Database**

**ALIS**
- Automated Pilot / Maint. Debrief
- Off-Board Prognostics
- Intelligent Help Environment
- Store / Distribute PHM Information

**VS Propulsion**

**Structures Mission Systems**

**Flight Critical**

**Mission Critical**

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Air System PHM IPT Products

VS/MS PHM SEIT
- Optimal Diagnostic / BIT Capabilities for Subsystem IPT’s
  - Diagnostics / BIT
  - IPT’s / supplier teams achieve the best and most cost effective coverage
  - Pertinent data acquisition at sensor, component and sub-system levels.
  - Requirements, top level design, use cases, verification.

VS/MS/AF PHM Area Managers (products)
  - Enhanced diagnostics, System models, Corroboration, Correlation, and Information fusion
  - Prognosis
    - Collect data, Compute life usage
    - Predict time to failure

Off-board PHM (product)
  - Prognosis models,
  - Failure resolution algorithms
  - Diagnostic Tools

Air Vehicle PHM (product)
  - Health management
    - Report Remaining Functionality
  - Information broker for on- and off-board users
  - High-level service requirements for data reduction, file management

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Advanced Techniques Are Applied to JSF Weapon System PHM Solution

Performance Monitoring / Trending:
- PTMS (IPP, Filters, Reservoirs, Coalescer, etc.)
- Hydraulic System (Pumps, Filter, Reservoirs, Accumulators)
- Fuel System (Pumps, Valves, Heat Exchanger)
- Weapon Bay Door Drive (Pump Speed & Swashplate Angle)
- Rotary Actuators, EHAs
- Weapon Racks
- OBIGGS Filter

Auto Calibration / Gain Trending:
- Radar
- Displays
- Fuel Probes
- Stick & Throttle

Enhanced Sensor Technologies:
- Engine - FOD Detection, Oil Debris, Oil Condition, Blade Tip Monitoring, Vibration Monitoring
- SDLF - FOD Detection, Oil Debris, Oil Condition, Shaft Alignment / Torque, Clutch Wear / Vibration
- Brake Temperature
- Landing Gear (Strut Servicing, ‘Smart Tire’)

Operational Loads/Usage Monitoring:
- Structures, Landing / Arresting Gear
- Gun, EPS Starter/Generator
- CSMU (Write Cycles)

Cross-Comparison (Redundancy Management):
- Flight Controls (VMC, Inceptors, EHAs, Sensors)
- EPS (Degraded modes, Emergency Power)
- Fuel Probes

Capacity Trending:
- 28 & 270 volt Batteries
- Cryo Cooling Capacity
- ESA (loss of Elements)
- OBIGGS / OBOGS
- HIPPAG Recharge Rate

Information Management:
- Model-Based Reasoning, Trending, Pattern Recognition (Enhanced Diagnostics, Fault Isolation)

Automated Testing:
- WBDD Actuator Backlash
- External Fuel Tanks
- RIOs, VSP Software
- Nose Wheel Steering Friction Collar
- CSMU (Periodic Read/Write Testing)
- Aircraft Wiring

Off-Board Technologies:
- Diagnostic Tools
- Intelligent Help
- Prognosis Models

PHM Is an Integral Part of Every Facet and Subsystem of the Weapon System
Off-Board PHM Overview

- Downlink Health Data
- Assess and Report Aircraft Health
- Uplink Combat Turn Requirements

Aircraft Support
- Maintainer Vehicle Interface
- Augment Aircraft Diagnostics
- Component Performance Tracking
- Support PHM Maturation

- Clear Faults
- Execute Test
- Display Repair Task List
- Execute Diagnostic System Control
- Upload Algorithm Updates

Fleet Support
- Intelligent Help Desk
- Distribute PHM Information
- Support Knowledge Discovery
- Support PHM Maturation

- Report Maintain History for Maturation and Sustainment
- Report Usage of Parts/Aircraft
- Distribute Algorithm Updates

Maintenance Interface Panel
Portable Maintenance Aid
Supplier
Contractor
AUTONOMIC LOGISTICS SYSTEM
TECHNICAL SOLUTION

INTEGRATED SUPPORT
- Design Data → Direct to Support Information
- Failure Prediction → Remove Unit Before Failure

TECHNOLOGICALLY-ENABLED MAINTAINER

INTELLIGENT AIR VEHICLE
- Prognostics & Health Management
- Design for Supportability
- High Reliability & Maintainability

FLIGHT OPERATIONS
- Integration for Optimal Mission Performance
- High Sortie Generation Rate
- Low Logistics Footprint

INTEGRATED TRAINING
- Common, Joint Pilot/Maintainer Training
- Modular, Flexible Training
- Embedded Training

Joint Aircrew & Maintainer Training

PHM Enables the Integrated JSF AL System - Affordable, Supportable, Survivable, & Lethal

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Summary

• PHM Is the Key Enable for the Autonomic Logistics Vision
• Technology is Now NOT the Limiting Factor
  – And It will Only Improve With Time
• All Elements Are Coming Together To Enable Our Visions of Advanced Diagnostics, Prognostics and Real Health Management
• Must Implement and Apply Smartly and Wisely to Maximize Affordability Benefits
• PHM Must Be a Critical Element in all System Design Trades to Achieve Envisioned Reduction in Total Ownership Cost

Successful PHM Implementation Is Achievable and Critical to JSF Program Goals