Joint Strike Fighter

LOCKHEED MARTIN

Applying Autonomic Logistics to the F-35

6 March 2003

Luke J. Gill

F-35 Program

F-35A

CTOL

F-35B

STOVL

F-35C

CV

JSF Program Pillars

Affordability

Survivability

Lethalilty

Supportability

The right mix to be effective and affordable

JSF is Redefining the Way We Do Business

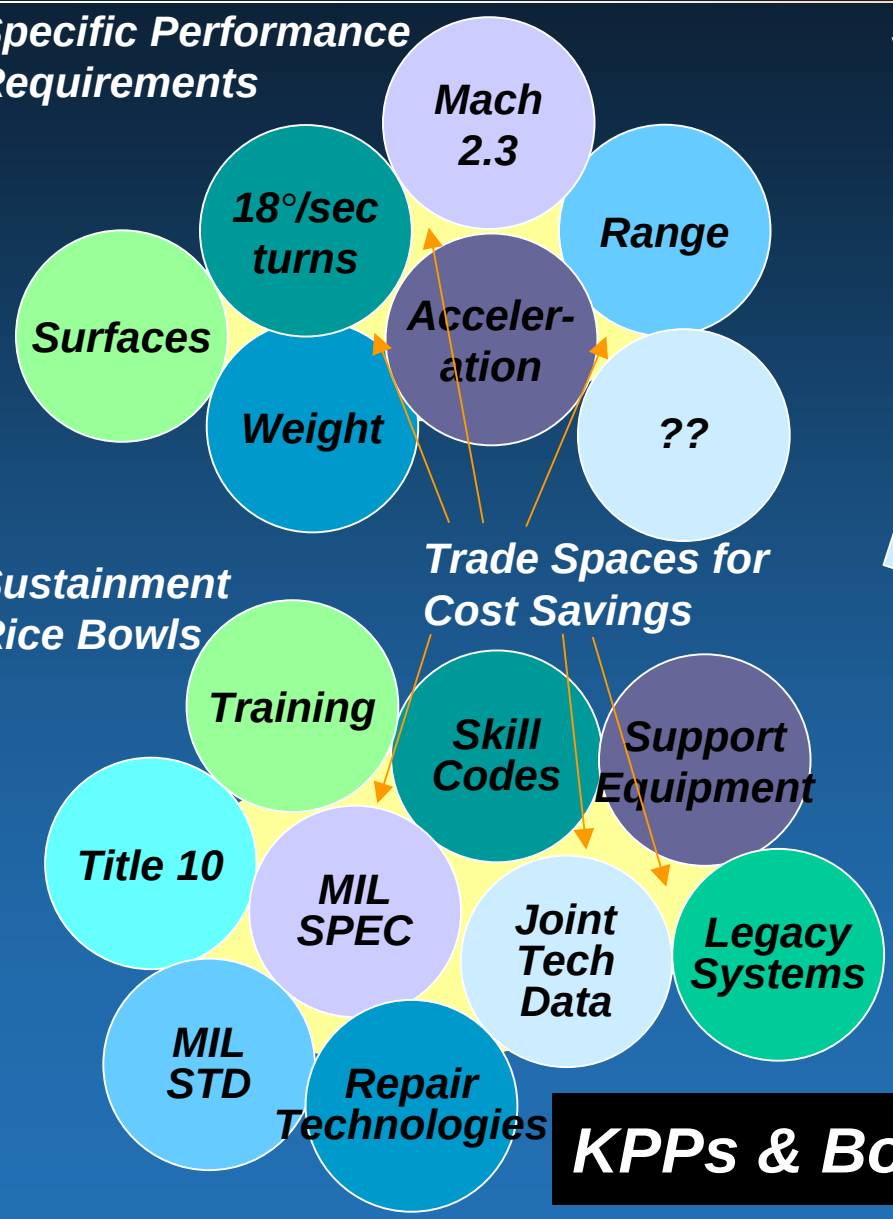
This Program is Different …

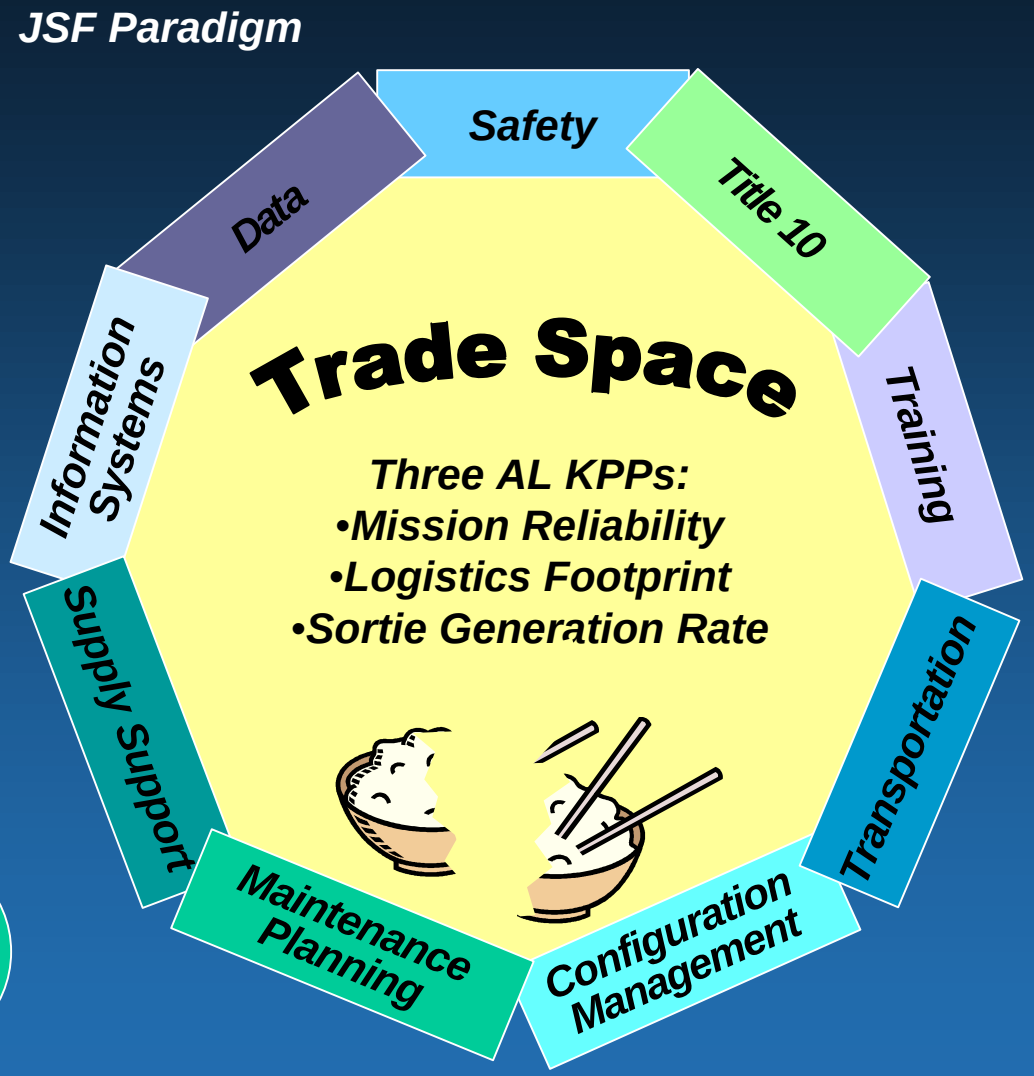
…VERY Different

Different in Everything We Do

- **Transformational Weapon System**
  - Multi-role Combat Aircraft Infrastructure Replacement
  - Coalition Operations Enabler
- **Innovative, Integrated Management Concepts**
  - Best Athlete, Best Practices, Best Value
  - Integrated Management Framework
- **Affordability Based Paradigm(s)**
  - Economies of Commonality and Scale
  - Global Best Value Supply Chain Management
  - Autonomic Logistics
- **True International Partnerships**
  - Allied Co-Development and Long Term Relationships

Breaking Rice Bowls

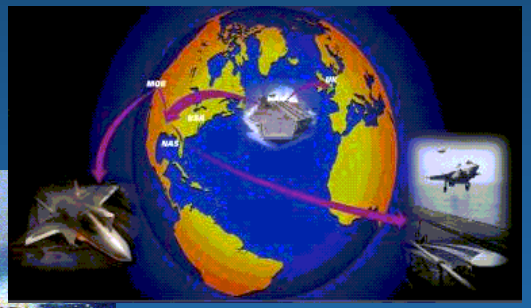




KPPs & Boundaries Open Up Trade Space

The Autonomic Logistics Concept

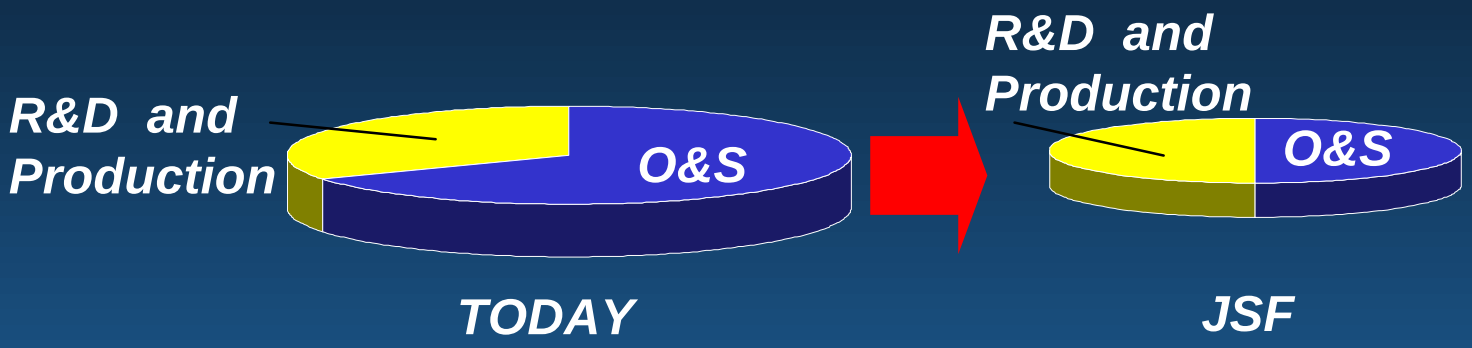
- Smart, Reliable Aircraft
- Agile Support
- Integrated Electronic Training of Pilots and Maintainers
- ALIS-Integrated Infrastructure
- Partnering with Government and Industry for Best Value



A global evolution of our role in fighter sustainment

Why Autonomic Logistics?

- The Affordability Challenge

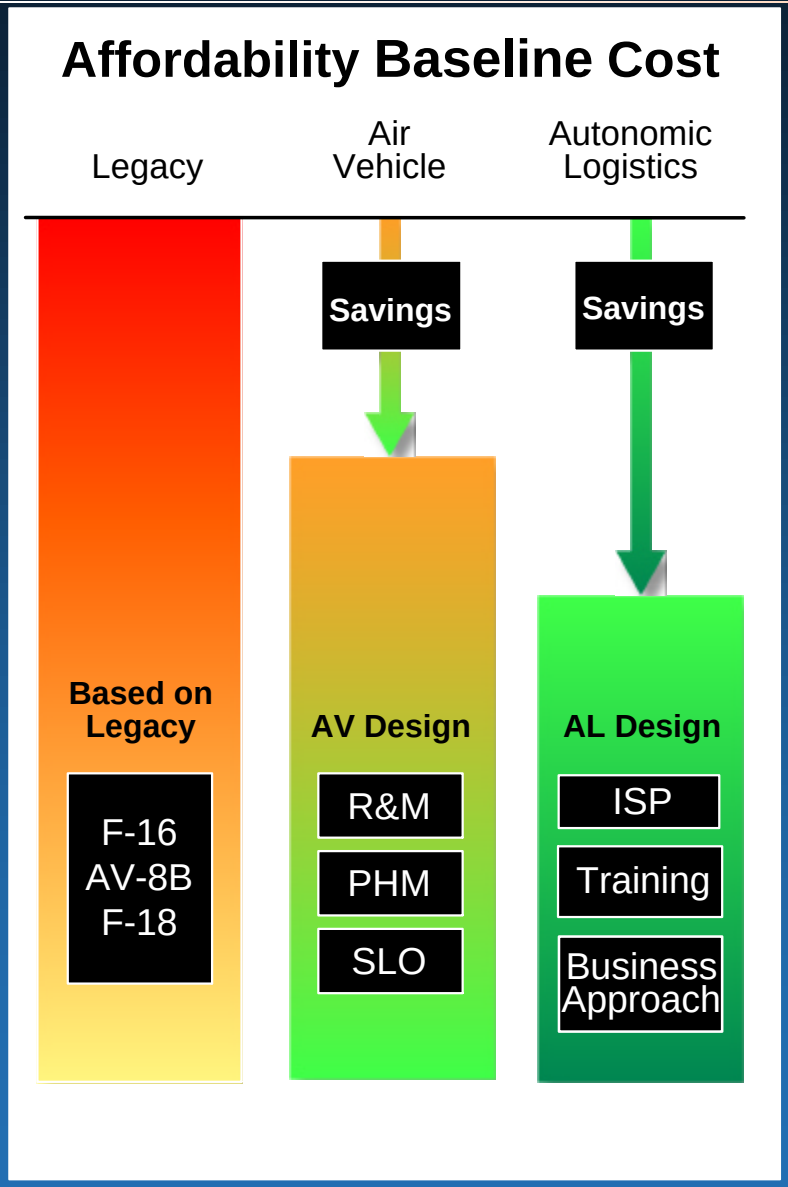


DoD has to reduce O&S costs

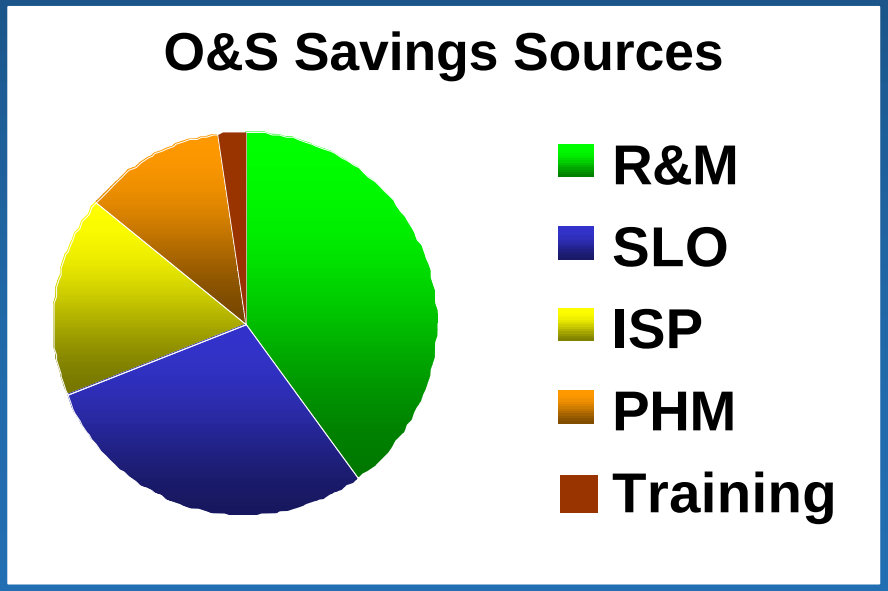
- AL Performance Requirements
  - *Logistics Footprint*
  - *Sortie Generation Rate*
  - *Mission Reliability*

Three of Eight KPPs are in AL

An Affordable, Integrated Solution



- **Prognostics and Health Management (PHM) is part of the affordable solution**
- **Training and Information Systems are also Logistics Elements**



JSF Autonomic Logistics System

Highly Supportable Aircraft

- Reliable Design
- Prognostics and Health Management
- Repair/Return (R/R) Maintenance

Training System

- Pilot Embedded Training
- On Demand Maintenance Training
- Air Vehicle Software Reuse
- Integrated Training

Support System

- Maintenance Support
- Supply Chain Management
- Support Equipment
- Joint-Service Tech Data
- Sustaining Engineering
- Intelligent Help Desk

Autonomic Logistics Information System

- Distributed Information System
- Elements include
  - Support Services
  - Training Services
  - Mission Support Services

Autonomic logistics provides order of magnitude O&S savings

The "Intelligent" Air Vehicle

PHM

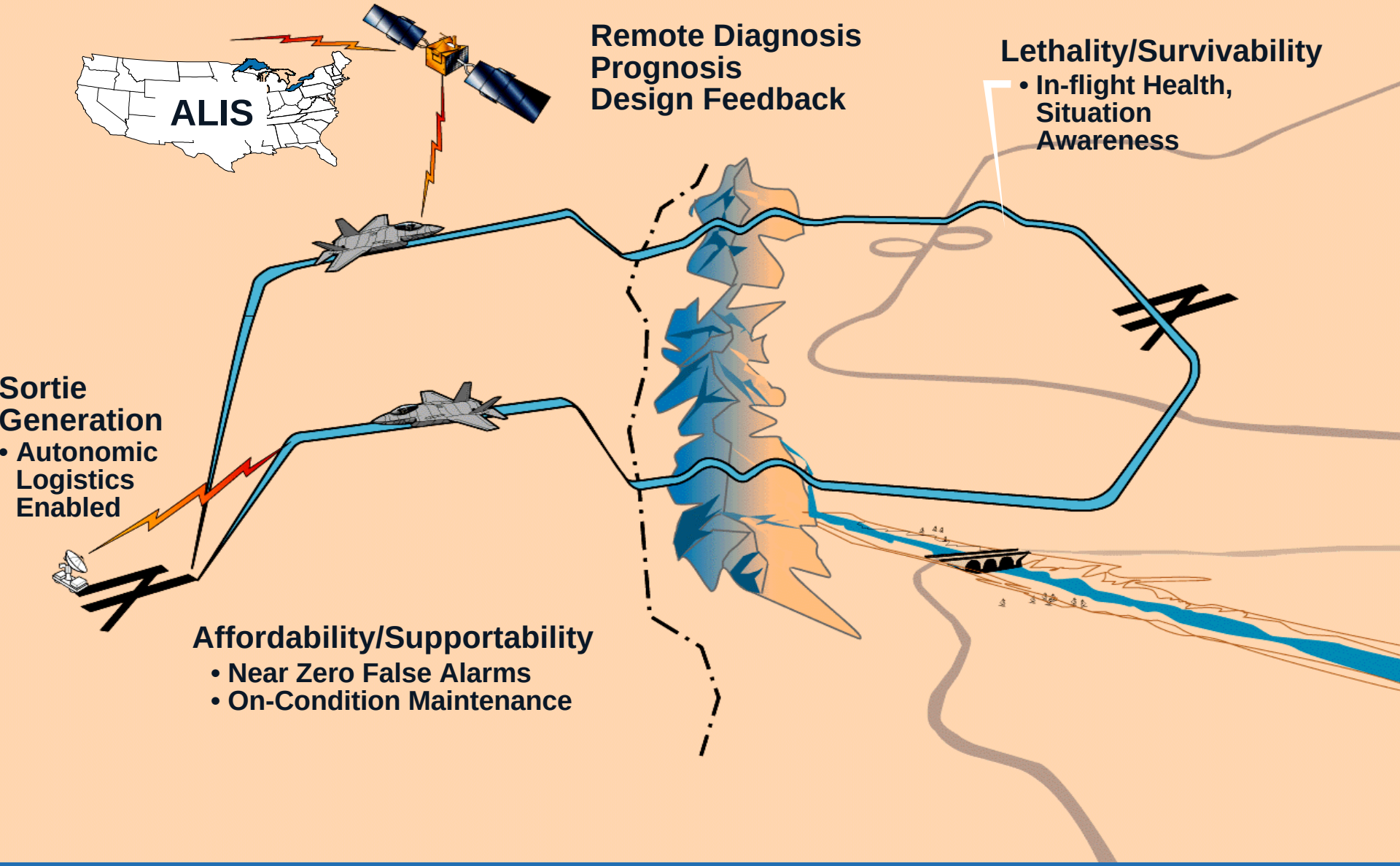
- Enables opportunistic and on- condition maintenance
- Eliminates troubleshooting
- Dramatically reduces CND/A799s
- Significantly reduces support equipment
- Reduces training required
- "Triggers" the Autonomic Logistics System

RM&S

- Reduces spares
- Reduces support equipment
- Reduces manpower requirements
- Allows skill level reductions
- Reduces training requirements

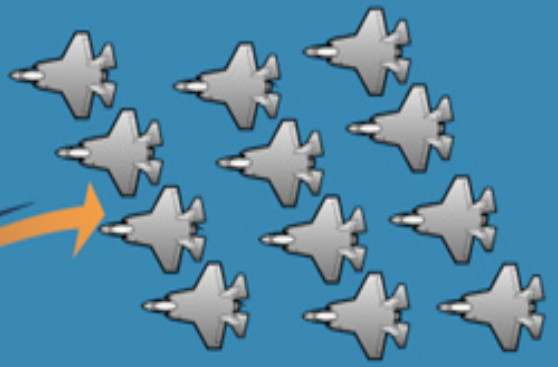
Design Interface – The First Step to O&S Affordability

On-Board PHM CONOPS



Off-Board PHM CONOPS

- 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

ALIS

Fleet Support

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

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

- Clear Faults
- Execute Test

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

Maintenance Interface Panel

Portable Maintenance Aid

Contractor

Supplier

J463500

PHM Architecture

Air Vehicle On-Board Health Assessment

Integrated Caution, Warning, and Advisory System

Propulsion

PHM Area Managers

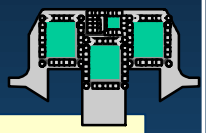
- *Vehicle Systems*
- *Flight Control Systems*
- *Utility Subsystems*
- *Structures*
- *Mission Systems and Subsystems*

Provides:

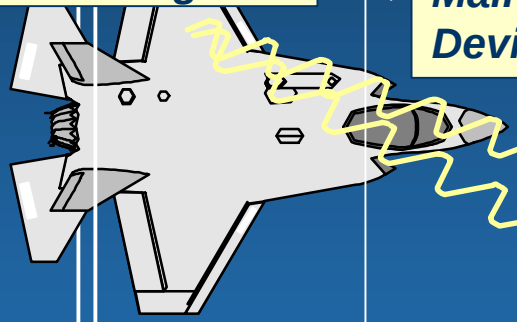
- AV-Level Info Management
- Intelligent Fault Isolation
- Prognostics/Trends
- Auto. Logistics Enabling/Interface

Health Management, Reporting & Recording

Non-volatile Crash Recorder

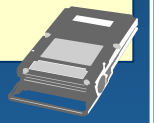


Air Vehicle PHM Manager



Displays & Controls

Portable Maintenance Device



Maintenance Interface Panel

Methods Used:

- Sensor Fusion
- Model-Based Reason
- Tailored Algorithms
- Systems Specific Logic / Rules
- Feature Extraction

Autonomic Logistics & Off-Board PHM

Results In:

- Decision Support
- Troubleshooting and Repair
- Condition-Based Maintenance
- Efficient Logistics

Portable Maintenance Aid

ALIS

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

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

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

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

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)

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

Benefits of PHM

Change of Maintenance Philosophy

- On-condition
- Opportunistic
- Not “on-failure” nor “per schedule”
- Less interruption of mission schedule

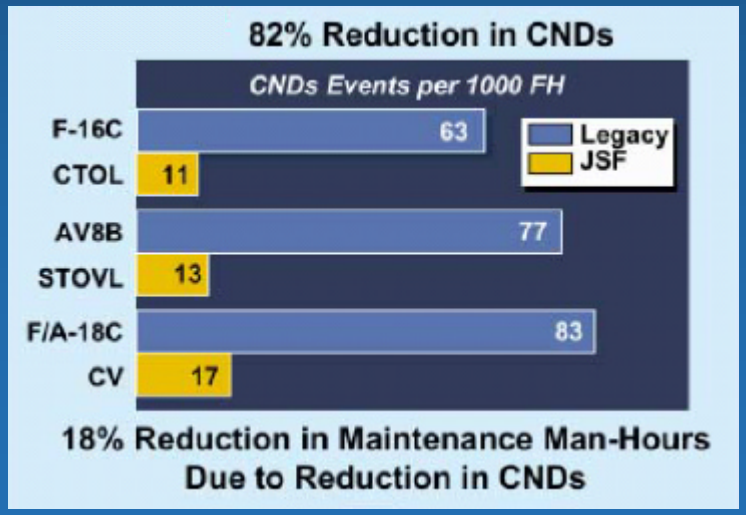
Benefits to the Maintainer

- Unprecedented insight into vehicle/squadron/fleet health
- Less time spent on inspections
- Better ability to plan maintenance
- Simplified training
- Improved fault detection

Reduction in Test Equipment

- Less intermediate and flight line TE
- 35% less peculiar support equipment during SDD
- Eliminated O-level TE:
  - *81 CTOL pieces*
  - *77 STOVL pieces*
  - *61 CV pieces*

PHM Cost Savings



ALIS Provides Off-Board PHM Support

ALIS Architecture

Interoperable With DoD/MoD External Systems
- Command & Control
- Maintenance
- Mission Planning
- Supply Support
- Training
- Transportation

Air System Interfaces
- Air Vehicle
- Training Devices

Autonomic Logistics Information System

Training Services | **Support Services** | **Mission Planning Services**

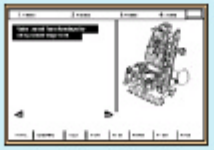
LM JSF Commercial Virtual Enterprise Infrastructure
- Product Data Mgmt
- Integrated Mgmt Framework
- Procurement

Status/Decision Support

Generate Maintenance Actions

Locate/Issue Parts

Training



Joint Tech Data

Analyze Health of Fleet

Autonomic Logistics Information System Concept
- Interoperable
- Affordable
- Effective
- Proven Processes
- Rationale Justifies Concept
- Achievable Software Development
- Open Architecture
- Meets Requirements

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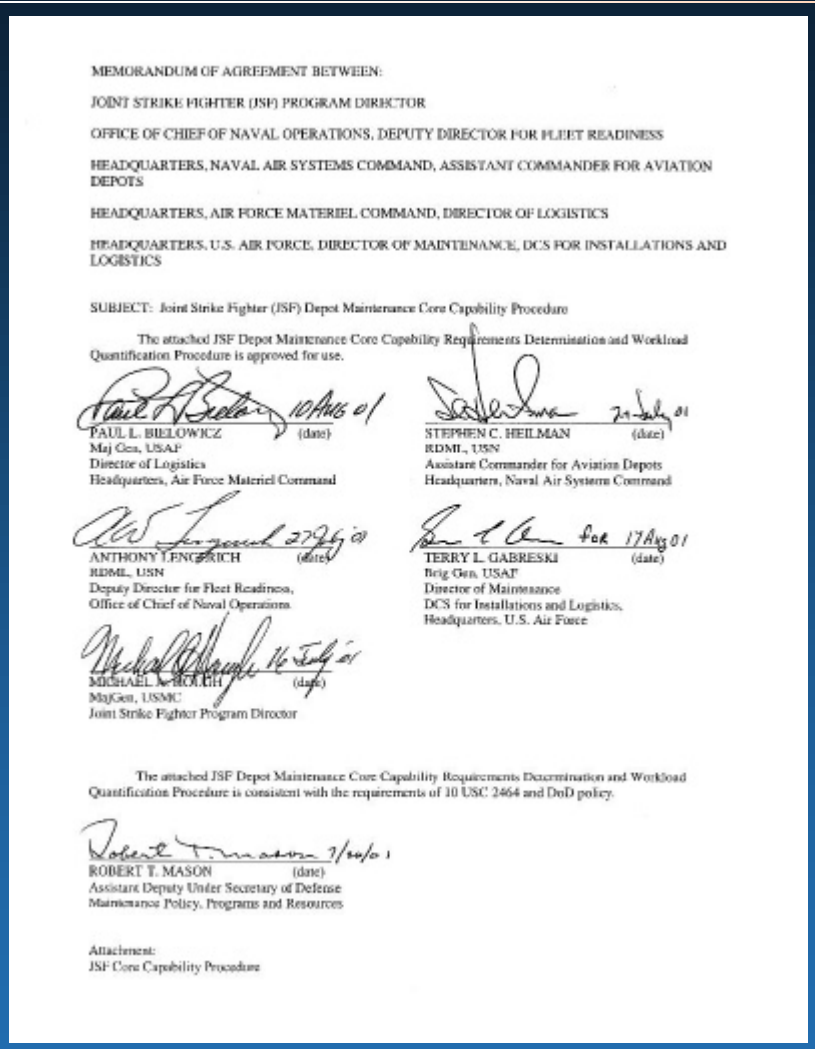
Supportive Business Processes



MEMORANDUM OF AGREEMENT BETWEEN:

JOINT STRIKE FIGHTER (JSF) PROGRAM DIRECTOR

OFFICE OF CHIEF OF NAVAL OPERATIONS, DEPUTY DIRECTOR FOR FLEET READINESS

HEADQUARTERS, NAVAL AIR SYSTEMS COMMAND, ASSISTANT COMMANDER FOR AVIATION DEPOTS

HEADQUARTERS, AIR FORCE MATERIEL COMMAND, DIRECTOR OF LOGISTICS

HEADQUARTERS, U.S. AIR FORCE, DIRECTOR OF MAINTENANCE, DCS FOR INSTALLATIONS AND LOGISTICS

SUBJECT: Joint Strike Fighter (JSF) Depot Maintenance Core Capability Procedure

The attached JSF Depot Maintenance Core Capability Requirements Determination and Workload Quantification Procedure is approved for use.

10 Aug 01
PAUL L. BIELOWICZ (date)
Maj Gen, USAF
Director of Logistics
Headquarters, Air Force Materiel Command

24 July 01
STEPHEN C. HEILMAN (date)
RDML, USN
Assistant Commander for Aviation Depots
Headquarters, Naval Air Systems Command

27 July 01
ANTHONY LENGERICH (date)
RDML, USN
Deputy Director for Fleet Readiness,
Office of Chief of Naval Operations

for 17 Aug 01
TERRY L. GABRESKI (date)
Brig Gen, USAF
Director of Maintenance
DCS for Installations and Logistics,
Headquarters, U.S. Air Force

16 July 01
MICHAEL A. HOUGH (date)
MajGen, USMC
Joint Strike Fighter Program Director

The attached JSF Depot Maintenance Core Capability Requirements Determination and Workload Quantification Procedure is consistent with the requirements of 10 USC 2464 and DoD policy.

7/24/01
ROBERT T. MASON (date)
Assistant Deputy Under Secretary of Defense
Maintenance Policy, Programs and Resources

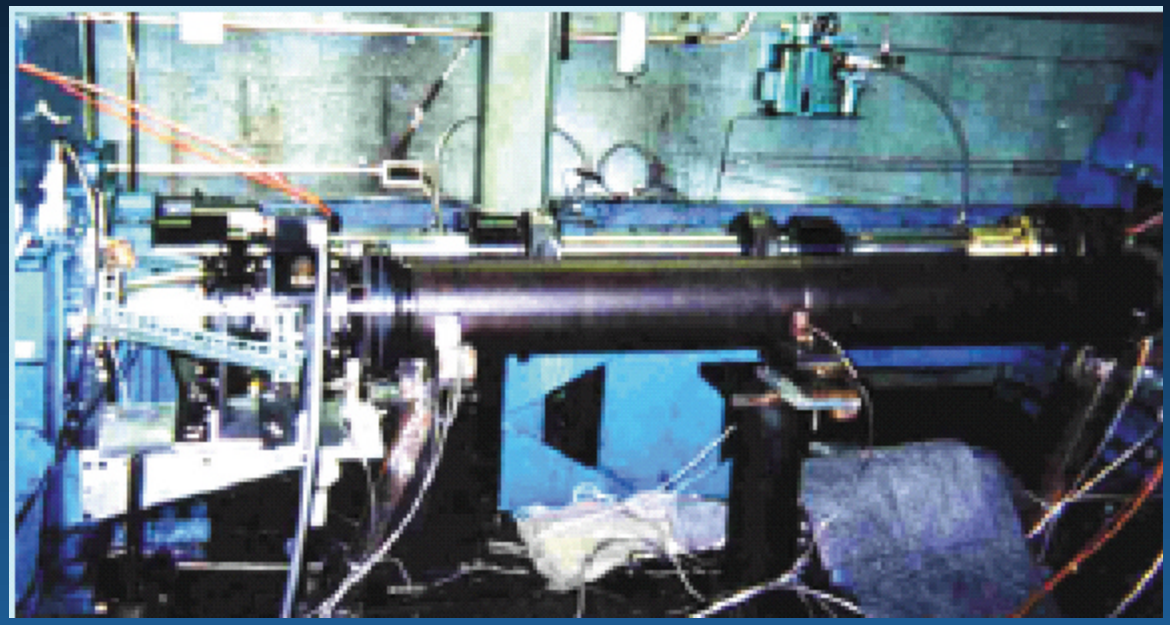
Attachment:
JSF Core Capability Procedure

- **Joint Depot Maintenance Core Capability Requirements Determination and Quantification Procedure**
- **Joint Depot Source of Repair Determination**
- **Partnering with Depots**
- **“Power-by-the-Hour” Performance-based Logistics Contracting**
- **Supply Chain Management**


Joint Strike Fighter
Questions?

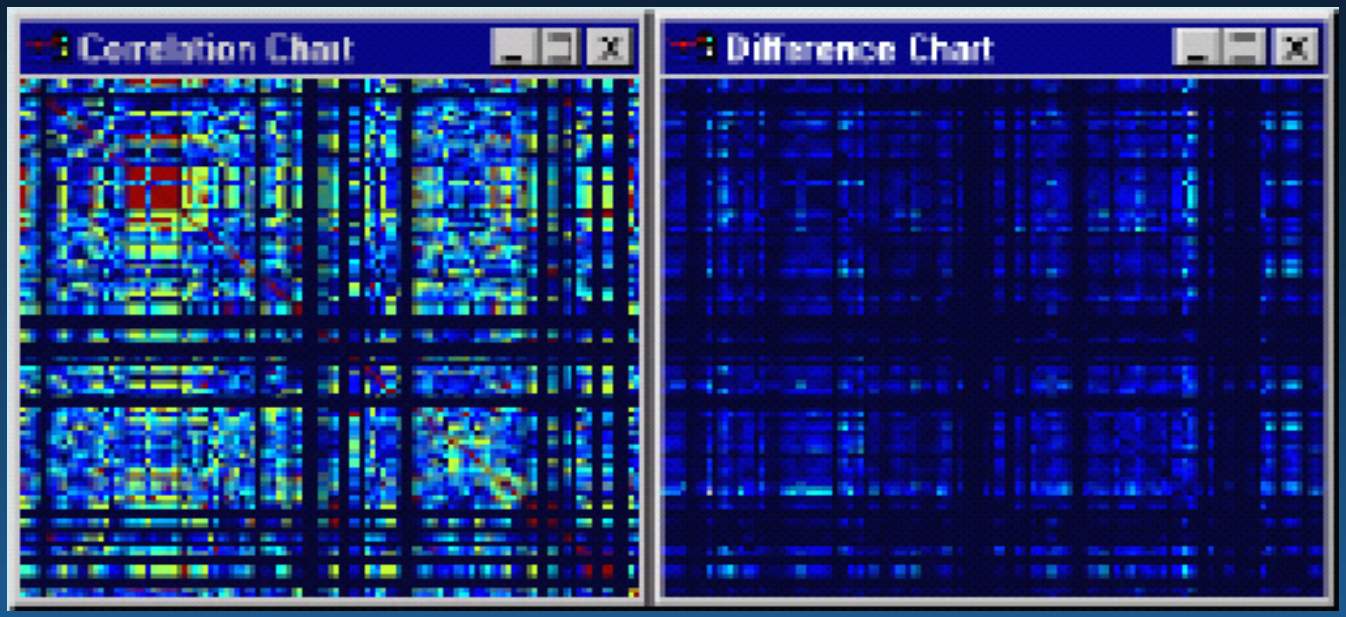
Backup slides

Lift Fan Shaft Alignment Demo



- Health assessment of engine and lift fan
- Non-contact sensors
- Measured 50 out of 50 within required accuracy (+/-0.2 degree)

Beacon-Based Exception Analysis for Maintenance (BEAM)

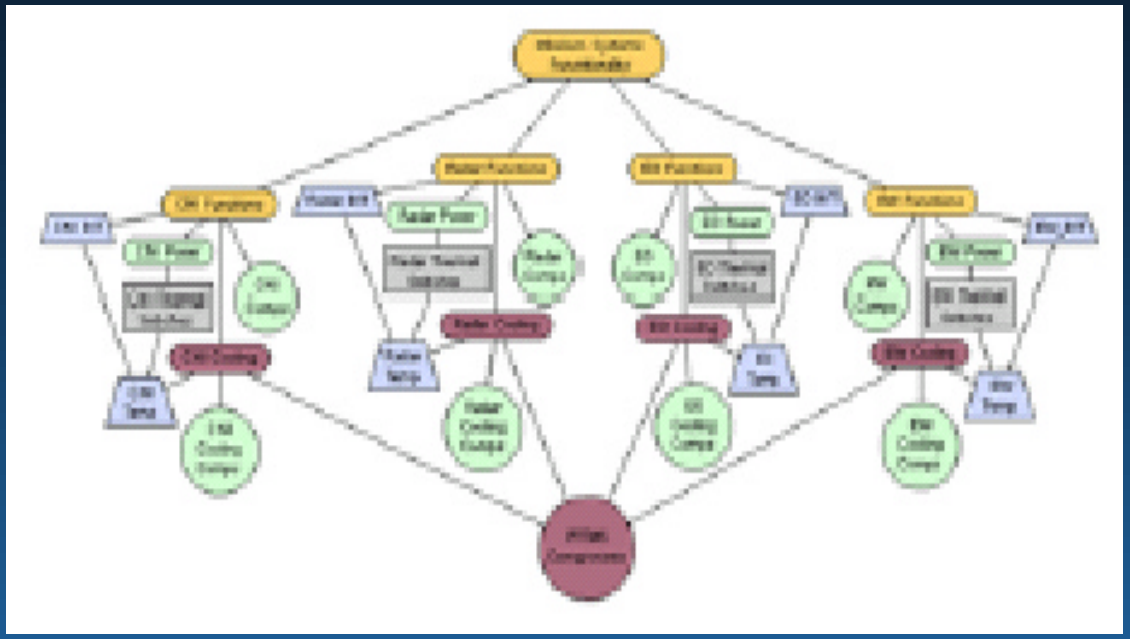


- **BEAM Technology developed and demonstrated at Jet Propulsion Laboratories (JPL), applied to JSF**
- **Provides failure detection and isolation**
- **Fusion of complex inputs - combines**
  - ***Advances in wavelet theory***
  - ***Non-linear information filtering***
  - ***Neuro-fuzzy systems identification***
  - ***Stochastic modeling***

Rotational Machinery Prognostics

- Combines vibration analysis techniques with data fusion
- Detects and assesses equipment damage
- Predicts remaining component life
- Demo showed that impending lift fan failure can reliably be detected in time to avert catastrophe

Model Based Reasoning



- Prognostics Not Diagnostics
- Redundancy management
- Demonstrated on
  - *Engine*
  - *Radar*
  - *Fuel system*

- Fusion of diagnostic information using intelligent system techniques
  - *Fault and degradation detection*
  - *Fault confirmation*
  - *Enhanced isolation*
  - *Cross-system correlation*
  - *Evaluation of AV functional capabilities*