Prognostics-Informed Diagnostic Analysis

DSI International

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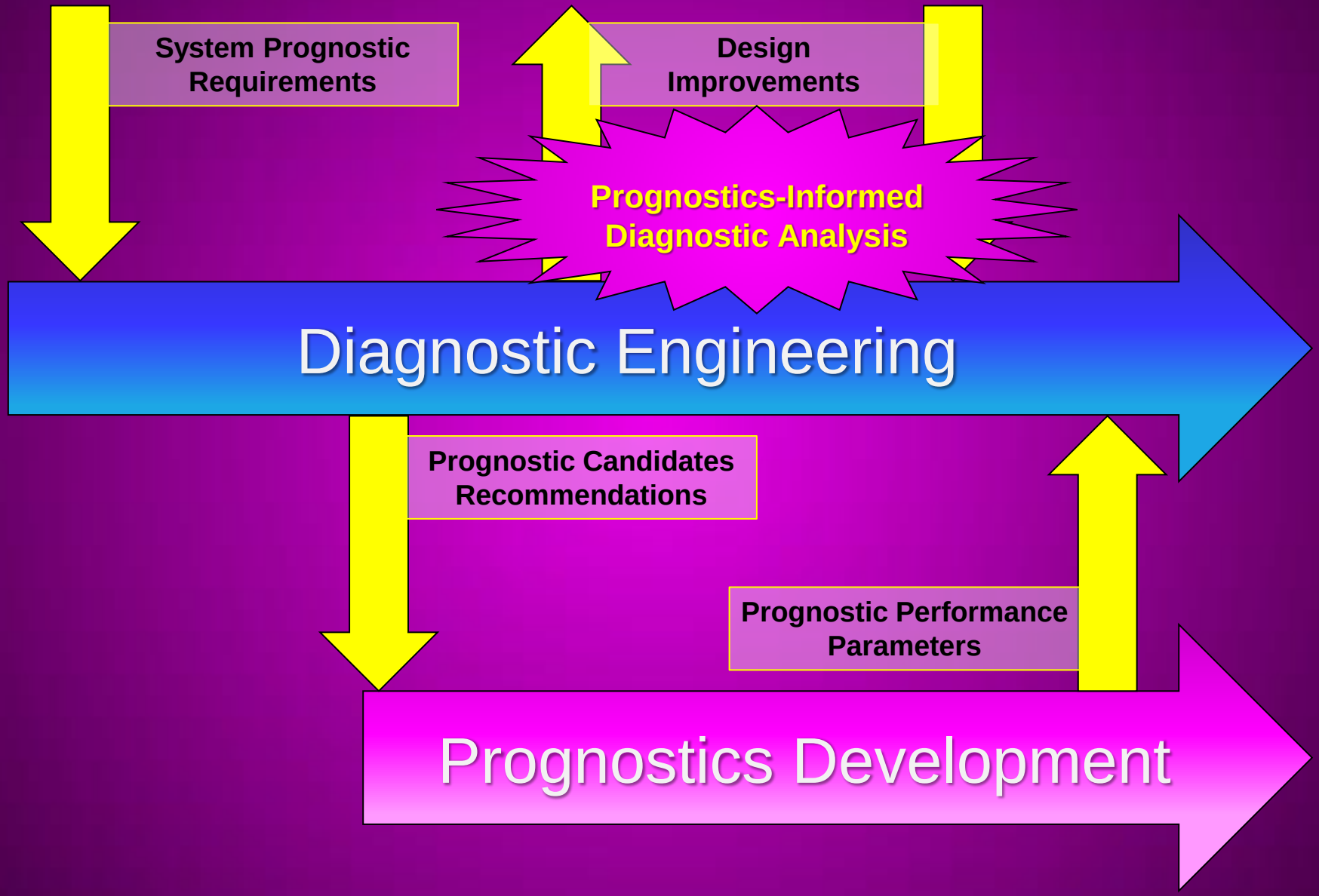
The Issue

- Analyses affected by Diagnostic Engineering should take prognostics into account.
- The full impact of these analyses is often only realized if they are performed during relatively early phases of system development.
- Prognostic performance parameters are typically not available when the analysis of diagnostic performance would be most profitable.

Steps Toward A Solution

- Prognostic Recommendations should be derived from early analyses of the system design.
- When prognostic performance details are unavailable, diagnostics-related analyses can assume that the prognoses will meet contracted requirements.
- Prognostics-informed analyses can then be used to improve the diagnostic design.
- As actual prognostic parameters become available, analyses can be repeated to insure that system requirements are met.



System Prognostics Requirements

Most requirements can be broken down into five parameters:

- **Scope** – failures to which a requirement applies
- **Category** – prognoses to which a requirement applies
- **Horizon** – time before failure that prognosis must occur
- **Coverage** – desired percentage of prognosed failures
- **Accuracy** – accuracy of the overall prognostic capability

Prognostics Requirements: Example 1

Prognostics shall predict at least 80% of the mission critical failures 96 hours in advance of occurrence with 90% probability.

Scope:	Mission Critical Failures
Category:	All Prognoses
Horizon:	96 hours
Coverage:	80%
Accuracy:	90%

Prognostics Requirements: Example 2

[Prognostics] shall accurately predict pending critical system failures that might occur in a 72 hour mission, early enough to allow corrective action before the unit begins the mission. Prognostics will provide coverage for 65% SA and 50% EFF at a 90% accuracy rate

Scope:	System Aborts
Category:	All Prognoses
Horizon:	72 hours + CA time
Coverage:	65%
Accuracy:	90%

Scope:	Essential Fctn Failures
Category:	All Prognoses
Horizon:	72 hours + CA time
Coverage:	50%
Accuracy:	90%

Prognostics Requirements: Example 3

Prognostics shall predict 60% of impending critical faults or failures within no less than 36 hours before mission failure.

Scope:	Critical Faults or Failures
Category:	All Prognoses
Horizon:	36 hours
Coverage / Accuracy:	60%

PHM Analysis: Prognostics Parameters

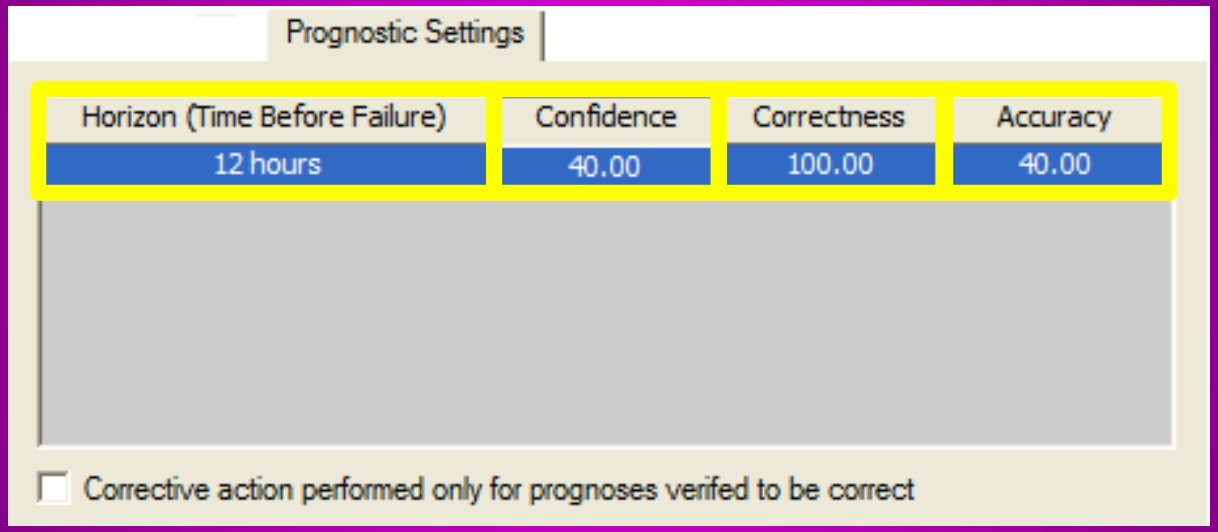
Usage of prognostic parameters in system PHM analysis:

- **Horizon & Accuracy** – defined for each prognosis
- **Scope & Category** – used to constrain PHM analysis
- **Coverage** – calculated during PHM analysis

Prognostic Definitions in *eXpress*

Horizon – time before failure

Accuracy – by default, set to the Confidence

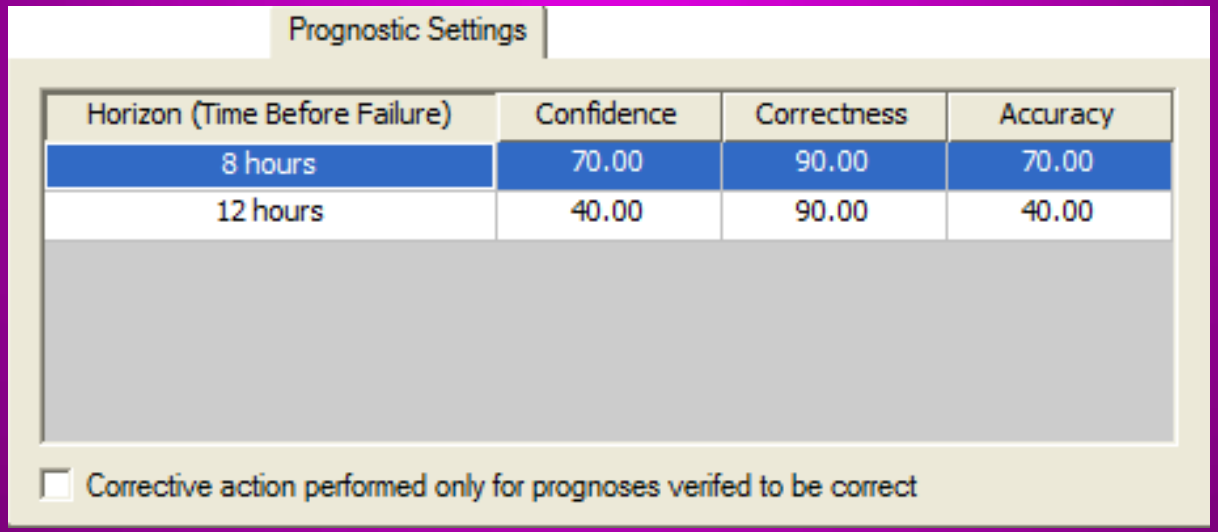


Confidence – likelihood that the failure will be prognosed by the specified horizon

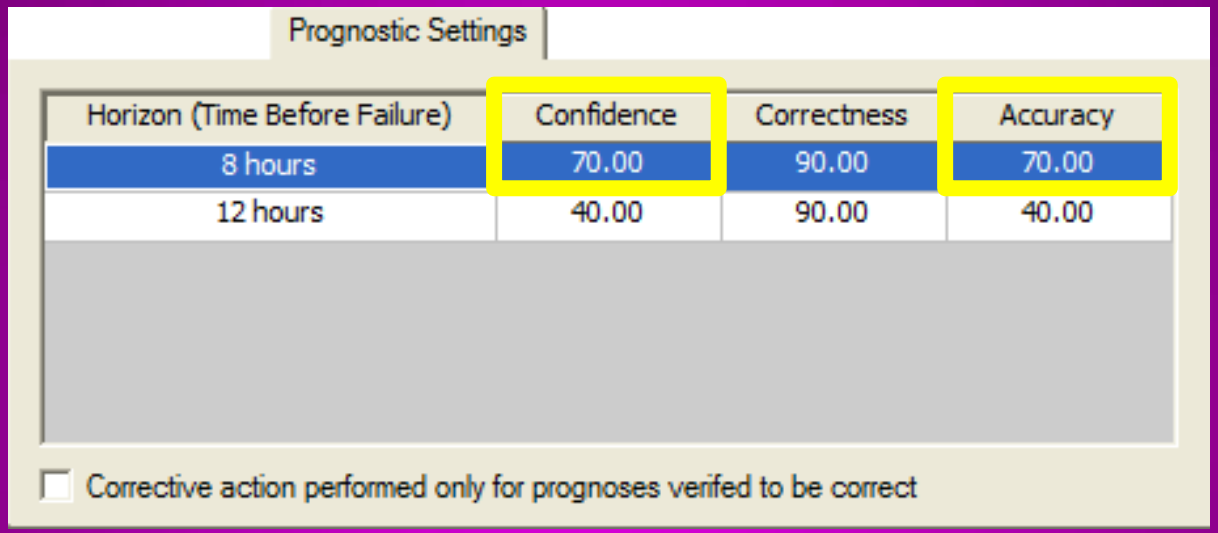
Correctness – likelihood that a prognosed failure will have actually occurred during the specified horizon

Prognostic Definitions in *eXpress*

Multiple Horizons can be used to represent the changing accuracy of a prognosis over time



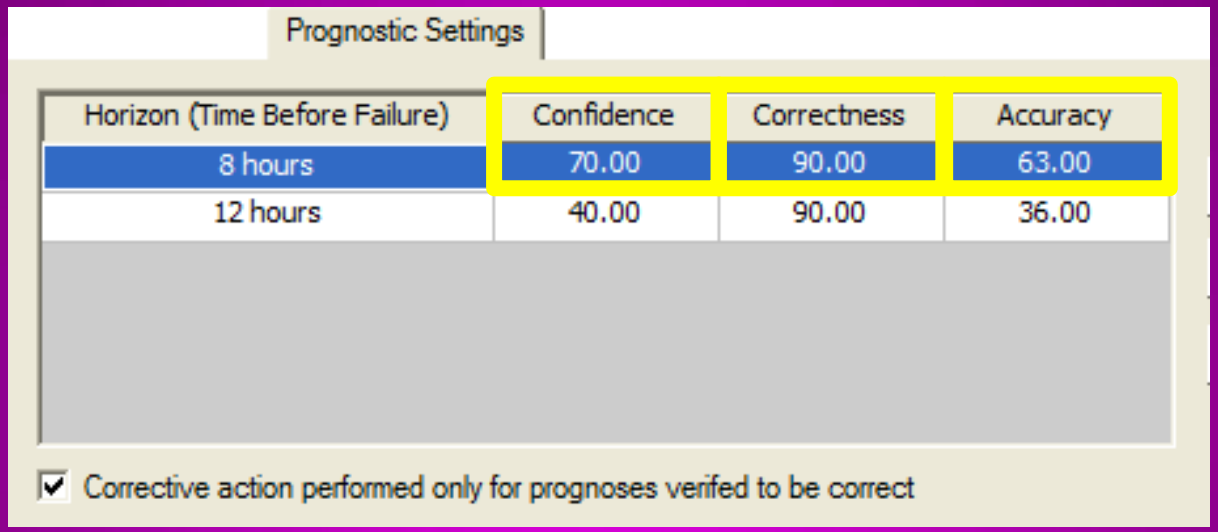
Prognostic Definitions in *eXpress*



When corrective action is performed without verification, then

Accuracy = Confidence

Prognostic Definitions in *eXpress*



When corrective action is performed only for prognoses that can be verified, then

Accuracy = Confidence * Correctness

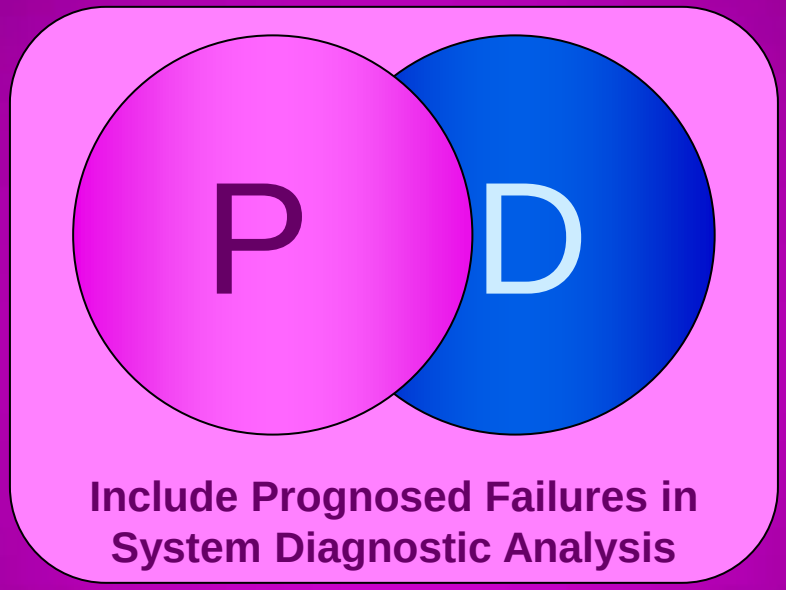
Prognostics-Informed Diagnostic Analysis

- Characterizes expected diagnostic performance for systems that will use prognostics.
- Impacts the calculation of any metrics that are affected by diagnostic performance, such as
  - Testability (FD/FI)
  - False Alarm Rate (FA)
  - Criticality Analysis (CA)
  - Mean Time to Repair (MTTR)
  - Availability (A_I/A_O)

Methods of Representing the Impact of Prognostics Upon Diagnostics

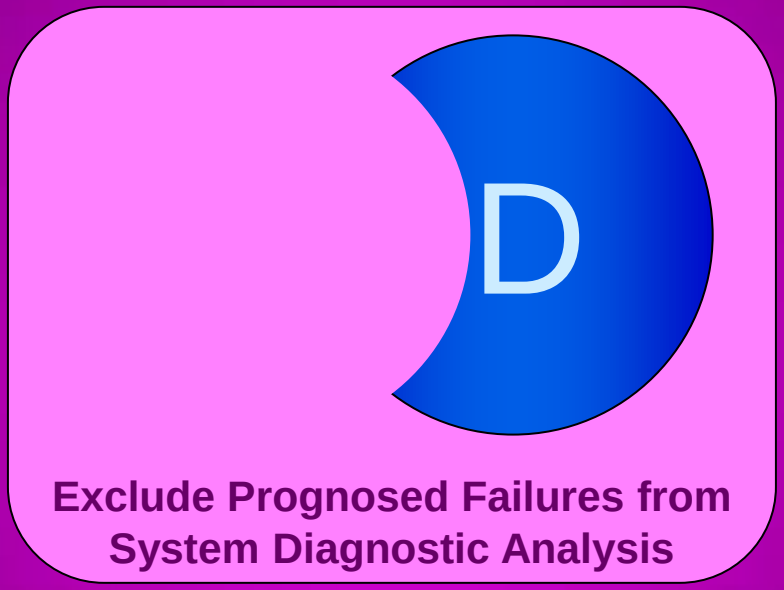
- Diagnostic Analysis
  - Include Prognosed Failures
  - Exclude Prognosed Failures
  - Ignore Prognosed Failures
- Prognostic Analysis
  - Ignore Diagnosed Failures

System Diagnostic Analysis That Includes Prognosed Failures



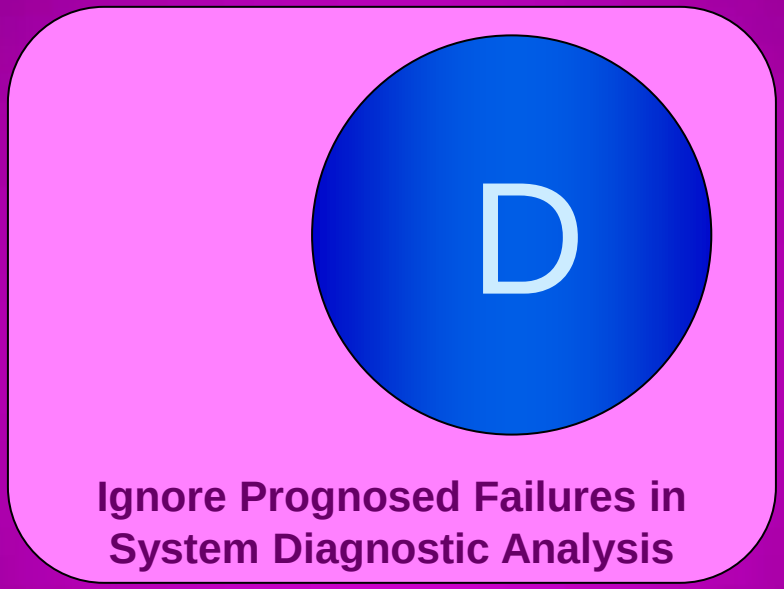
The repair of prognosed failures is taken into account (e.g. MTTR and Availability predictions).

System Diagnostic Analysis That Excludes Prognosed Failures



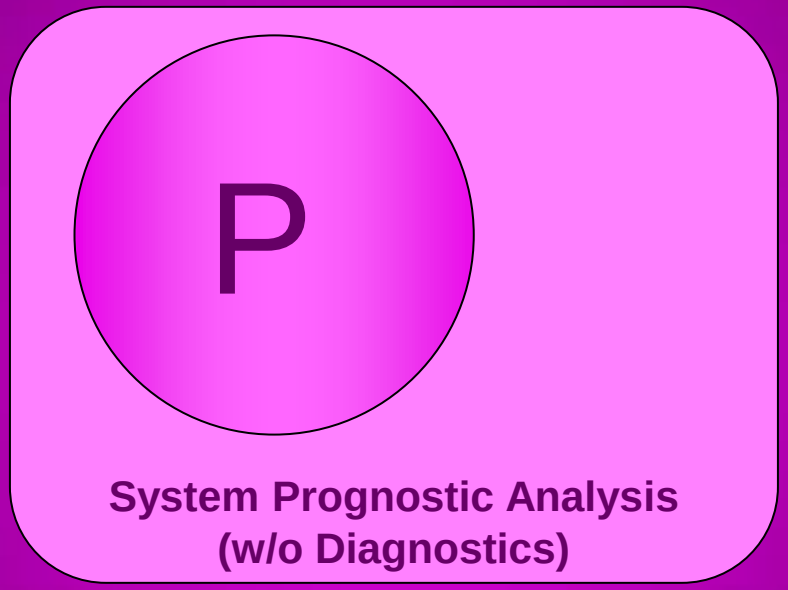
Only non-prognosed failures are considered – including failures prognosed with less than 100% accuracy (e.g., FD/FI percentages).

System Diagnostic Analysis That Ignores Prognosed Failures



Every failure is taken into account, just as if prognostics were not developed (e.g., Critical Fault Detection).

System Prognostic Analysis



Prognostics are evaluated, independently of diagnostics, to ensure that prognostic requirements are met for the entire system.

Next Steps – Improving Requirements

- Requirements should state whether they represent non-weighted percentages of possible failures or probability-weighted predictions for expected failures.
- There needs to be a greater Systems Diagnostics awareness when taking prognostics into consideration.
- Diagnostic Requirements should indicate how prognostics shall be incorporated into the full Systems Engineering process.