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Customer Success Is Our Mission

Designing for Health; A Methodology for Integrated Diagnostics/Prognostics

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Health Management Systems Burning Platform

- Eliminate unnecessary maintenance actions
  - Industry findings indicate that a high percentage of all maintenance actions are unnecessary and a waste of resources.
  - This waste is estimated at $200 billion per year across all of industry
- Greatly improve customer affordability by reducing logistics footprint

The Integrated Health Management System Methodology targets improving mission readiness and reducing the logistics footprint

Integrated Health Management System (HMS)

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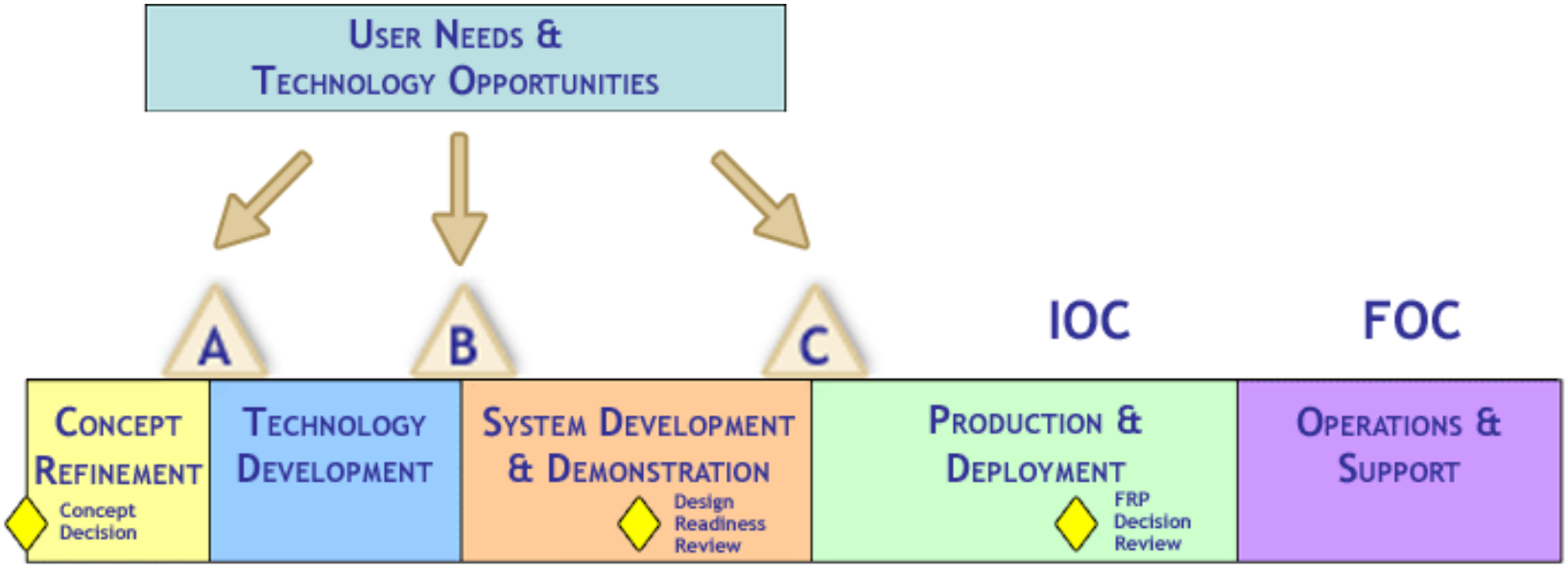
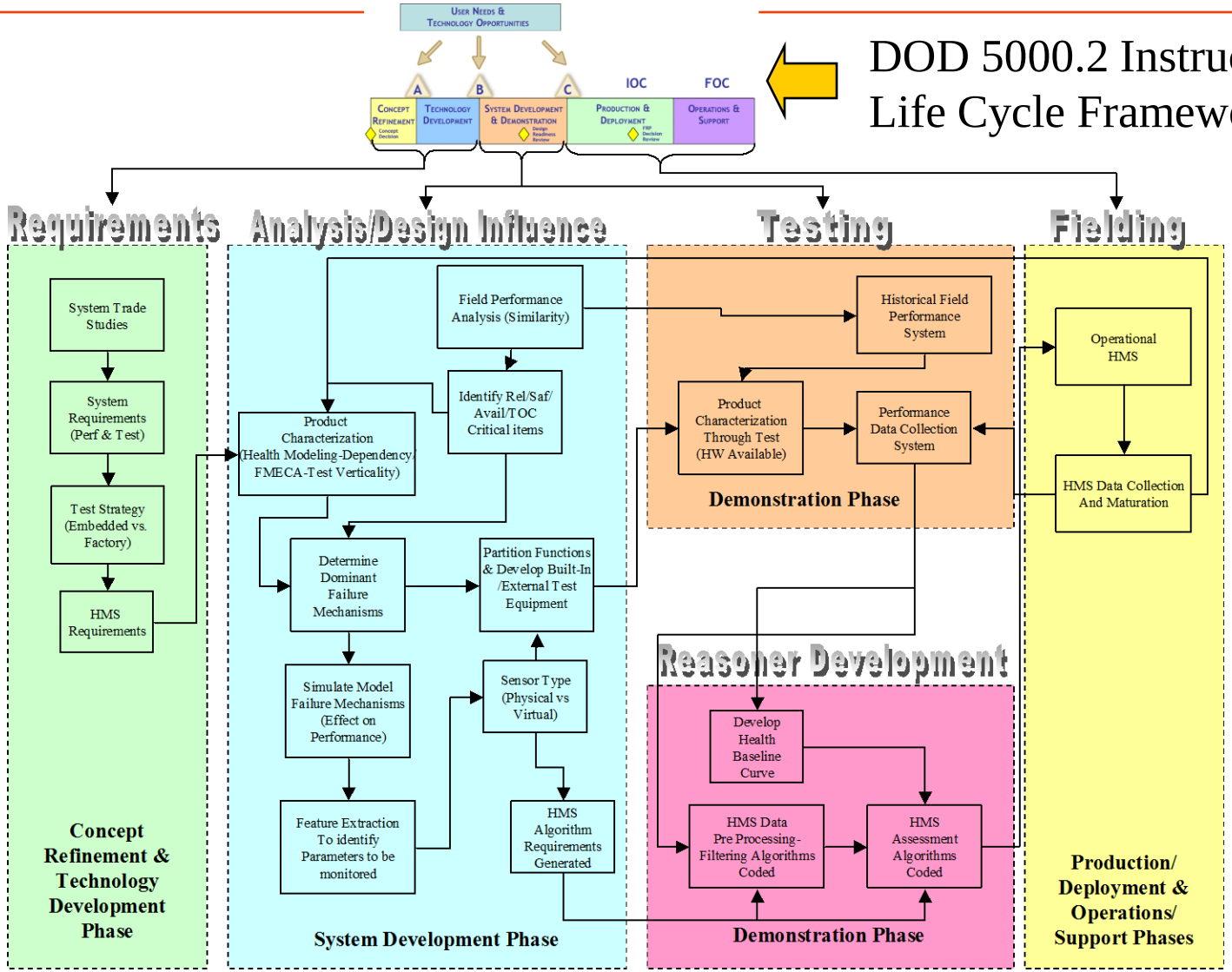
- Complies with DOD 5000.2 Instruction: (Integrated Defense Acquisition, Technology and Logistics Life Cycle Management Framework)
- Increases Mission Readiness through:
  - Robust on platform and off platform health monitoring
    - Maximizing Fault Detection, Fault Isolation, & Fault Reporting
    - Minimizing False Alarms and Re-Test Okays
  - Closed loop maturation process
    - Continual HMS improvement over the life cycle
- Supports the Missile Defense Agency Assurance Provisions
  - 3.2.7 Design for Testability
  - 3.2.8 Design for Supportability
  - 3.7 Integrated Test and Evaluation Program

DOD 5000.2 Instruction Life Cycle Framework



"Life Cycle Framework serves as a pictorial roadmap of most key activities in the system acquisition process"

Integrated Health Management Methodology



Integrated Health Management Methodology fits into the Life Cycle Framework

Concept Refinement & Technology Development Phase

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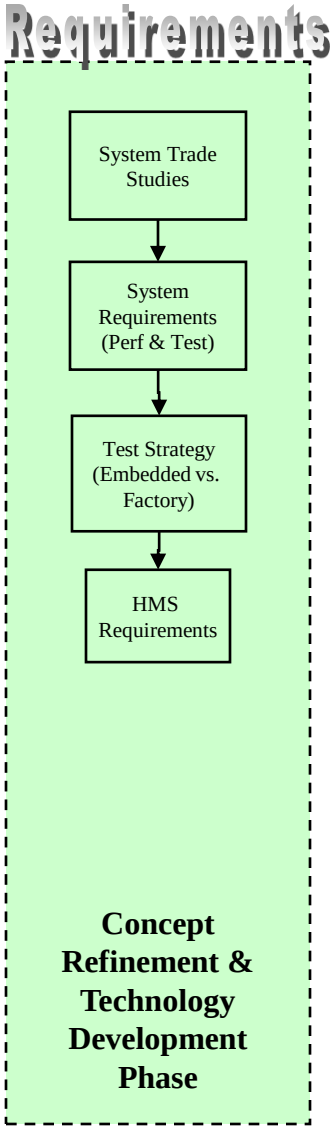

Phase Objectives

•Perform trades to refine and optimize the system HMS design approach for the System Development & Demonstration (SDD) phase

System Trade Considerations

•Maintenance Concept(s) – Ao, MTBF, MTTR, MTBMA

•Embedded diagnostic, prognostic, & factory test features

•Mechanical & functional partitioning

•Maintainer Field Support Equipment, Factory Test Equipment

•Cost trades (engineering development cost, life cycle cost)

•Identify high risk HMS and Support requirements; mitigate with customer

Concept Refinement & Technology Development Phase

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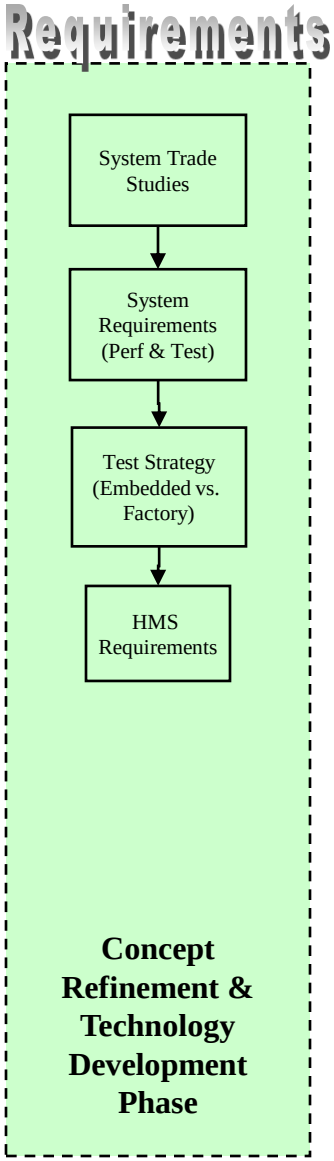

System Test Strategy Refinement

- Tops-down dependency models created
- Health monitoring strategies & requirements defined from dependency models
  - Embedded diagnostics/BIT
  - Prognostics
  - Preliminary FMECA
  - Framework (i.e. fault logs, fault reporting, reasoner)
  - Factory Test Strategies

HMS/Maintainability/Testability requirements are defined for the System Development & Demonstration phase of the program

Concept Refinement & Technology Development Phase

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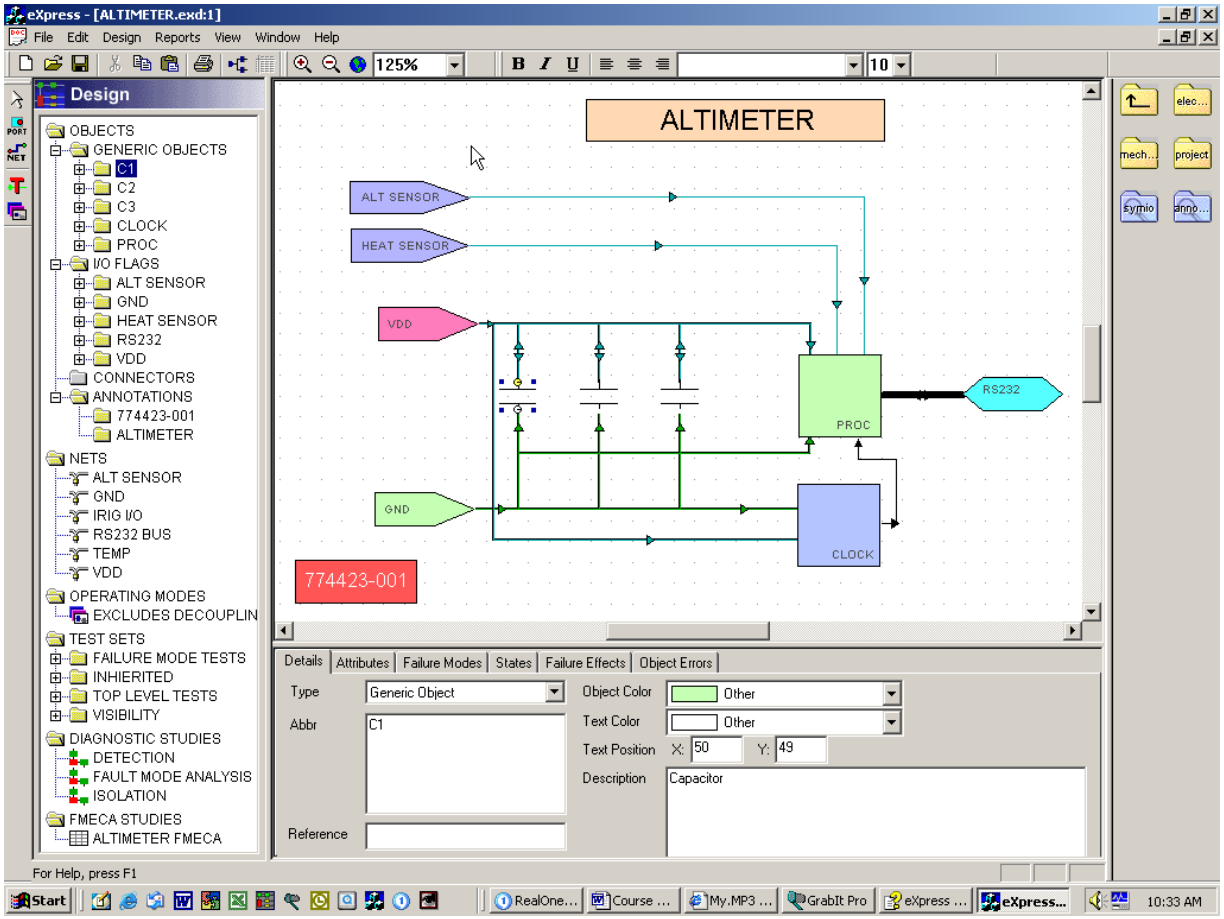
Sample Dependency Model

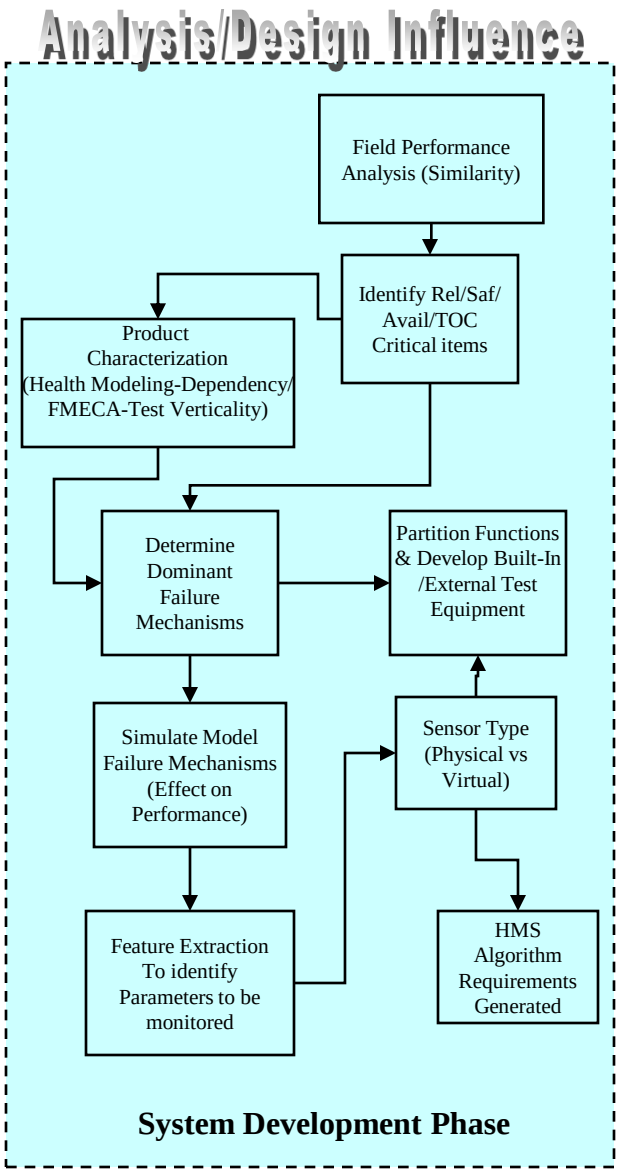


Completed concurrent with architecture trades

Provides

- Embedded Diagnostics & BIT strategies
- FMECA
- Fault Trees
- Factory Test Set Definition & Strategies
- FD/FI Coverage
- Extensive Reports

System Development & Demonstration Phase



Phase Objectives

- Design HMS with the following needs in mind:
  - Operational Availability (Ao)
  - Design for supportability
  - Minimize logistics footprint
  - Minimize Life Cycle Cost

Key Tasks

- Analyze legacy field data of similar systems to implement solutions for supportability problems
- Mature Dependency Models (diagnostics/prognostics)
- Mature FMECA
- Design for Test & Test Verticality

System Development & Demonstration Phase

Sample Test Verticality Spreadsheet

FIELD

Applicable Requirement	FMECA Failure Mode	O-level (System BIT)	O-Level Tolerance	I-level (LRU Troubleshoot)	I-Level Tolerance	D-level (SRU Troubleshoot)	D-level Tolerance
FLIR System							
Power Supply LRU							
Output Voltage of +12.0 VDC+/- 0.5 VDC	Loss of output power	Power Monitoring BIT					
Gimbal LRU							
Gimbal Slew Rate of 20 mRad/sec	Loss of gimbal movement	Gimbal Rate Status BIT	> 20.0 mRad/sec	Gimbal Slew Rate Test	>20.1 mRad/sec	Accelerometer Slew Rate Test	>20.2 mRad/sec
Gimbal Position Error of +/- 0.5 mRad	Loss of gimbal positional control	Gimbal Position Status BIT	+/- 0.50 mRad	Gimbal Position Test	+/- 0.49 mRad	Gyro Positional Test	+/- 0.48 mRad
Display LRU							
No more than 1% of pixels bad using TV	Loss of TV video	TV Video Status BIT	< 1% bad pixels	Display Unit TV Quality Test	< 0.9% bad pixels	TV Camera Image Quality Test	< 0.8% bad pixels
No more than 2% of pixels bad using IR	Loss of IR video	IR Video Status BIT	< 2% bad pixels	Display Unit IR Quality Test	< 1.9% bad pixels	IR Camera Image Quality Test	< 1.8% bad pixels

Green indicates a proper tolerance (larger than lower level and smaller than higher level)

FACTORY

Applicable Requirement	FMECA Failure Mode	Factory System AT	Factory System AT Tolerance	Factory LRU AT	Factory LRU AT Tolerance		Factory SRU AT
FLIR System							
Power Supply LRU							
Output Voltage of +12.0 VDC+/- 0.5 VDC	Loss of output power	Power Monitoring BIT	+/- 0.44 VDC	Power Supply Power Test	+/- 0.5 VDC	Powe Power T	
Gimbal LRU							
Gimbal Slew Rate of 20 mRad/sec	Loss of gimbal	Gimbal Rate		Gimbal	4	Accelerome e Test	
Gimbal Position Error o +/- 0.5 mRad						o Positional Tes	
Display LRU							
No more than 1% of pixels bad using TV	Loss of TV video	TV Video Status BIT	< 0.7% bad pixels	Display Unit TV Quality Test	< 0.6% bad pixels	TV Camera Image Quality Test	< pixe
No more than 2% of pixels bad using IR	Loss of IR video	IR Video Status BIT	< 1.7% bad pixels	Display Unit IR Quality Test	< 1.6% bad pixels	IR Camera Image Quality Test	< 1.5% pixels

Red indicates an improper tolerance (larger than lower level but also larger than higher level)

Cone of Tolerance

Organic

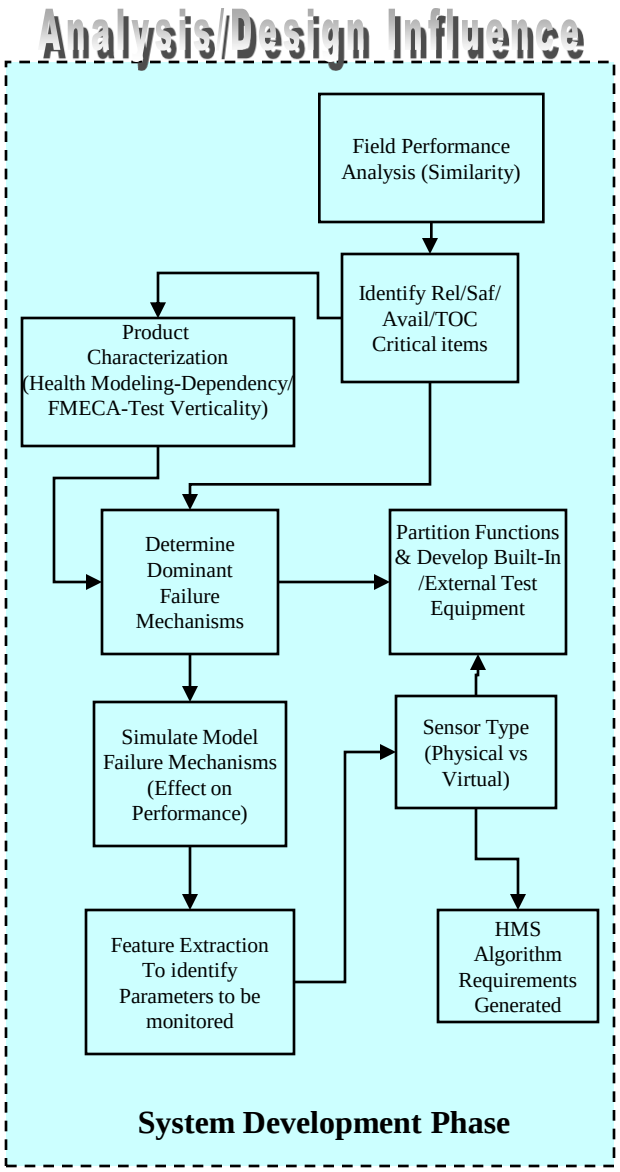
Intermediate

Depot

Factory

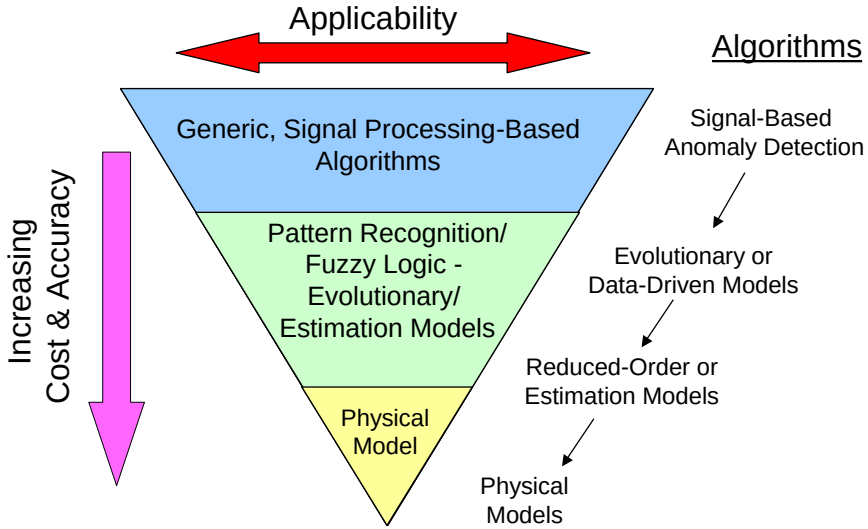
Test Verticality & Cone of Tolerance reduces CNDs/RTOKs

System Development & Demonstration Phase



Key Tasks (continued)

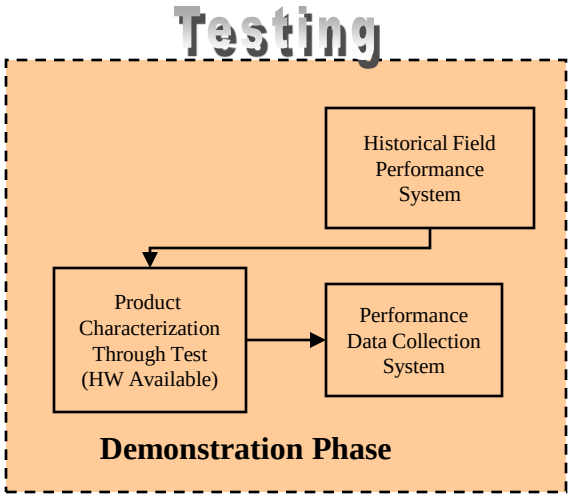
- Sensor types & placement
- Feature extraction
- Physics of failure modeling
- Health algorithm requirements



Algorithm Type Applicability*

* Byington, Roemer, et al., "Prognostic Enhancements to Diagnostic Systems for Improved Condition-Based Maintenance Systems", IEEE Aerospace Conference, March 9 - 16, 2002.

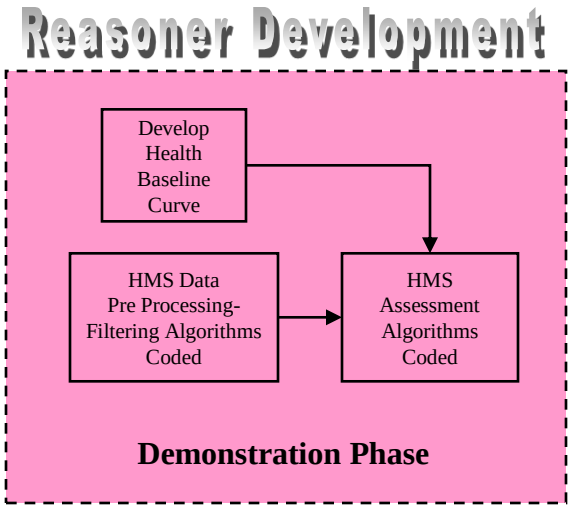
System Development & Demonstration Phase



Testing Key Tasks

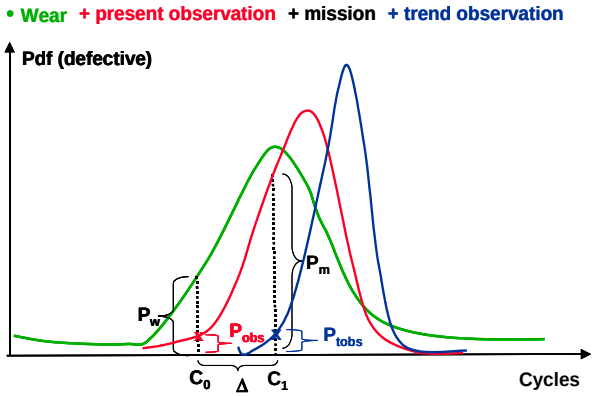
- Testing for Health
  - Further characterize BIT, embedded diagnostics & prognostics
  - Insert faults and ensure HMS works correctly
- Data Collection
  - Collect data from sensors
  - Validate sensors and feature extraction parameters
- Maturation
  - Add virtual sensors
  - Refine HMS algorithms
  - Refine false alarm filtering

System Development & Demonstration Phase

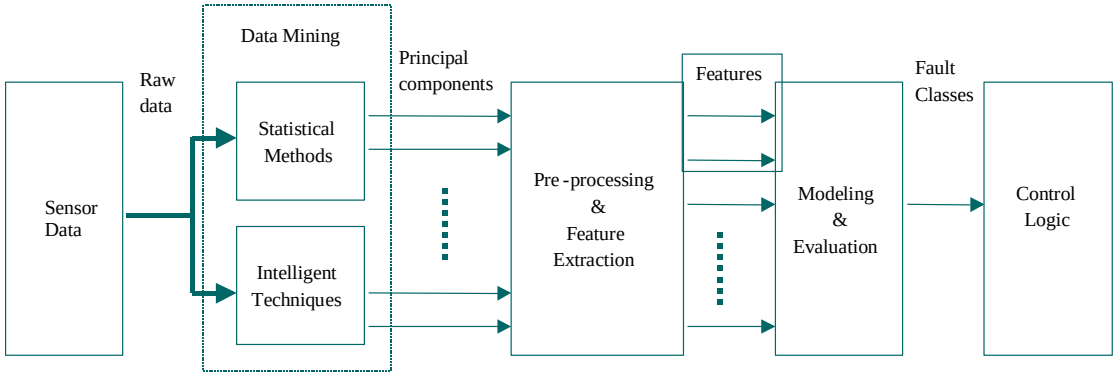


Reasoner Development Key Tasks

- Develop health curve
- Develop data mining and feature extraction algorithms
- Develop modeling, evaluation, and reporting algorithms



Example Health Curve



Example Reasoner Methodology

The reasoner provides the intelligence necessary to draw conclusions from the data

Production & Deployment Phase

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Fielding

Operational HMS

HMS Data Collection And Maturation

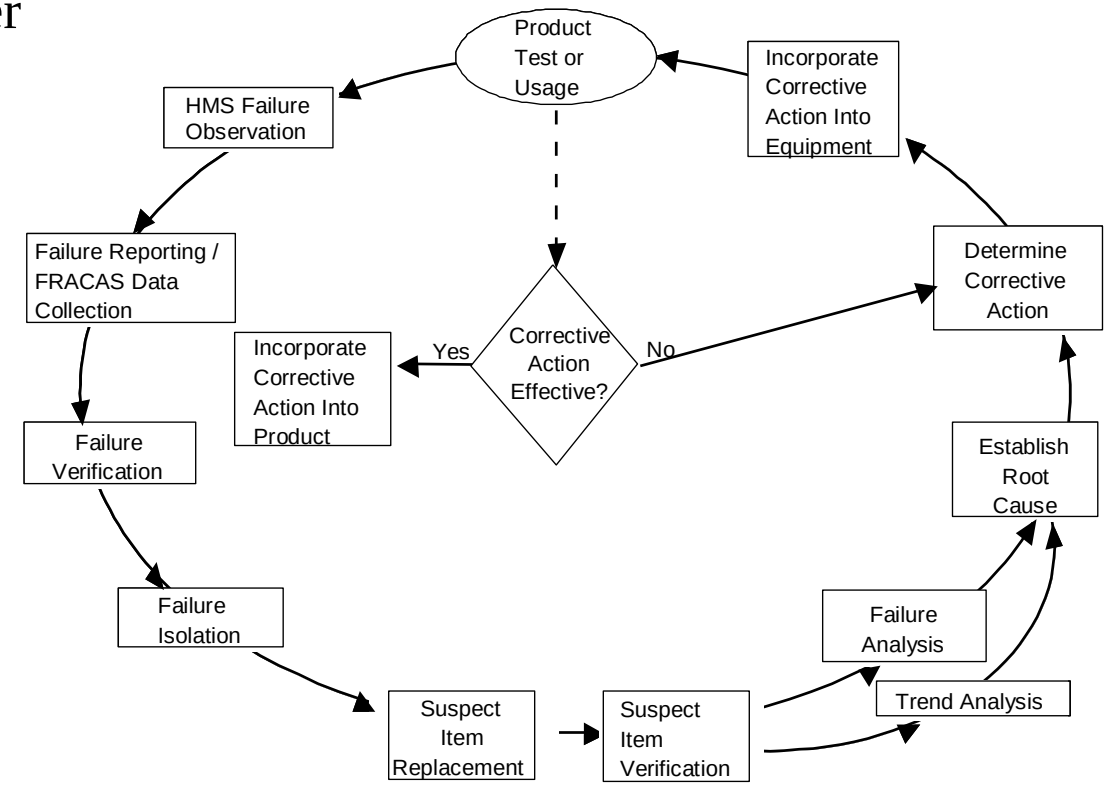
Production/ Deployment & Operations/ Support Phases

Phase Objectives:

- Monitor operational and supportability HMS requirement metrics for optimization
- Ensure HMS supports sustainment in the most cost effective manner

Maturation:

- Collect Data
- Analyze Data
- Refine HMS Capability



Example Closed Loop FRACAS Process

Integrated Health Management System Summary

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- A robust Health Management System reduces life cycle cost and enables the war fighter and maintainer to quickly assess the health of a system
  - Through accurate/reliable diagnostics
  - Probable failure impact of a mission through prognostics
- Increases probability of mission success
  - Confidence in health of system
  - Replace the correct faulty item at the right time
- Integrated diagnostics and prognostics provides the foundation to supporting the total test environment
  - Traceability of requirements through analysis and implementation
  - Reducing false alarms and CNDs.