# Prognostics Based Health Assessment System Approaches

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# VSE Corporate Overview

- Established in 1959
- Public company (NASDAQ:VSEC)
- Headquartered in Alexandria, Virginia
- ISO 9001:2000 registered
- Provides worldwide support through diversified engineering, technical, logistics, management, and information technology services to maintain and modernize equipment and systems
- Principal clients are agencies of the U.S. Government and other government prime contractors

# Prognostics? What is That?

- Prognostics is an engineering discipline focused on predicting the future condition of a component and/or system of components.
- In most cases, prognostic approaches are based on the analysis of failure modes, detection of early signs of wear, and correlation of these signs with an aging profile (or model).
- Technical approaches to prognostics can be categorized broadly into reliability driven and conditioned based approaches.
- The VSE approach to Prognostics Based Health Assessment incorporates both reliability and condition based methodologies.

# An Example of VSE's Prognostics Based Health Assessment Systems

- **F/A-18 Automated Maintenance Environment**
  - **Integration of system maintenance resources and configuration data and into an integrated system**
    - **Diagnostics •Prognostics • Health Management**
    - **Operator Debrief**
    - **IETMs**
    - **Life Usage Tracking**
    - **Asset • Configuration Management / Serial Number Tracking**
    - **Interfaces to Supply Chain and Maintenance Management Systems**

# VSE AME Concept

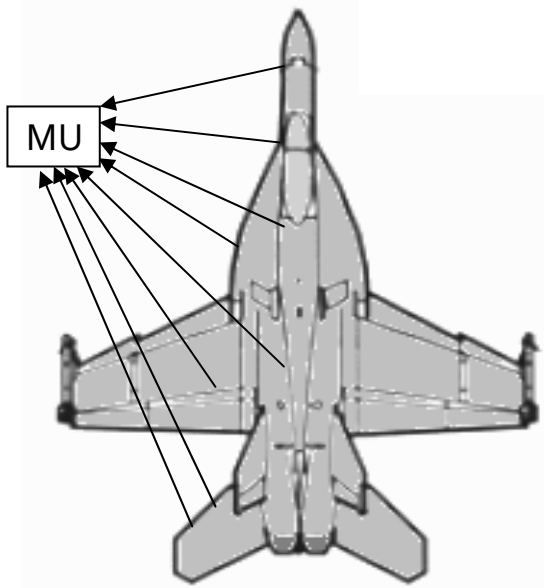
- AME is first instance of a geographically distributed information system that...
  - Supports strategic maintenance planning at
    - Headquarters
    - Each support level
    - Front line tactical maintenance operations
- Open system integrating framework
  - Software backplane that uniquely supports maintenance workflow and the Application Programming Interfaces (APIs) for plug-and-play software
  - Enables continuous use of “best of breed” COTS components
- Generalized APIs that are not system-specific

# F/A-18 Sensors & Built-in Test (BIT) Provide Foundation

Each individual sub-system has it own diagnostics, BIT or health monitoring capability.

BIT is fully integrated digitally via the primary data bus.

The BIT data is recorded and stored. Data is available by a removable memory storage unit.



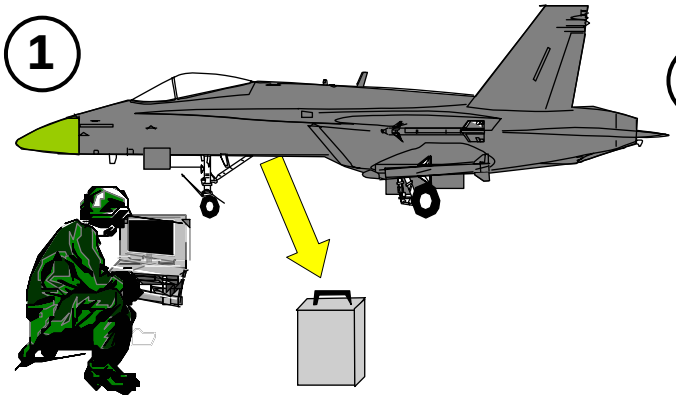

Mechanical, Pneumatics, Hydraulic, Engines, Structure, & Environment Systems are monitored via analog sensors.

The analog signals are converted to digital and used to verify, monitor, control and ensure optimum system performance.

All BIT, Go/No-Go, and self test data is transmitted via the data bus and recorded to the removable memory unit.

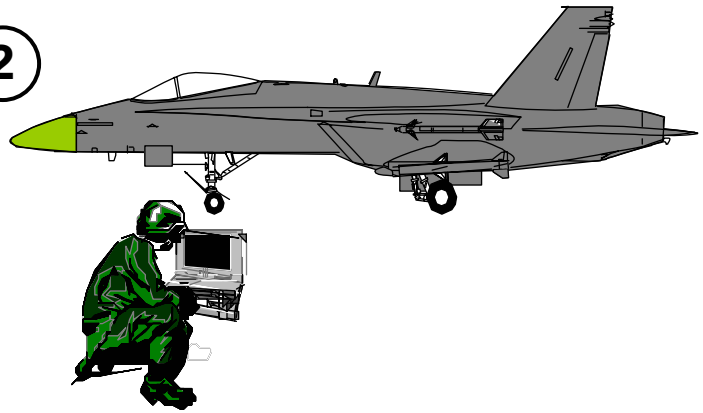
# AME Work Flow

1



Pilot initiates data stripping.

2

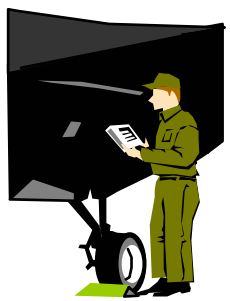


Pilot performs debrief.

3

Work Center Supervisor assign tasks.

4



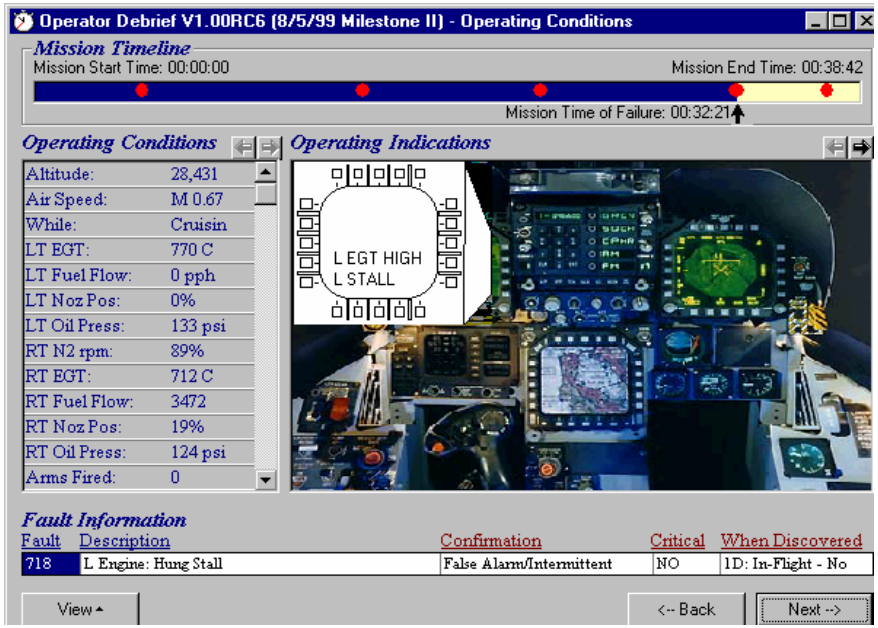
Technician performs repair procedure using IETM.

5

Materiel Control transfers item to Supply / I-level

# Debrief Logs any Additional Discrepancies

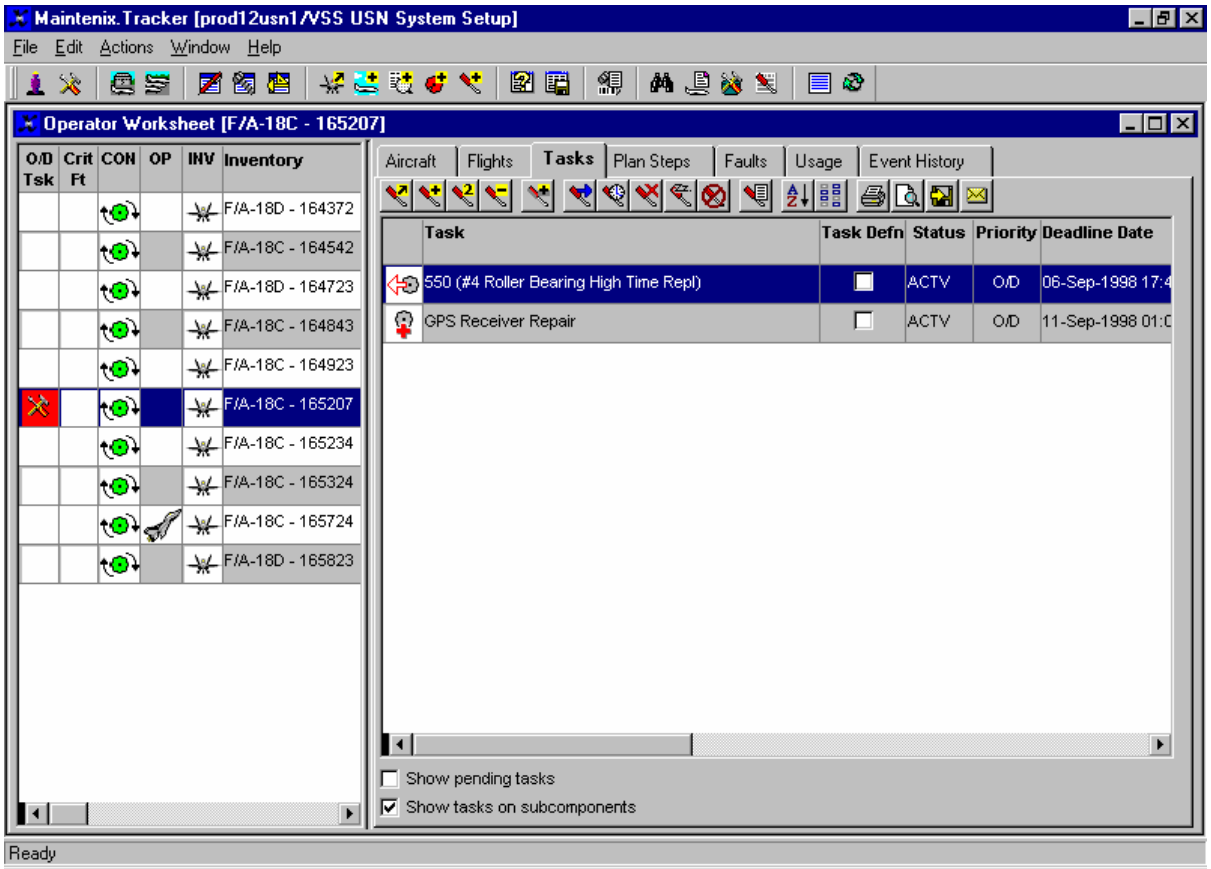
- The pilot reviews the faults identified by the expert system and adds any other discrepancies




- Maintenance tasks are passed to Maintenance Management Database

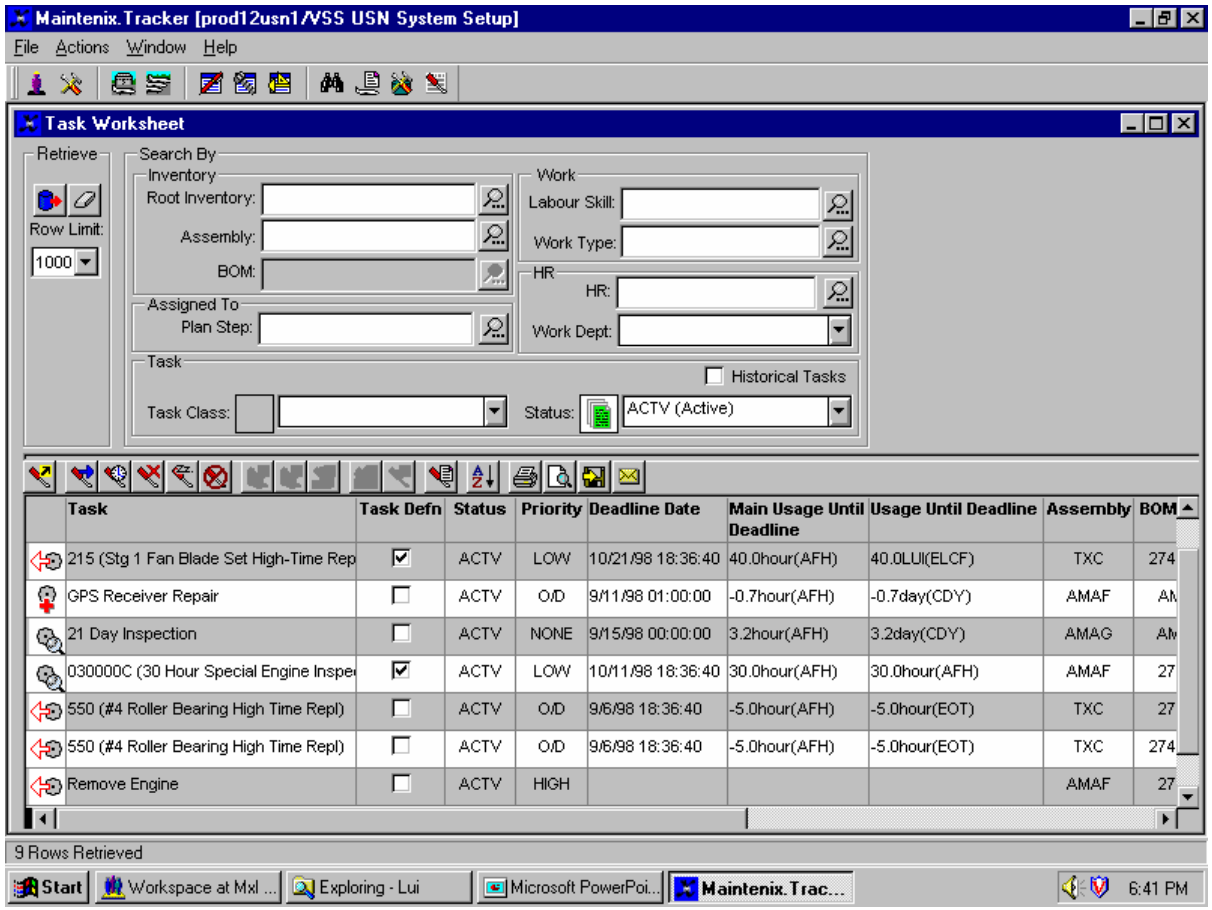
# Maintenance Alerted to Aircraft Caution

- The aircraft is shown with overdue tasks
- The maintenance tasks are shown
  - Debrief task is to repair GPS receiver *(Condition Based)*
  - The LUI increase has caused an engine turbine to go 'high-time', requiring an engine removal *(Reliability Based)*



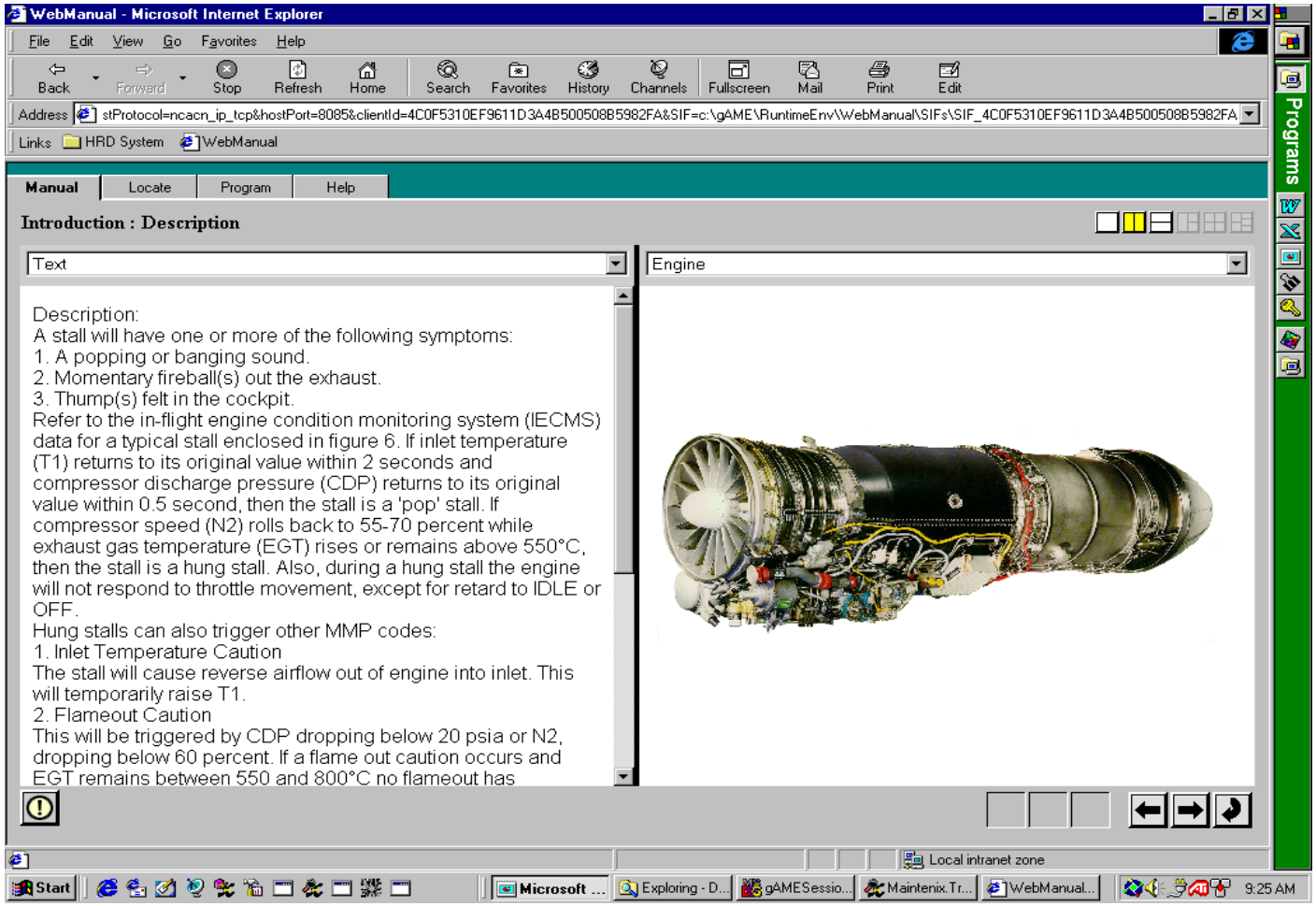

# Identify Maintenance Tasks

- System shows all upcoming work for the squadron to Maintenance Control
  - Work can be sorted to facilitate planning
- Maintenance Control initiates maintenance actions based on the identified tasks



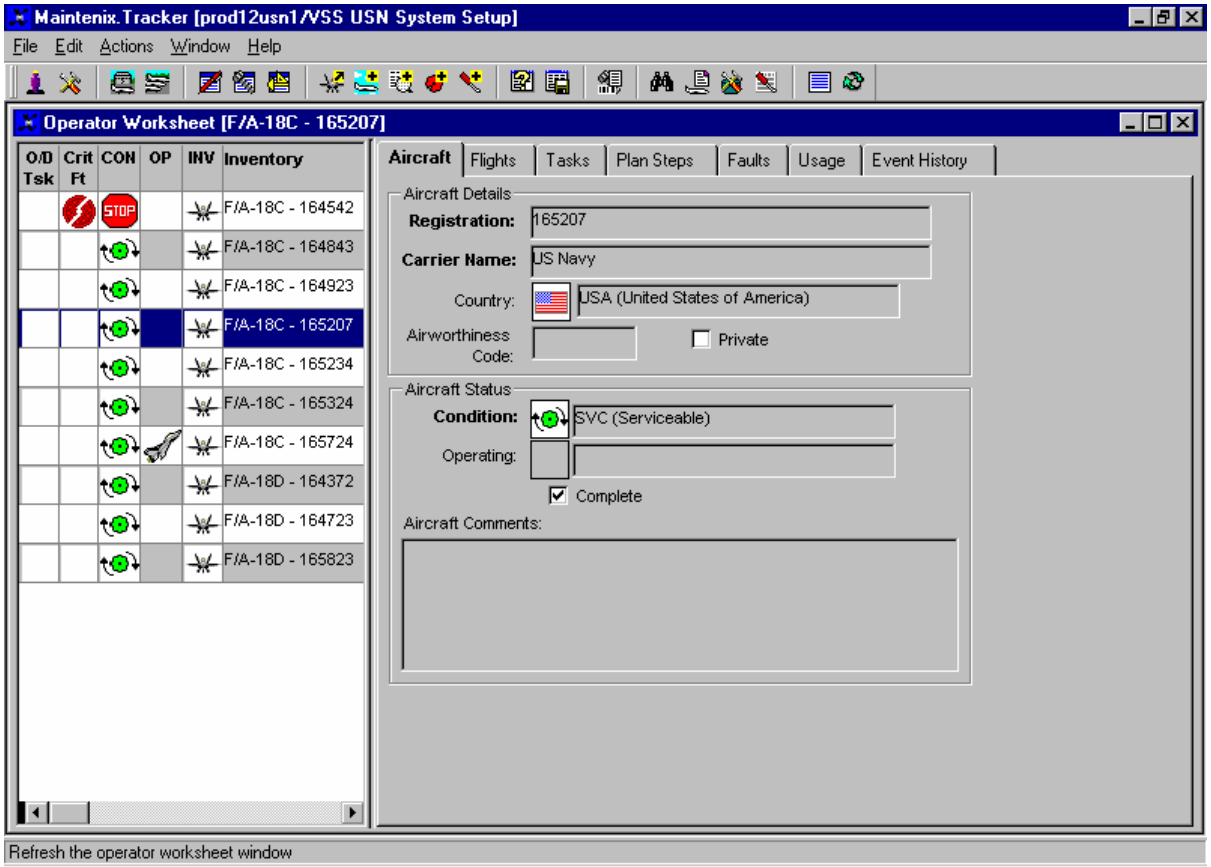

# Execute Maintenance Tasks

- The maintainer takes the PEDD/PMA out to the aircraft and uses the IETMs while executing the maintenance tasks



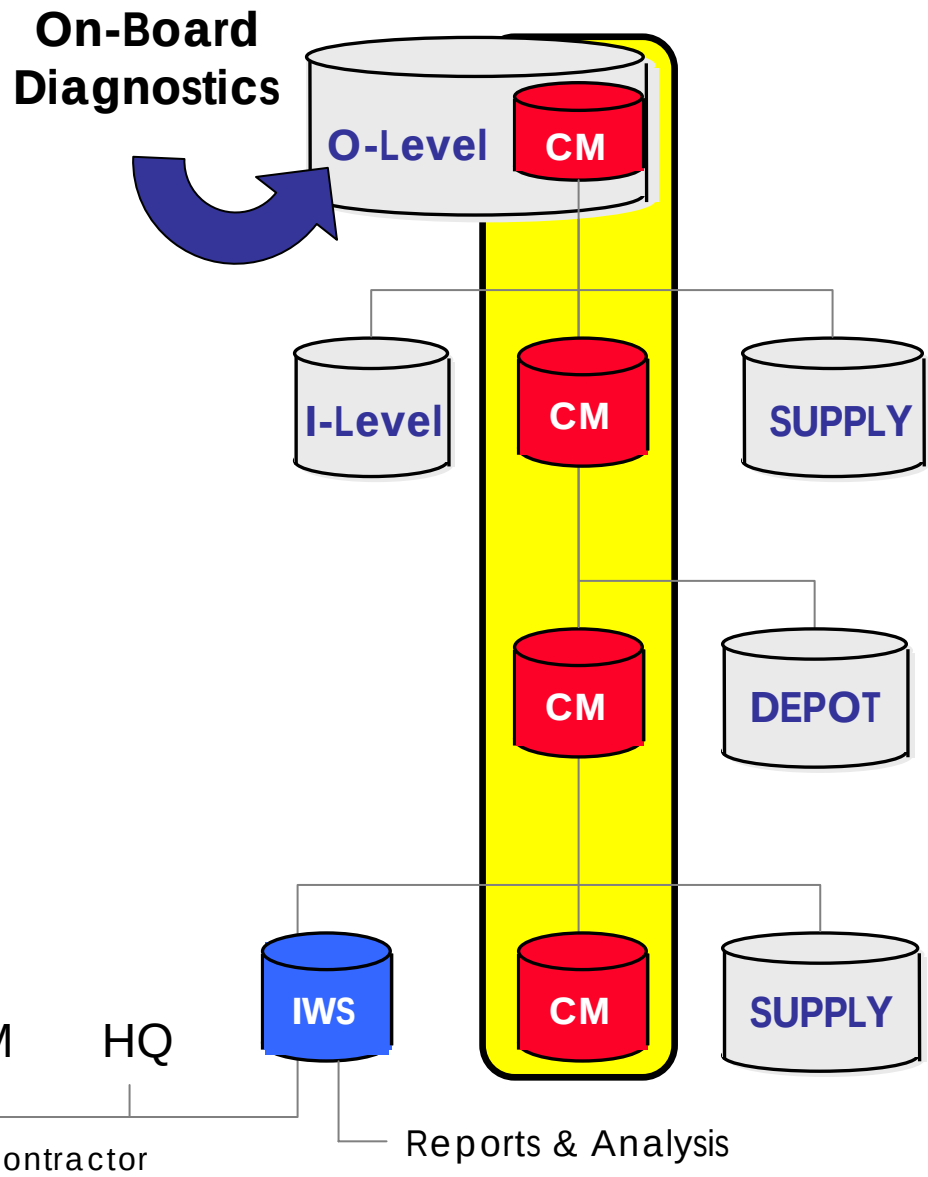

# Aircraft Status is updated

- The PEDD/PMA upload installed the new engine in the aircraft logset
- The Status Board now shows the aircraft as ready to fly




# AME Vertical Integration

- **Integrated environment linking maintenance and OEMs**
  - Accurate feedback to Logistics Support re: fleet status
  - Rapid and accurate deliveries of Maintenance Plan updates
- **Total Asset Visibility including O-Level activities**
  - PM can 'see' the demand for parts and other resources and properly trigger the Supply Chain
- **Modular components**
  - Can rapidly install on a component by component basis
- **Deployable**
  - Can fully operate in remote locations with no operational impact
  - 24/7 Global User Support

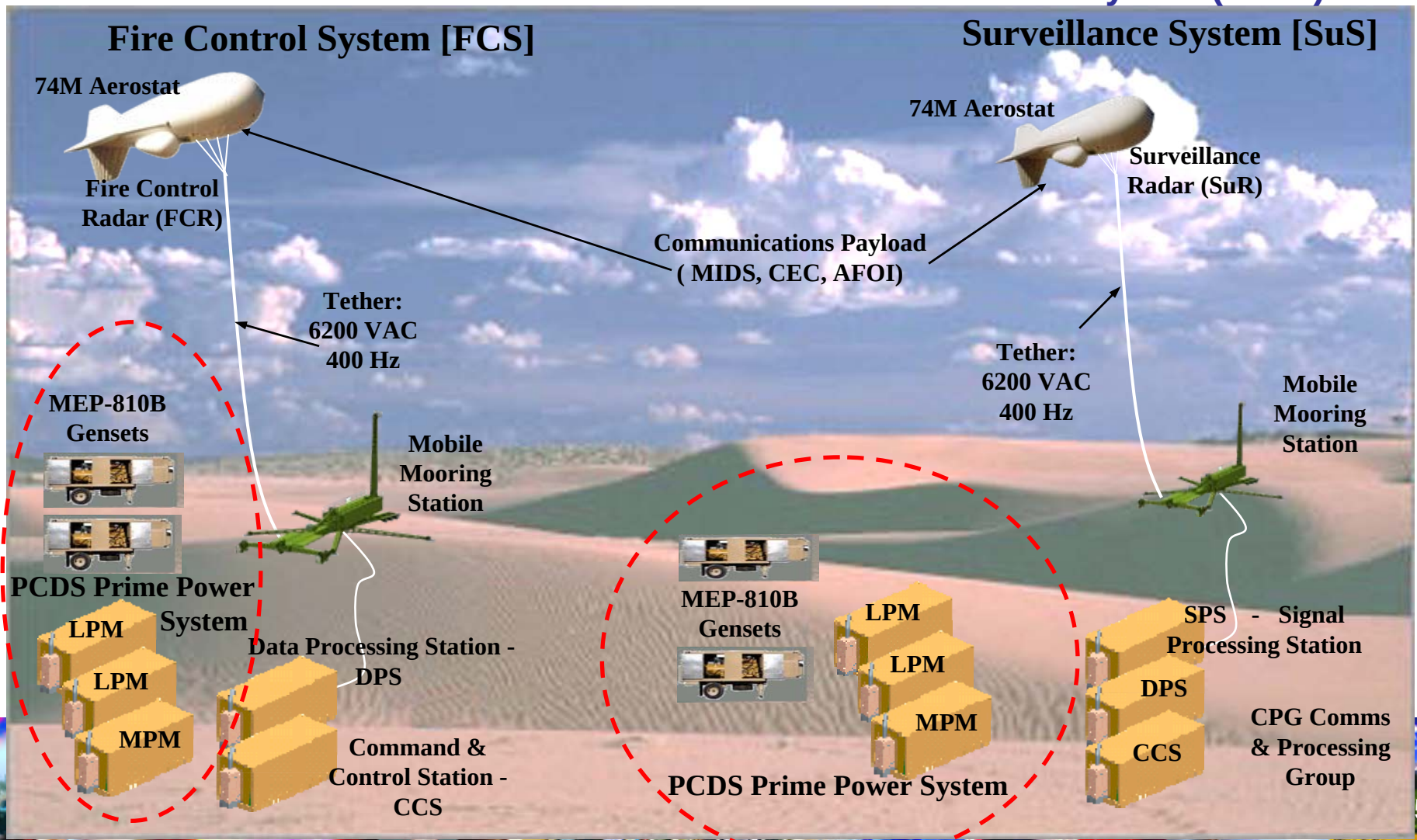


# AME Benefits

- **Increased Operational Availability**
  - IT-related improvements have increased F/A-18 Readiness by 8%
  - Significantly improved understanding of current status
  - Improved maintenance efficiency via comprehensive and accurate diagnostics
  - Ability to capture and use status information for maintenance and supply actions
  - Improved supply chain management based on knowledge of in-field demand for resources
  - Provides timely & accurate data for logistics analysis
- **At Reduced Cost**
  - More than $1B cost savings over the past decade
  - More efficient maintenance labor execution
  - Improved asset utilization
  - Significantly fewer good or unknown items floating through supply

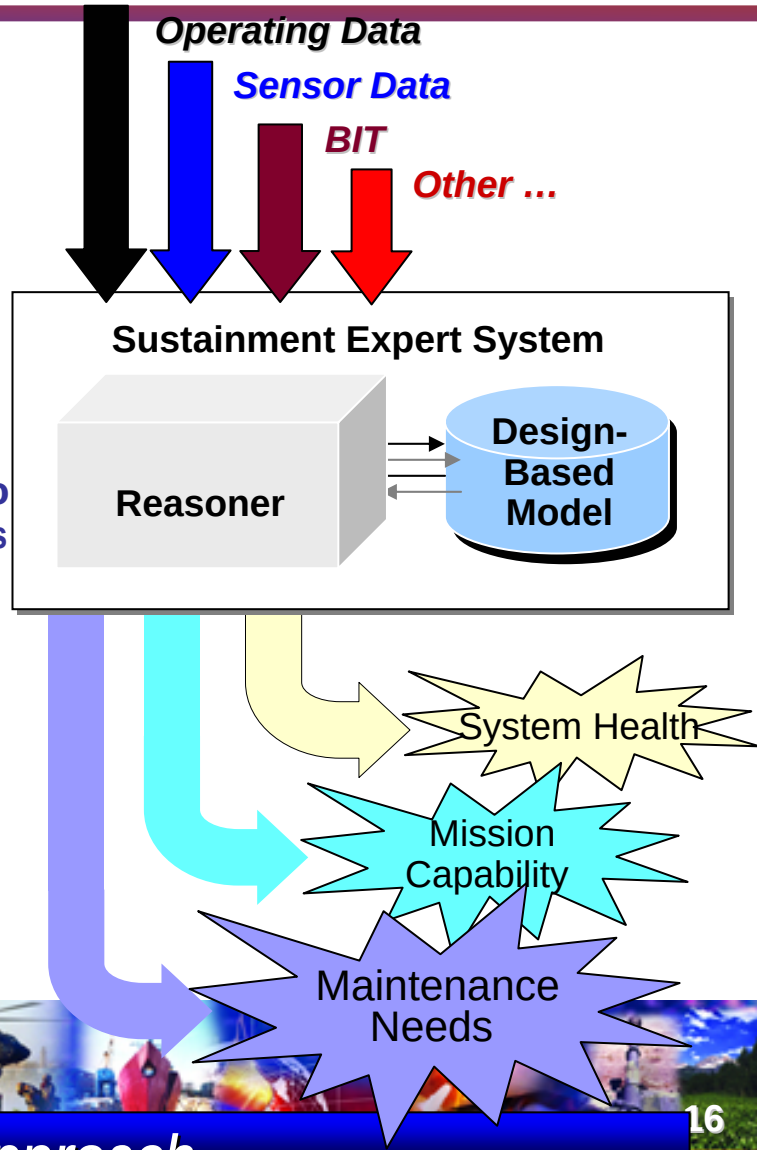
# Another Example of VSE's Prognostics Based Health Assessment Systems

## Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS)



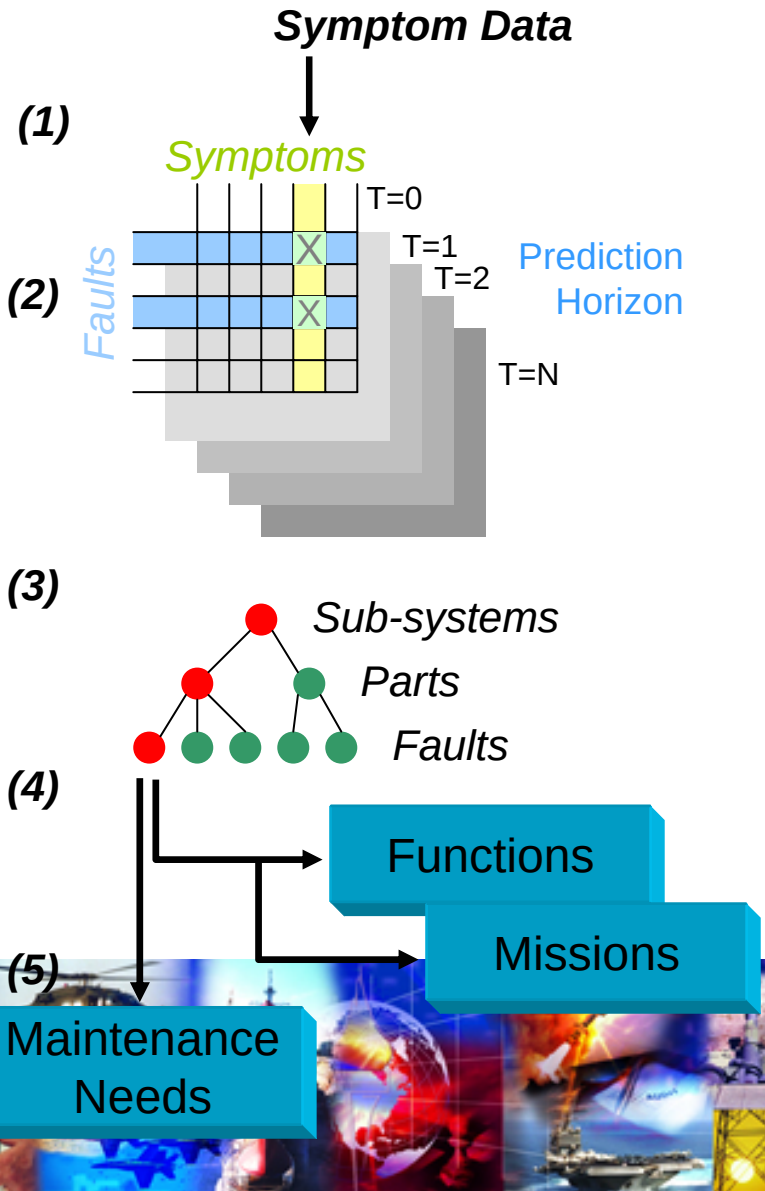
# Prognostics Framework Reasoning

- **Expert System using Model-Based Reasoning**
  - Uses design-based model for diagnostics/prognostics
  - Is deterministic model using "first principles" of design
  - Reasons by dynamically interpreting the inference of data
  - Reads streams of data from variety of sources
  - ☑ Interprets sensors, built-in test and operational data; to assess system health, predict, detect and isolate faults
  - ☑ Results in health monitoring, diagnostics ***and*** prognostics
  - ☑ Can be embedded (on-line, real-time) or off-line
  - ☑ Can be used on existing or new systems
  - ☑ Replaces traditional fault/logic tree



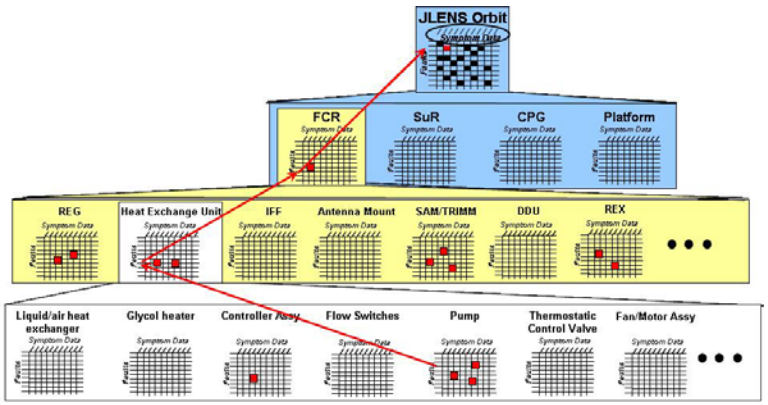
# Achieving Design-Base Comprehension

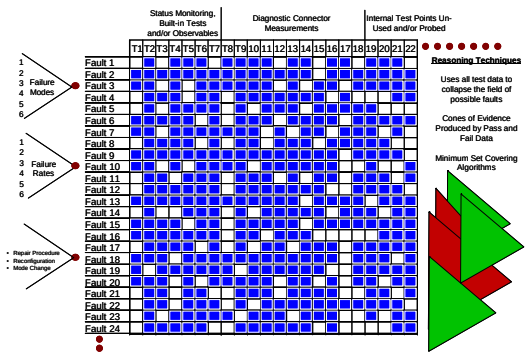
1. Accept operational data, sensor, BIT and parametric data as symptoms
2. Apply reasoning algorithms to predict & diagnose the implication of out of tolerance symptoms on each future time point defined in the model
3. Identify the components and sub-systems affected by predicted failures - **sub-system health**
4. Identify the functions and missions affected by predicted failures - **mission readiness**
5. Identify the repair actions needed - **anticipatory maintenance**

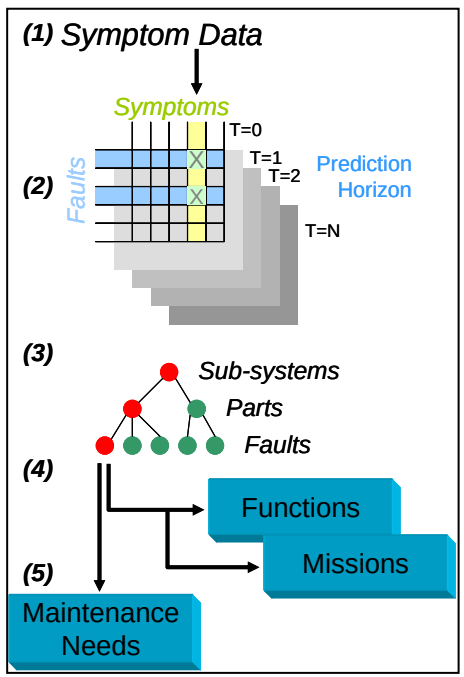


# Diagnostic/Prognostic Reasoning

- **Build a System Model to reflect system hierarchy**
- **Map fault propagation and test coverage in a Fault/Symptom matrix**
- **Correlate actual test data with faults across system hierarchy *(Intelligent Reasoner)***



# System Model Scope

## DESIGN DATA

- Definition of Parts, Faults, Failure Modes, Failure Rates, Tests, Interconnectivity and Test Coverage

## SYSTEM DATA MANAGEMENT

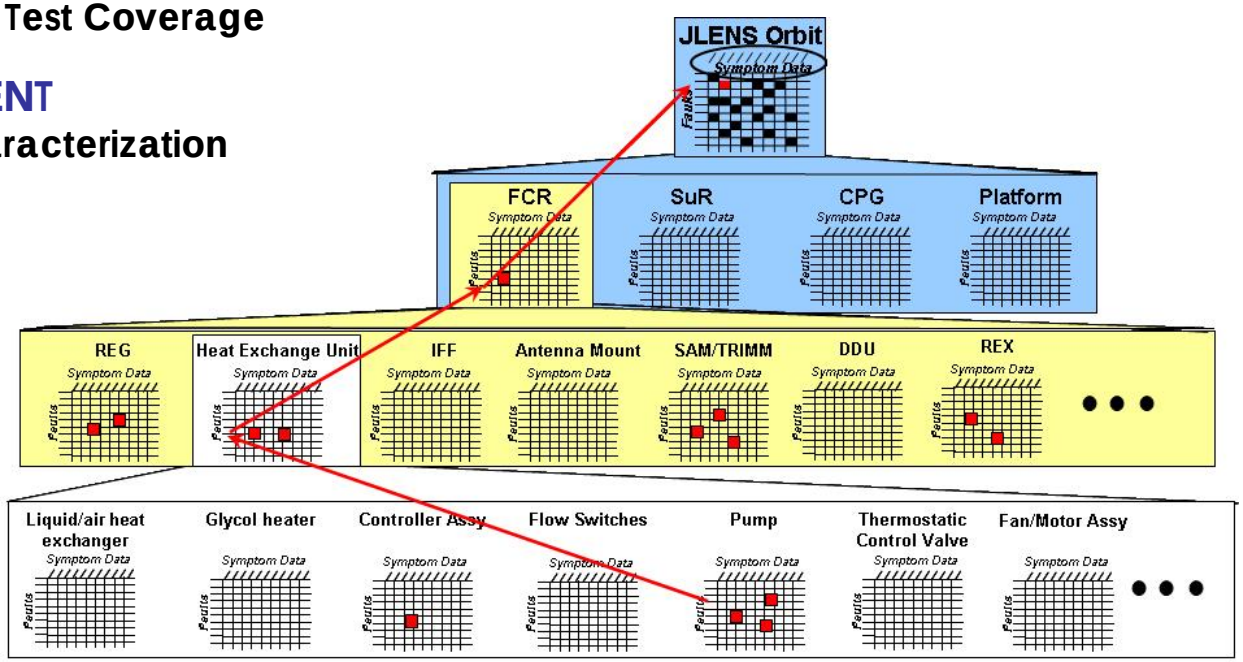
- Input Data Definition & Characterization
- Prediction Horizons

## TEST/SENSOR DATA

- BIT Inputs & Mapping
- Sensor Data & Mapping

## HEALTH MANAGEMENT

- Detection Algorithms
- Diagnostic Coverage
- System Stress Factors
- Prediction Algorithms
- Fault Criticality
- Input Data Processing & Filtering
- Confidence Factors




## MISSION SUPPORT

- Mission Profile
- Function Correlation to Mission Phases
- Function Criticality to Mission
- Immediate Operator Actions

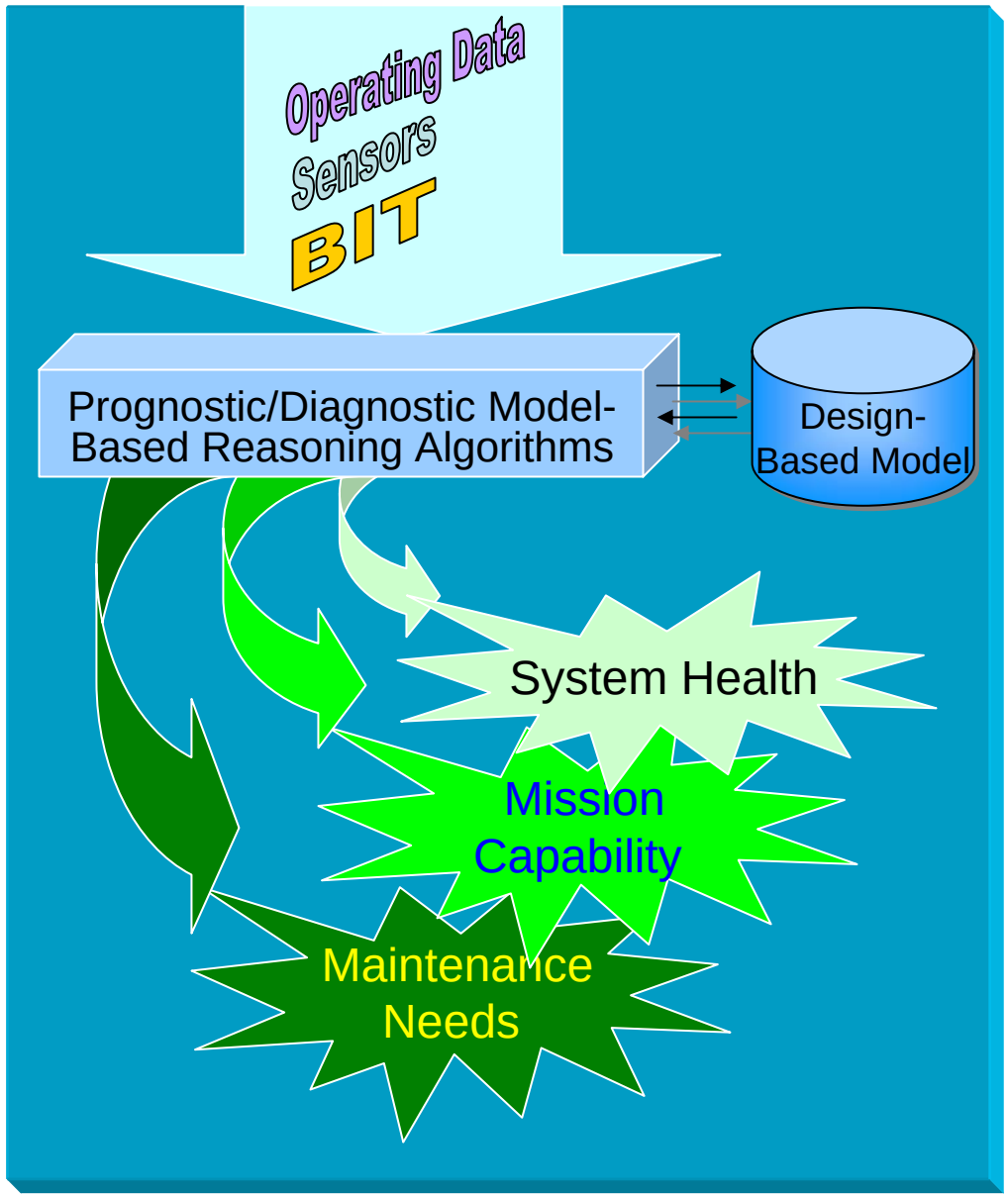
## MAINTENANCE SUPPORT

- Repair Item Definition
- Combinations of Repair Items
- Repair Actions (IETM Interface)
- Parts Ordering Data
- PMCS Triggering and Tracking

# Diagnostic/Prognostic Reasoning

- **Model-based reasoner maximizes the information gained from sensors and built-in test**

- **Diagnostic / Prognostic Reasoner**
  - **Identifies stress and wear factors**
  - **Detects and interprets anomalies**
  - **Determines mission capability**
  - **Serial Number Tracking - Determines remaining useful life of each item**
  - **Performs condition-based prognostics**



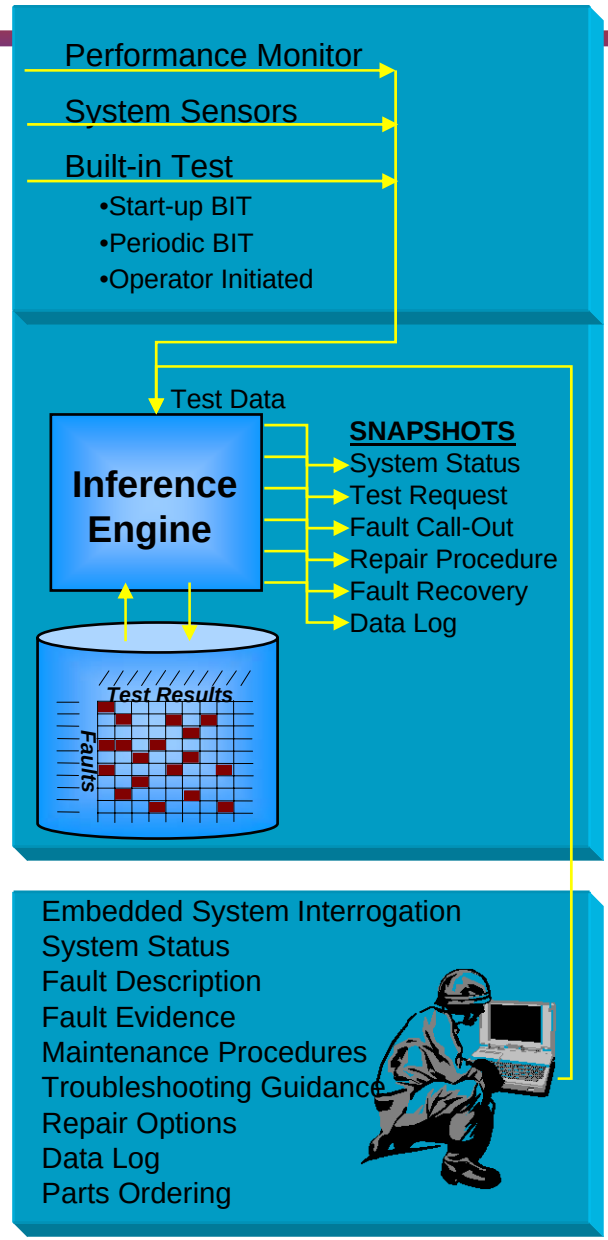
# "Dynamic" Diagnostic Capability

- **Test Results can be input**
  - **... in any order**
    - no pre-set sequence
  - **... from any source**
    - operator observations, test instruments, data bus, data file, built-in test, automatic test equipment, system panels & displays, etc.
  - **... as many as test source(s) can provide**
    - not restricted to one-at-a-time to traverse fault tree
    - zeroes-in on cause of fault(s)

- **Can identify multiple faults**
  - ... Diagnostic trees follow single-fault assumption

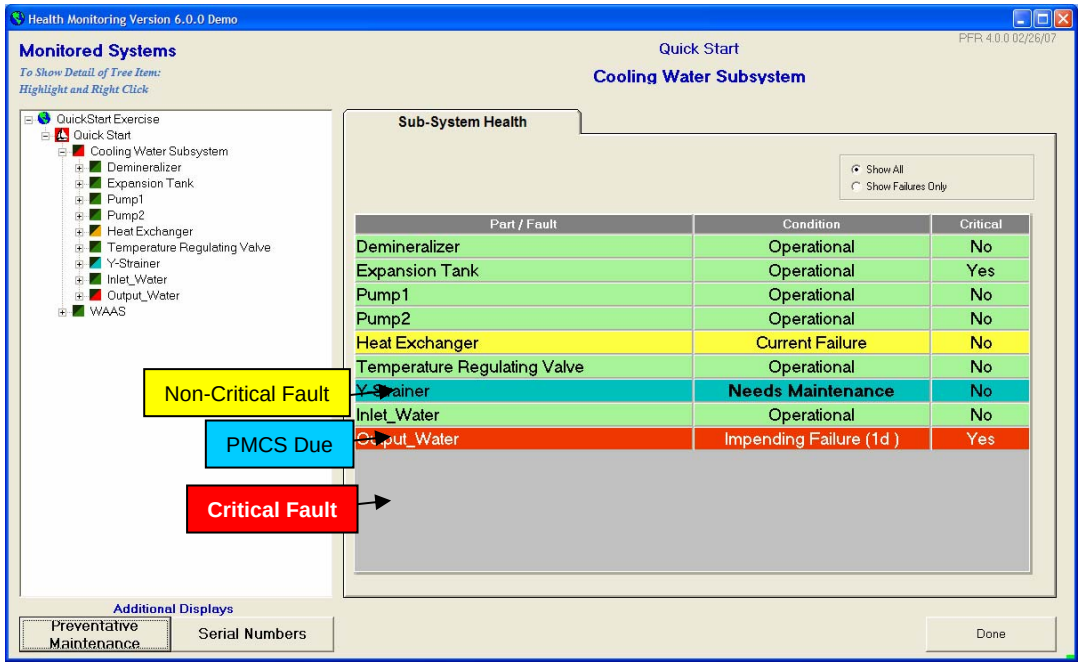
- **Will always zero in on fault**
  - ... Never leaves the technician hanging

- **Only requests tests of diagnostic significance**
  - ... Based upon snapshot of current fault possibilities



# Prognostics Based Health Assessment Functionality

- **Integrates diagnostic/prognostic results into a Health Management System**
- **Makes maximum use of existing Sensor/BIT data**
- **Provides Prognostics Analysis/Reasoning**
  - Degradation of signals/measurements over time
  - Depletion of consumable items
  - Accumulates wear factors
  - Engineering correlations
  - Tracks preventive maintenance based on time/wear/use
  - Serial number tracking
  - Remaining Useful Life



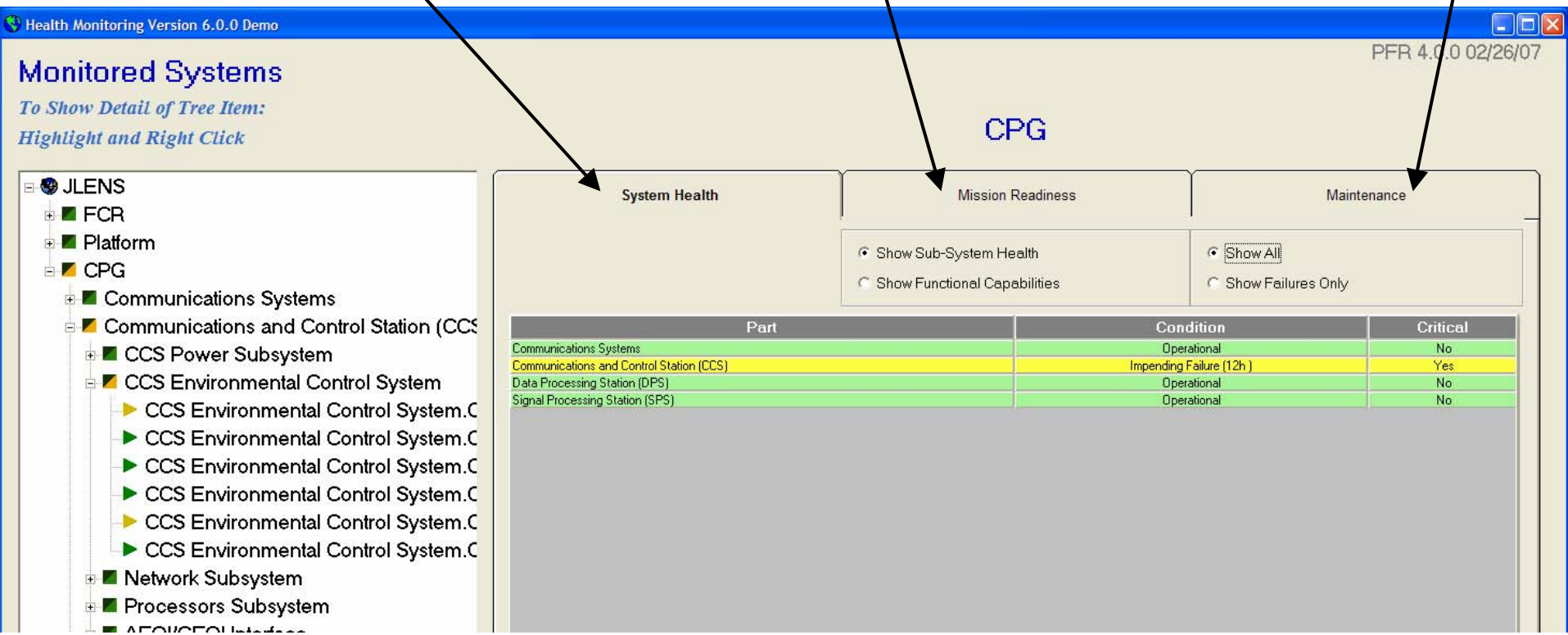

- **Allows for integration of 3rd party prediction techniques**
- **Compiles, interprets and displays trend data**
- **Creates multiple log files**
- **Links to maintenance systems (IETM, PMCS, Supply) based on specific fault**

# 3 Views into Health Data

**Operator – Am I OK? If not, why not? What do I do?**

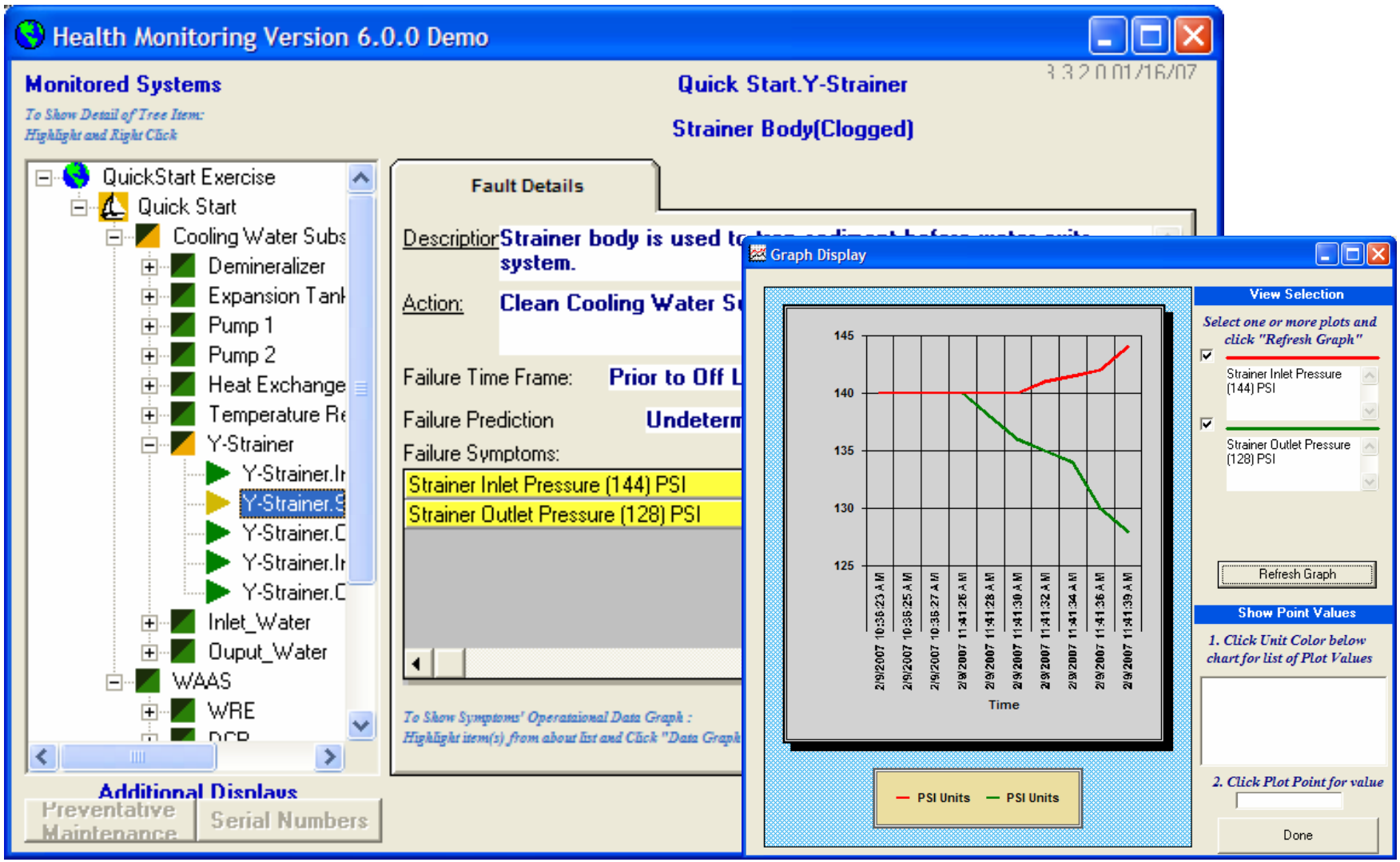
**Mission Commander – Will this system make it through mission without failure? Which of my systems will make it through the mission?**

**Maintainer – What repairs need to be made? What spares do I need to make the repairs? What are the repair procedures? What PMCS is currently due?**



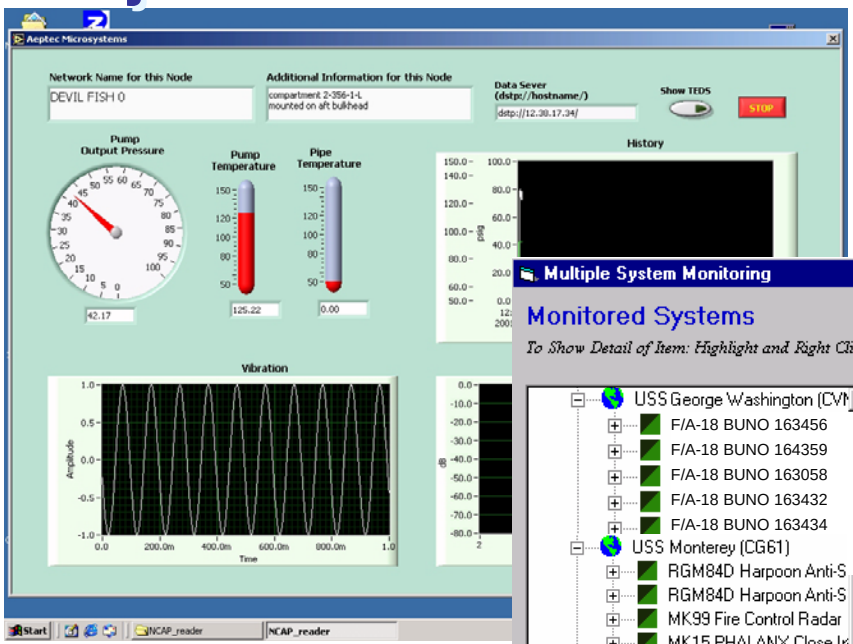
# Operator View - Real-Time Status Monitoring & Health Assessment

- **Drill down the hierarchical model to get the level of detail desired.**

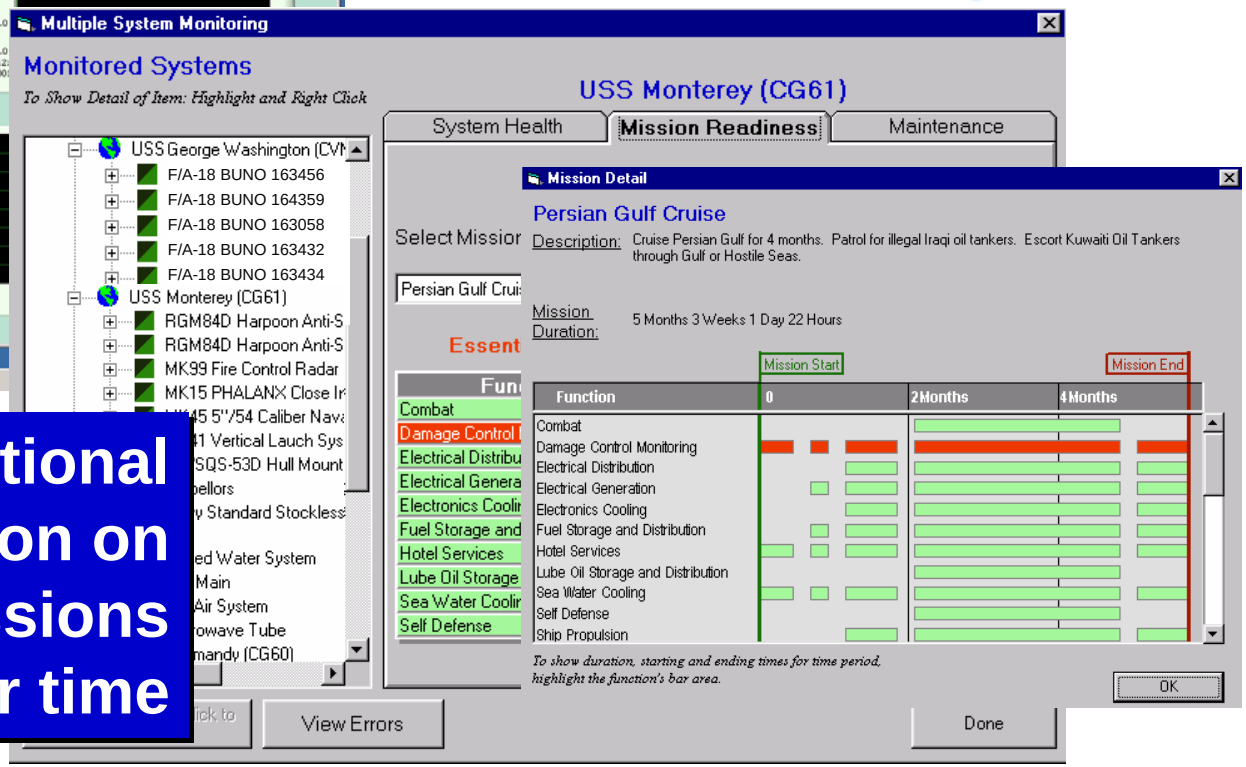


# Mission Commander View

## Not just sensor data…..

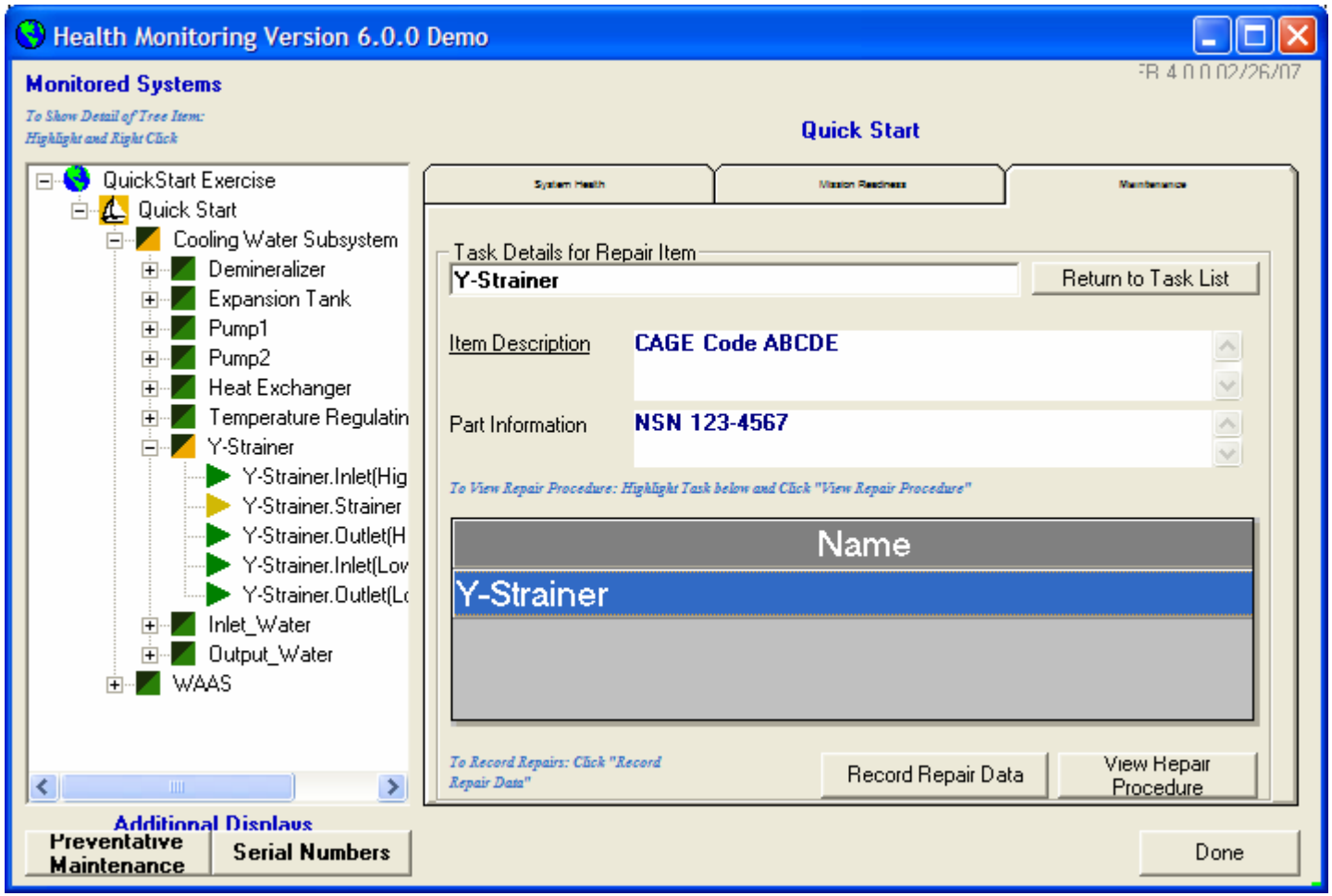



## ….but also mission readiness based on status of inter-related systems

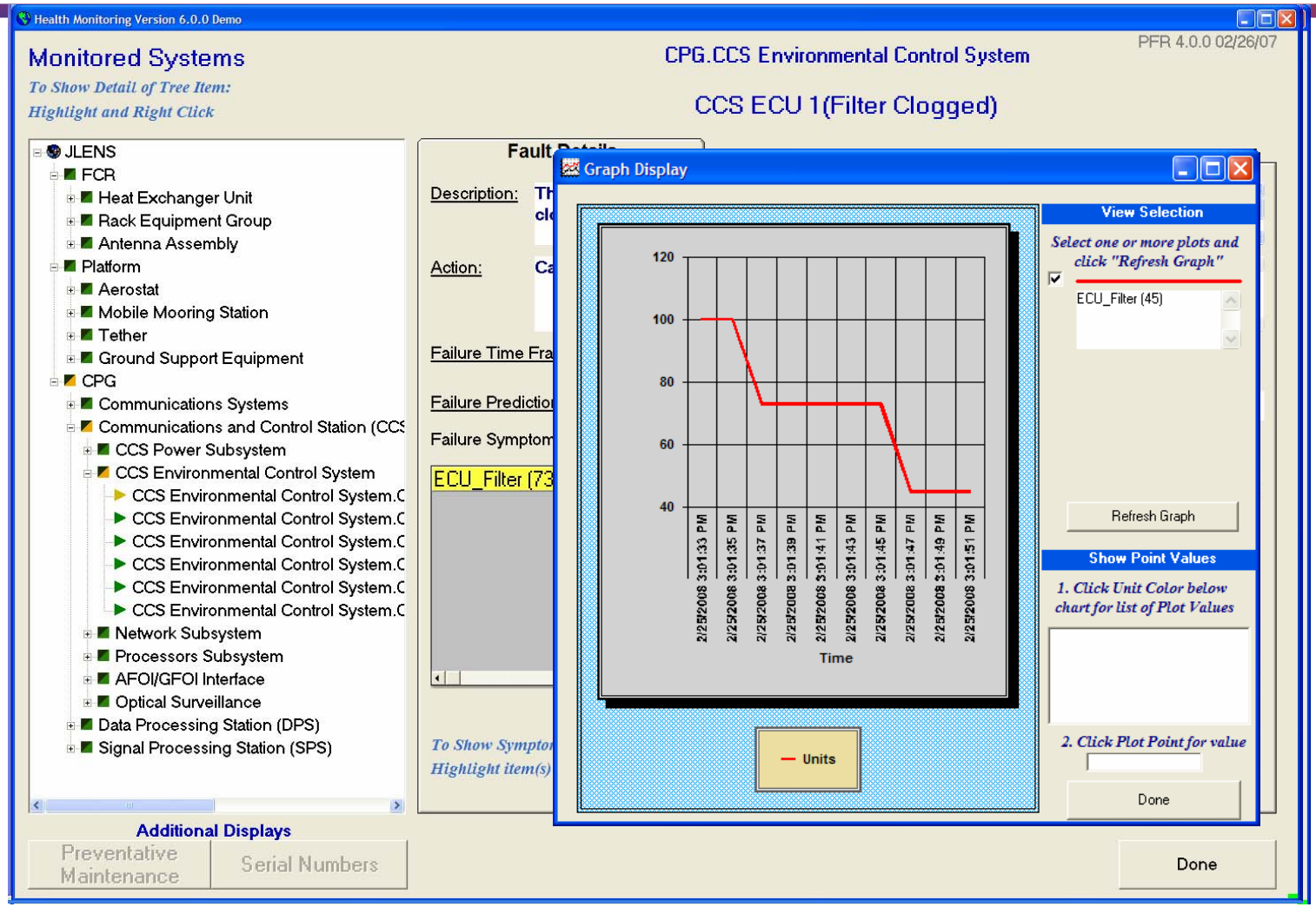



**Impact of functional degradation on specific missions over time**

# Maintainer View



# System Capability (SYSCAP)




- SYSCAP displays system status based on the hierarchical breakout of the system:
  - System
  - Prime Item
  - Critical Item
  - LRU
  - Fault
  - Failure Mode
- At each level, appropriate information is displayed.
- Operator can drill-down to investigate health

**HMS displays and interaction were demonstrated at Early User Assessment in March 2008**

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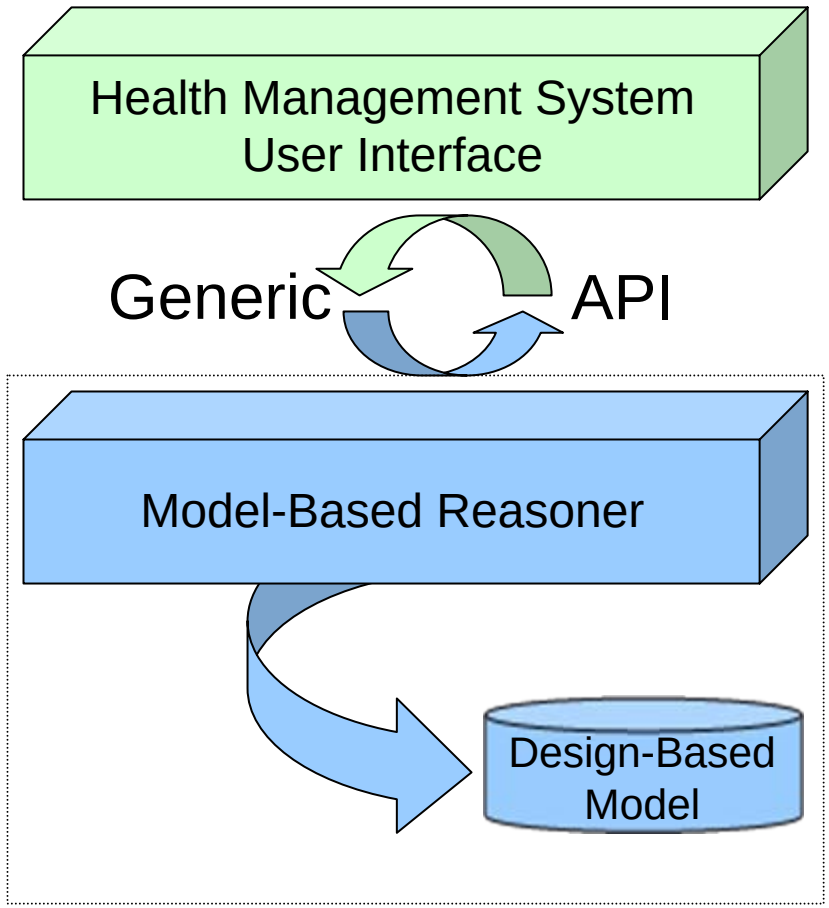
# Additional Features

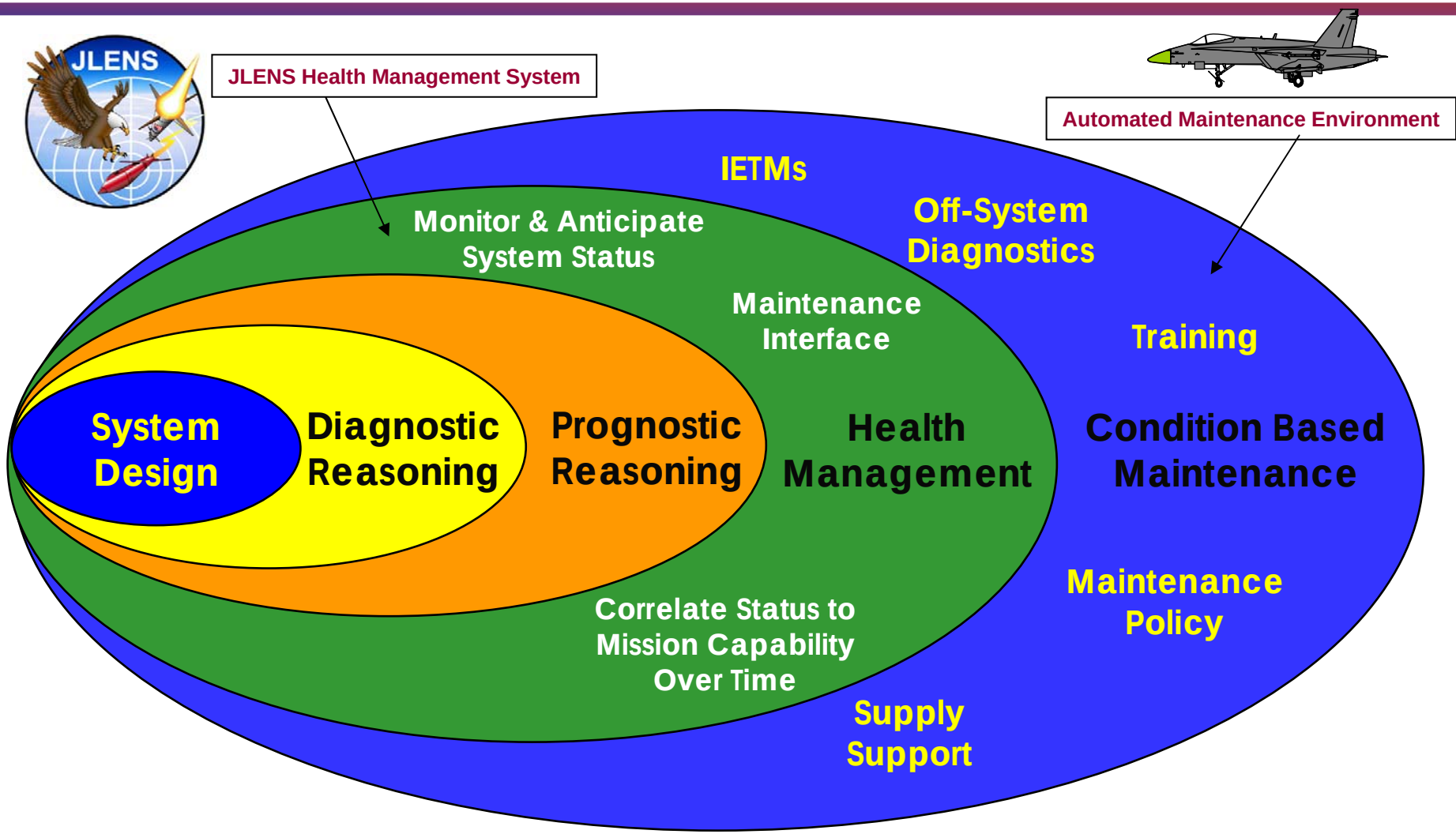
- Preventive Maintenance
- Maintenance and repair procedures linked to fault enunciation
  - Model can launch IETM to specific repair procedure for fault
- Serial Number Tracking
- Interface to Parts Ordering
- Data Logging
- Validate Sensor Data
  - Missing or invalid data
  - Valid sensor ranges

# Software Architecture of the Health Management System

- Run-Time Software designed for embedded applications
- C Code that can be cross-compiled to any platform
- Implementation Strategy:
  - Centralized
  - Distributed
  - Hierarchical
- Software functions serve as building blocks
  - Integrate building blocks to build desired functionality
  - Design User Interface as desired or use existing
  - Well-documented API



# Layers of CBM +




**Design-Based Comprehension of System Condition is the Most Fundamental Enabler of CBM+**

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# Other VSE Diagnostics/Prognostics Based Programs

- Navy SPS-48E Radar
- C-130 Gunship
- A-10/KC-135 Turbine Engine Monitoring System
- Kiowa Warrior Mast Mounted Sight
- Seawolf Ship Control System
- Avitronics Radar Warning Receiver
- NASA Remote Power Controller
- F-16 Universal Data Acquisition System
- Navy Total Ship Monitoring (TSM) Program
- Navy Battle Group Automated Maintenance Environment Program
- FAA Wide Area Augmentation System

# VSE Capabilities: Total Implementation Support

- Tailorable to any platform or system
- VSE has the capability and experience to bring all of the resources together to forge a PRACTICAL, EXPEDIENT and, COST EFFECTIVE solution:
  - Requirements Analysis/Implementation Strategy
  - Integration & Middleware
  - Legacy Data Capture
  - Development of System Diagnostic/Prognostic Models
  - Installation & Fielding
  - Training
  - Fleet Support Team

# Points of Contact


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