Model-Based Integrated Health Management

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

Engineering Resilient Space Systems

Keck Institute for Space Studies

2 August 2012

Erv Baumann

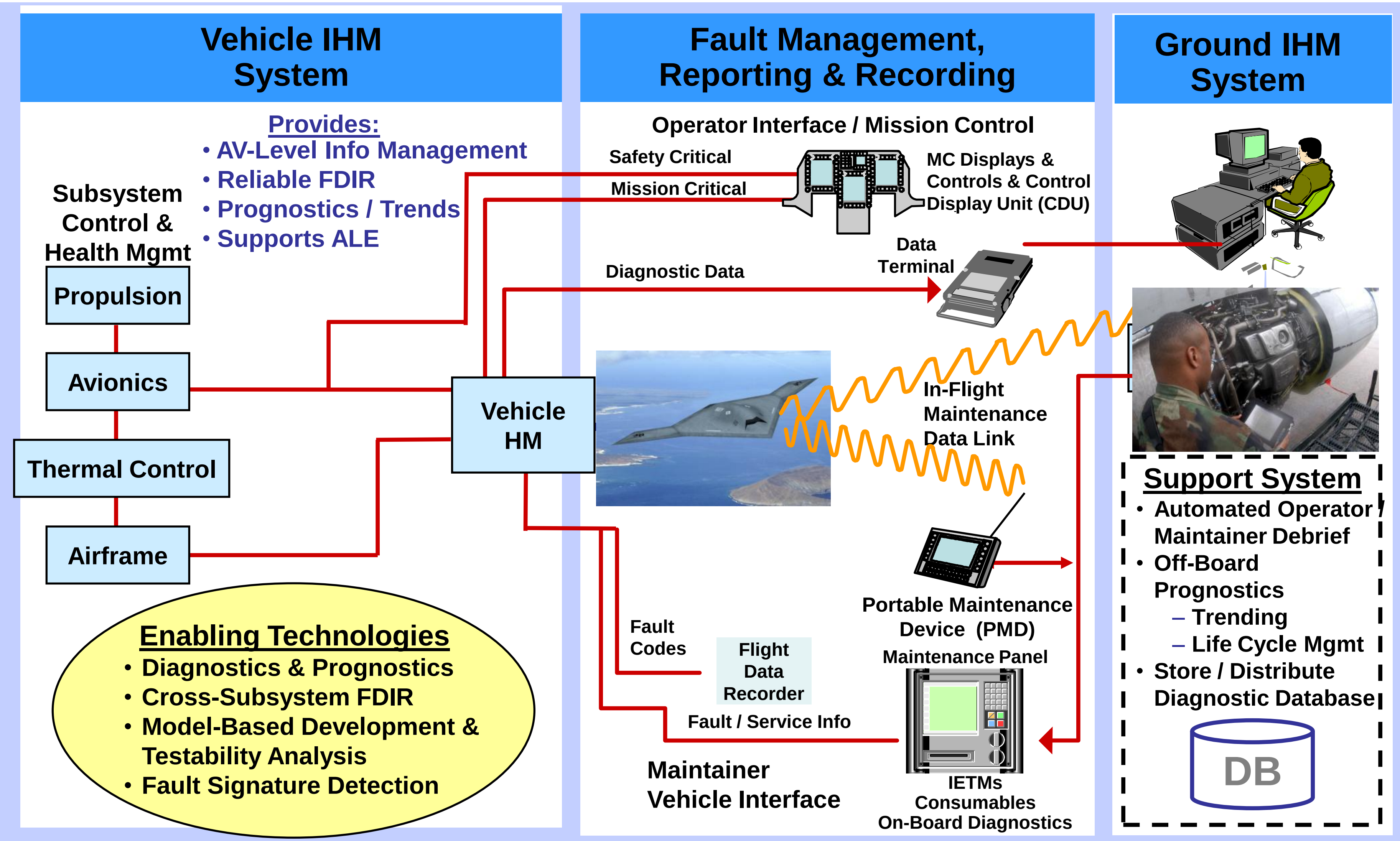
Integrated Health Management Lead

Advanced Programs & Technologies

Northrop Grumman Aerospace Systems

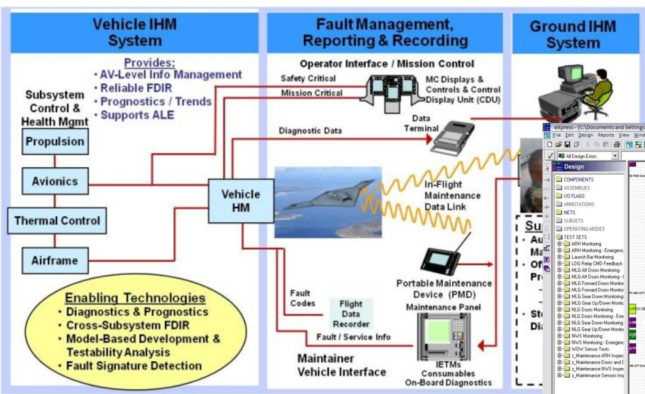
IHM Operational Elements

(for purposes of this presentation **IHM = PHM = ISHM = IVHM**)

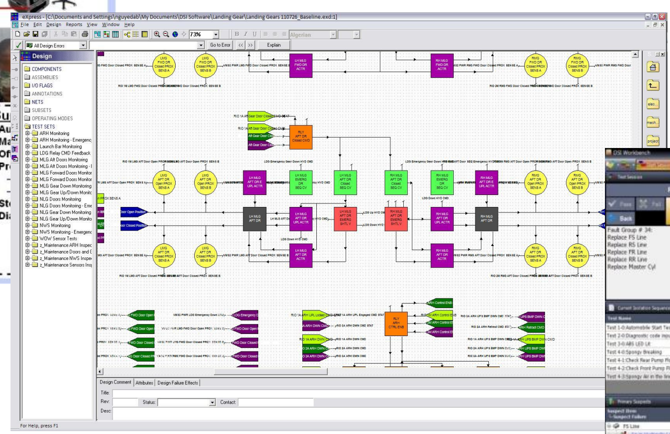


Objective of Model-Based Diagnostic Design Analysis -
Support "Design for Maintainability" While Reducing Costs

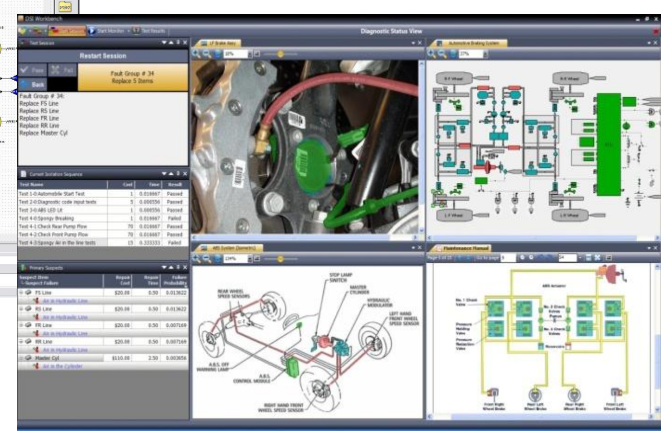
- Use Model-Based Testability Analysis Tools to Assess Fault Coverage vs. Reqmts
- Reduce Replication in Related FMECA and Testability Analysis Efforts
- Support IETM Generation and Informed Maintenance Activities
- Enable Effective Discrepancy Analysis and Design Updates During Sustainment
- Reduce Time Required to Develop Variants of Baseline Vehicle Design



Architect for Growth

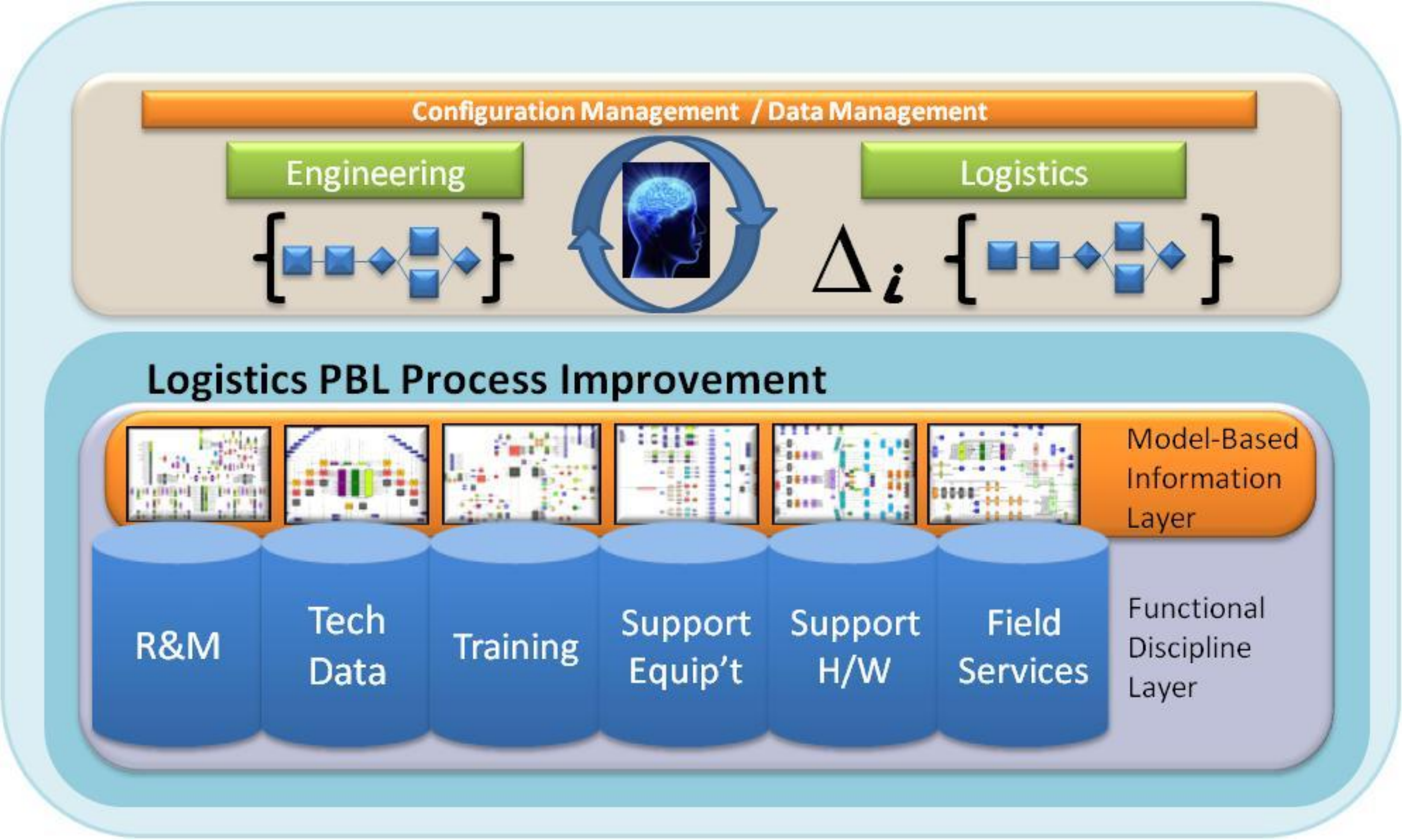


Design for Supportability



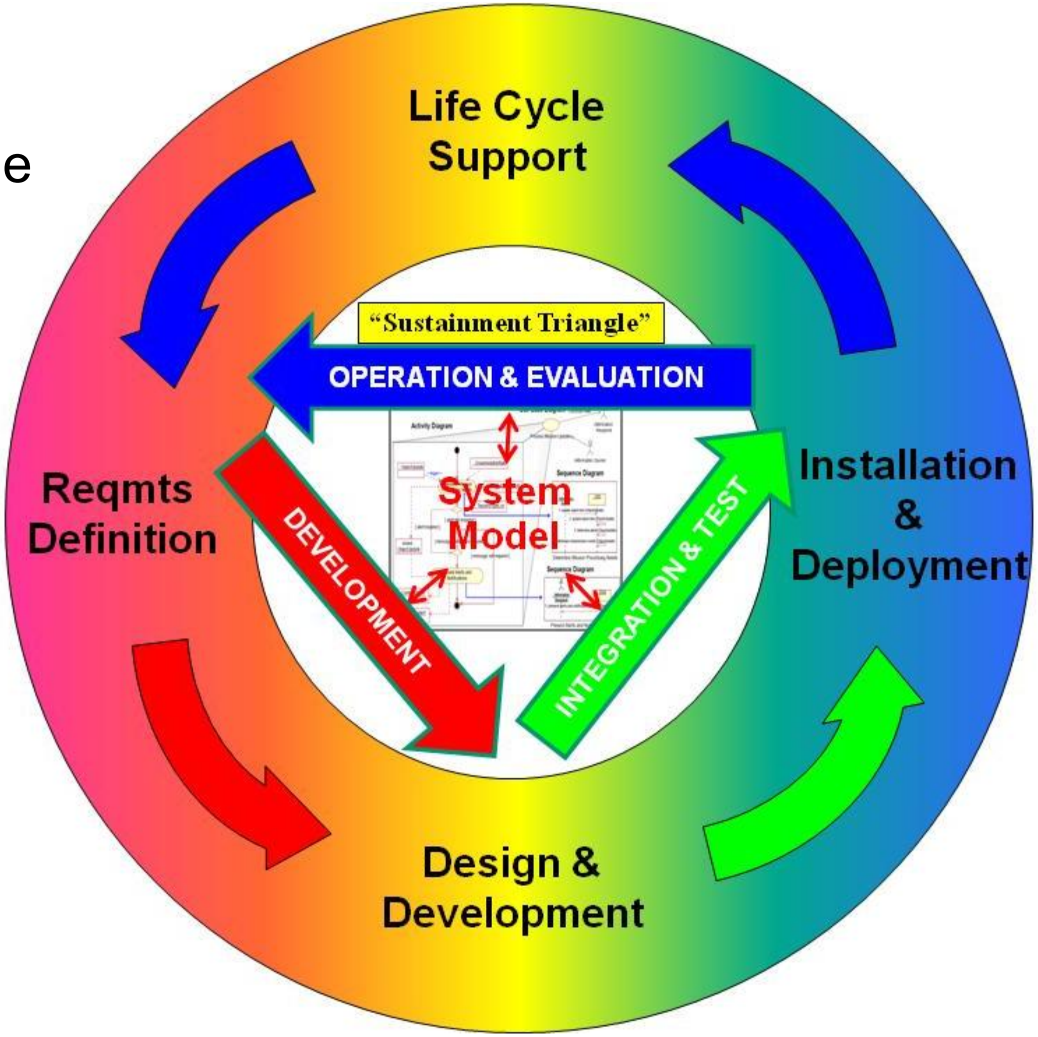
Improve Maintenance & Sustainment

Model-Based System Design Enables Performance-Based Logistics Improvements

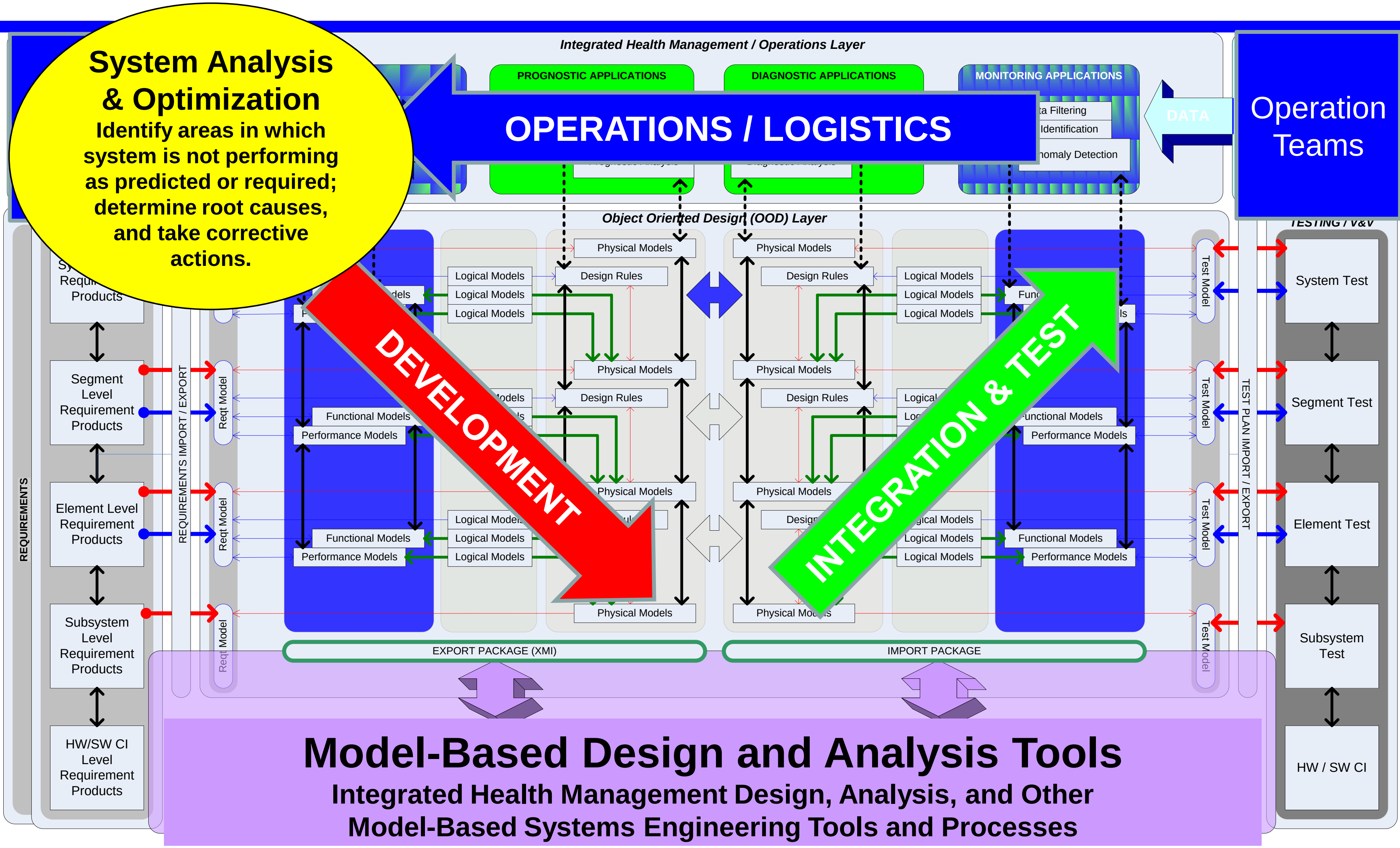


Model-Based System Design and Life Cycle Logistics Loop

- Inner "Sustainment Triangle (Loop)" is Executed Many Times Within a Typical Product's Life Cycle
- Shared System Model Facilitates Timely Life Cycle Support, Block Upgrades, Variant Development, & Configuration Mgmt



Model-Based System Development and Sustainment Loop

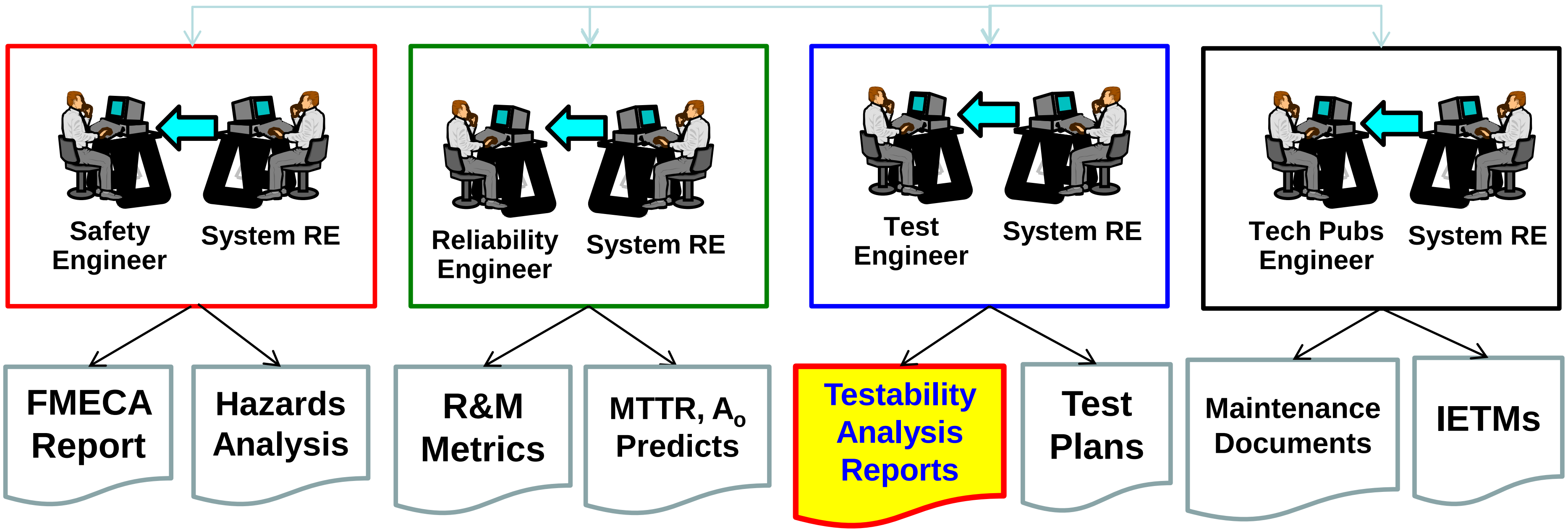


Current Design Analysis Methods Repeat Similar Thought Processes for Related Products

NORTHROP GRUMMAN

Current Process
(Simplified View)

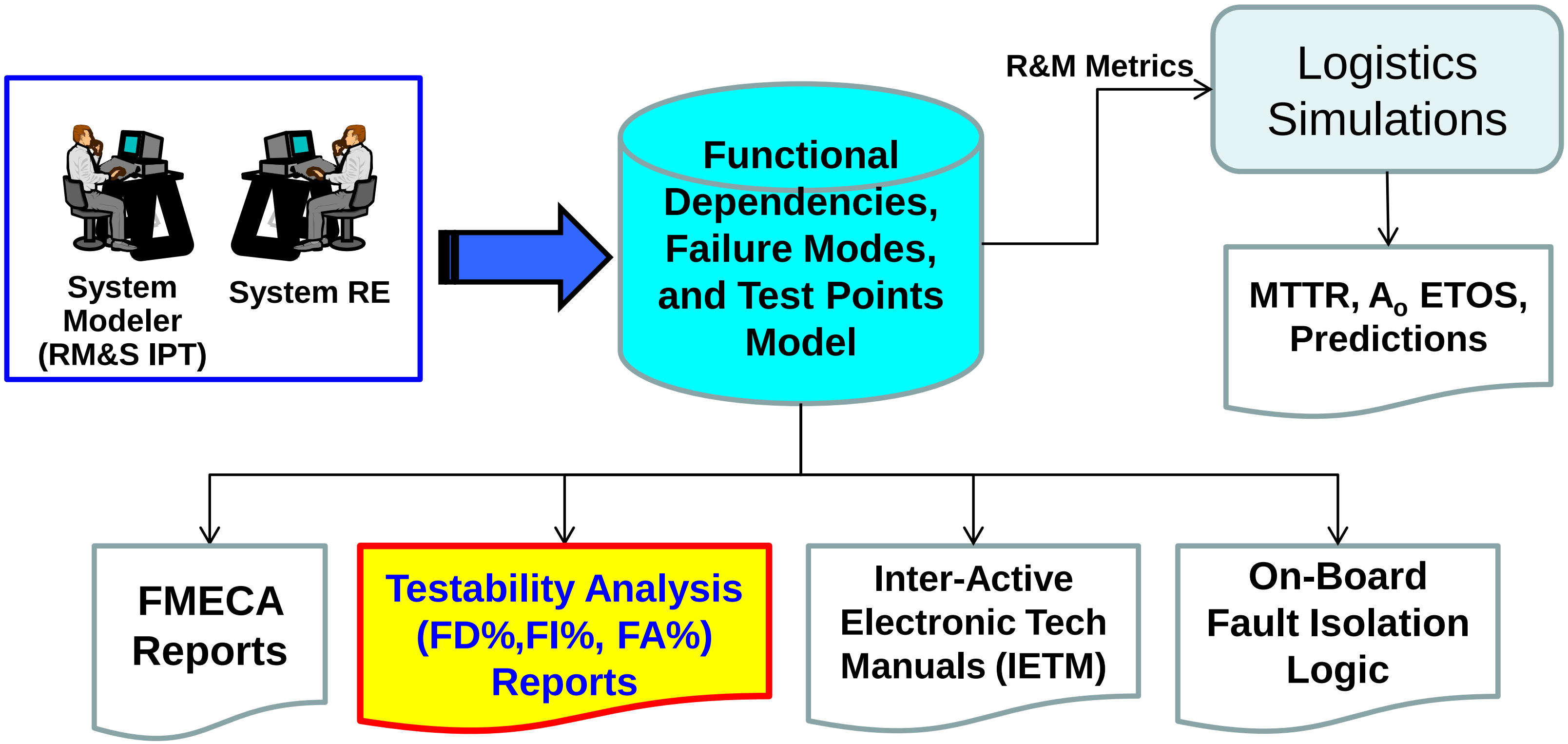
Replicated Thought Processes and "Filtered" Information Flow



Model-Based Diagnostic Design & Analysis Provides an Opportunity to Reduce the Replication of Effort in Deriving Related Products

Model-Based Process Reduces Duplication of Effort and Simplifies Analysis

Model-Based Process



By Investing in the Development of Diagnostic Models for Systems, One Can Transition to a More Timely and Cost-Effective Automated Testability Analysis and Report Generation Process

Key Model Characteristics for Health Management Applications

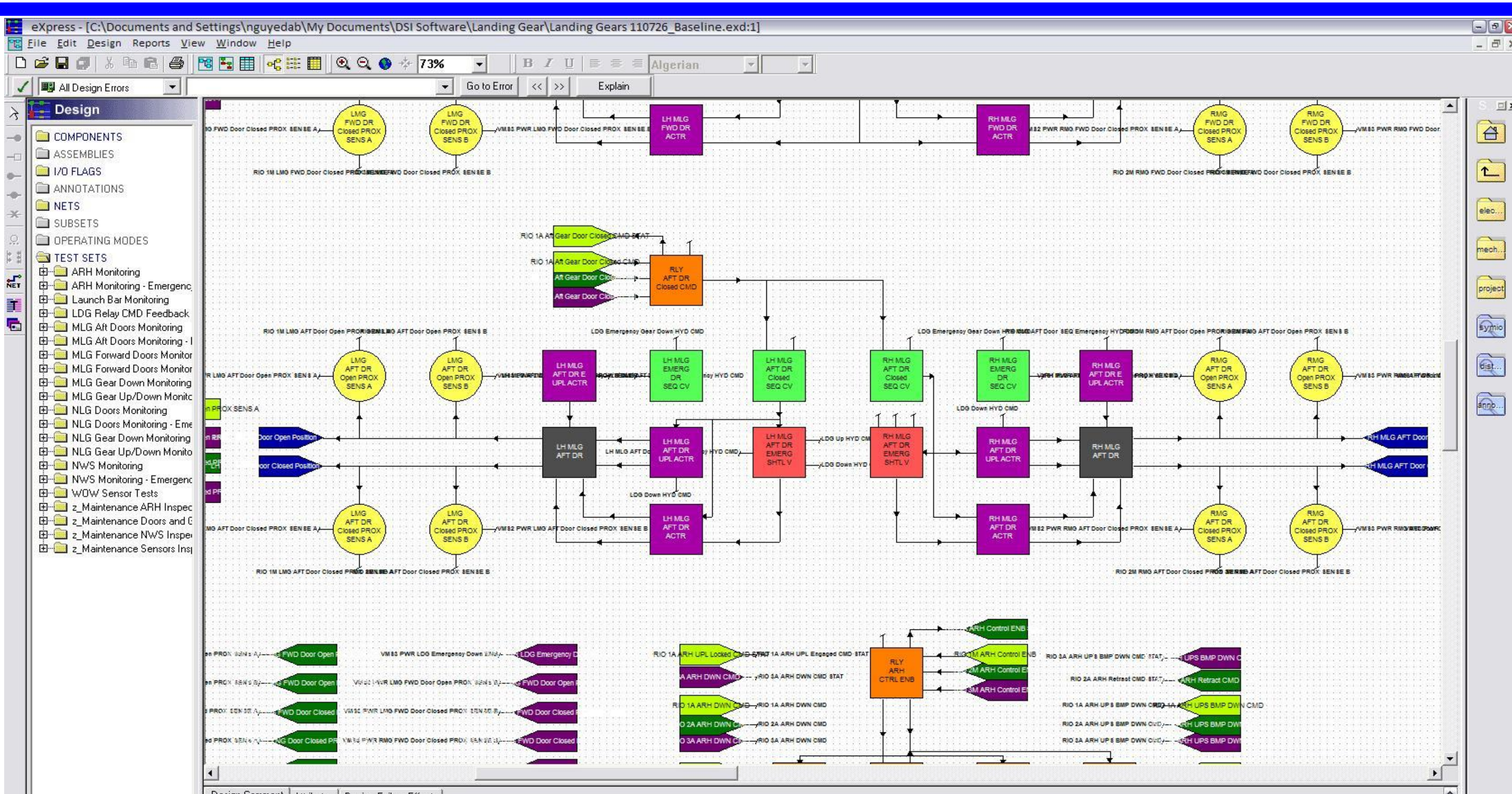
NORTHROP GRUMMAN

For our purposes a model must support the representation of:

- Physical Features and Properties of Components
  - Static/Fixed Part (e.g., the number and type of I/O ports)
- Functional, Operational, Behavioral Description of Components
  - Dynamic/Procedural/Executable Part (e.g., the function performed)
- Connectivity between Components
  - Functional Dependencies and Fault Propagation Paths
- A Graphic Depiction of the Model That is Understandable by Users (Typically Engineers and Maintenance Technicians)
  - Enables Efficient Model Input, Explanation, and Human Interaction

NORTHROP GRUMMAN

Example: Landing Gear Diagnostic Model



Diagnostic Models Are Developed Graphically and Define WRA Functional Relationships, Failure Modes, and Tests. Fault Detection (FD%), Fault Isolation (FI%), and Other Diagnostic Performance Metrics Are Automatically Calculated.

Input & Output Data Items

- **Input Data Items:**

  To Modeler:
  - **Engineering Schematics**
  - **Functional Descriptions**
  - **Interface Control Documents**
  - **Sub-contractor Engineering Documents**

  Directly into Model:
  - **Reliability & Maintainability Data**
  - **FMECA Reports**

- **Output Data Items:**
  - **Diagnostic Model**
  - **Testability Analysis Reports**
  - **FMECA Update Reports**
  - **Diagnostic Logic / Fault Isolation Sequences**
  - **S1000D Compliant IETM Data Files**

Example of Model-Based Testability Analysis of Design Alternatives

NORTHROP GRUMMAN

Testability Analysis of Landing Gear Design With and Without Sensor Fault Disambiguation

Landing Gear Testability Performance Metric	Before Adding Sensor Fault Test	After Adding Sensor Fault Test		
Fault Detection Coverage (FD%)	99.9%	99.9%		
Fault Isolation Coverage (FI%)	65.3%	88.3%	23.0%	Improvement
False Removal% (The % of all unit removals that could result from ambiguous fault isolation)	39.3%	18.6%	20.7%	Improvement

Model-Based Analysis Allows Designers to Assess the Impact of Design Options on Testability and Maintenance Efficiency

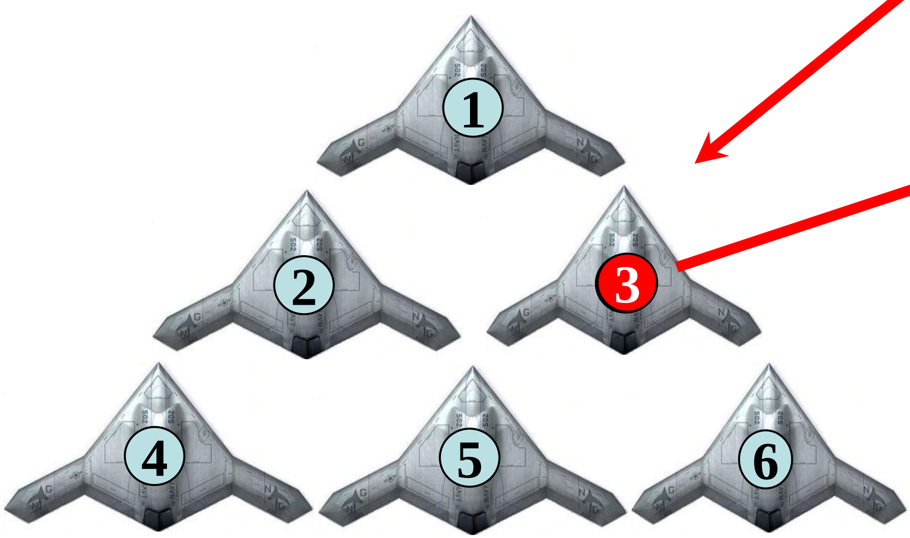
Integrated Health Management (IHM), an Enabler for Integrated Operations

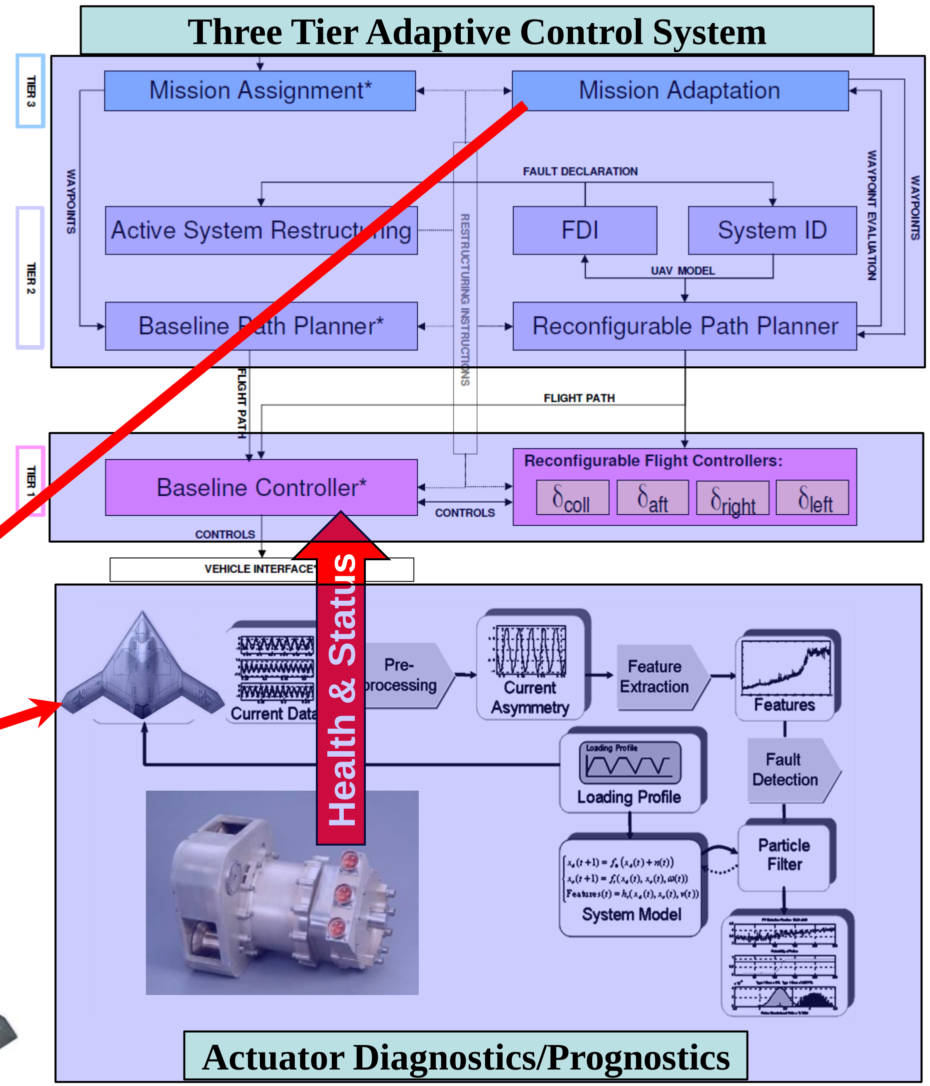
NORTHROP GRUMMAN

Scenario: Detection & Multi-Level Response to Degraded Control Surface Actuation

In-Flight Detection & Mgmt of Degraded Actuation System

1. Flight group embarks with all systems operational.
2. Nearing the target area, IHM detects degradation of control surface actuation and maneuverability in one of the key payload-carrying aircraft in the flight group.
3. IHM provides health & status diagnostic & prognostic information required by adaptive flight control system.
4. Control system reconfigures to maintain control and manage Remaining Useful Life (RUL) of the actuators.
5. Automated Mission Mgmt software automatically changes flight group formation and tactics to reduce vulnerability of degraded aircraft for remainder of mission.

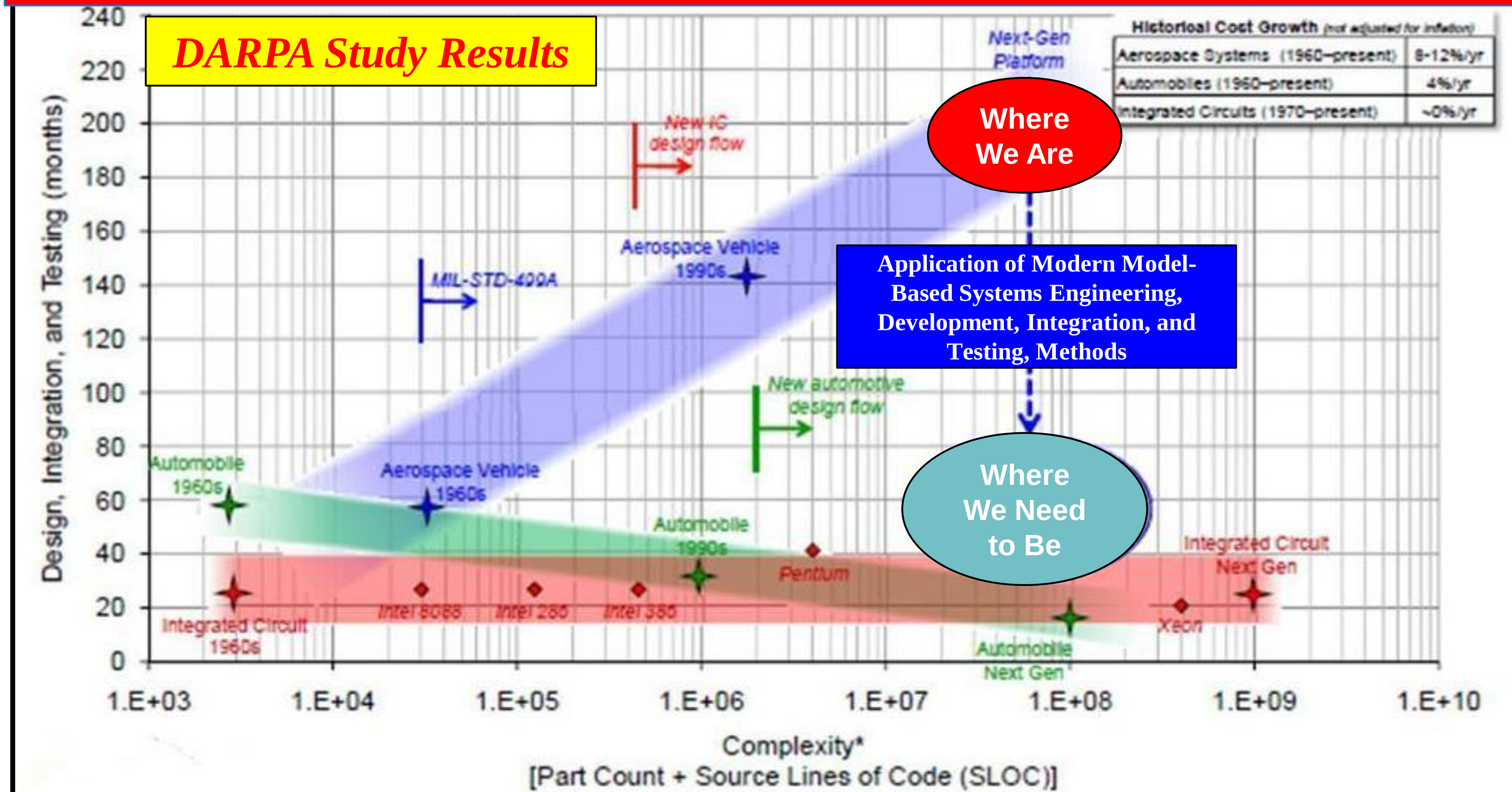




Managing Complexity in Aerospace System Development Through Model-Based Systems Engineering

NORTHROP GRUMMAN

Aerospace Programs Require More Than 5 Times Longer to Perform Comparable Development & Sustainment Tasks than the Auto & Electronics Industries



Several Key Reasons for "The Gap":

1. **Inconsistent Aerospace Application of Systems Engineering Tools and Processes**
2. **Differences in Major Aerospace Systems Acquisition and Regulatory Processes**
3. **Lack of Model-Based Design, Analysis, Production, and/or Operations Tools**

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN