The U. S. Army Prognostics Framework Research and Development

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PROGNOSTICS FRAMEWORK (PF) TEAM

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PROGNOSTICS FRAMEWORK

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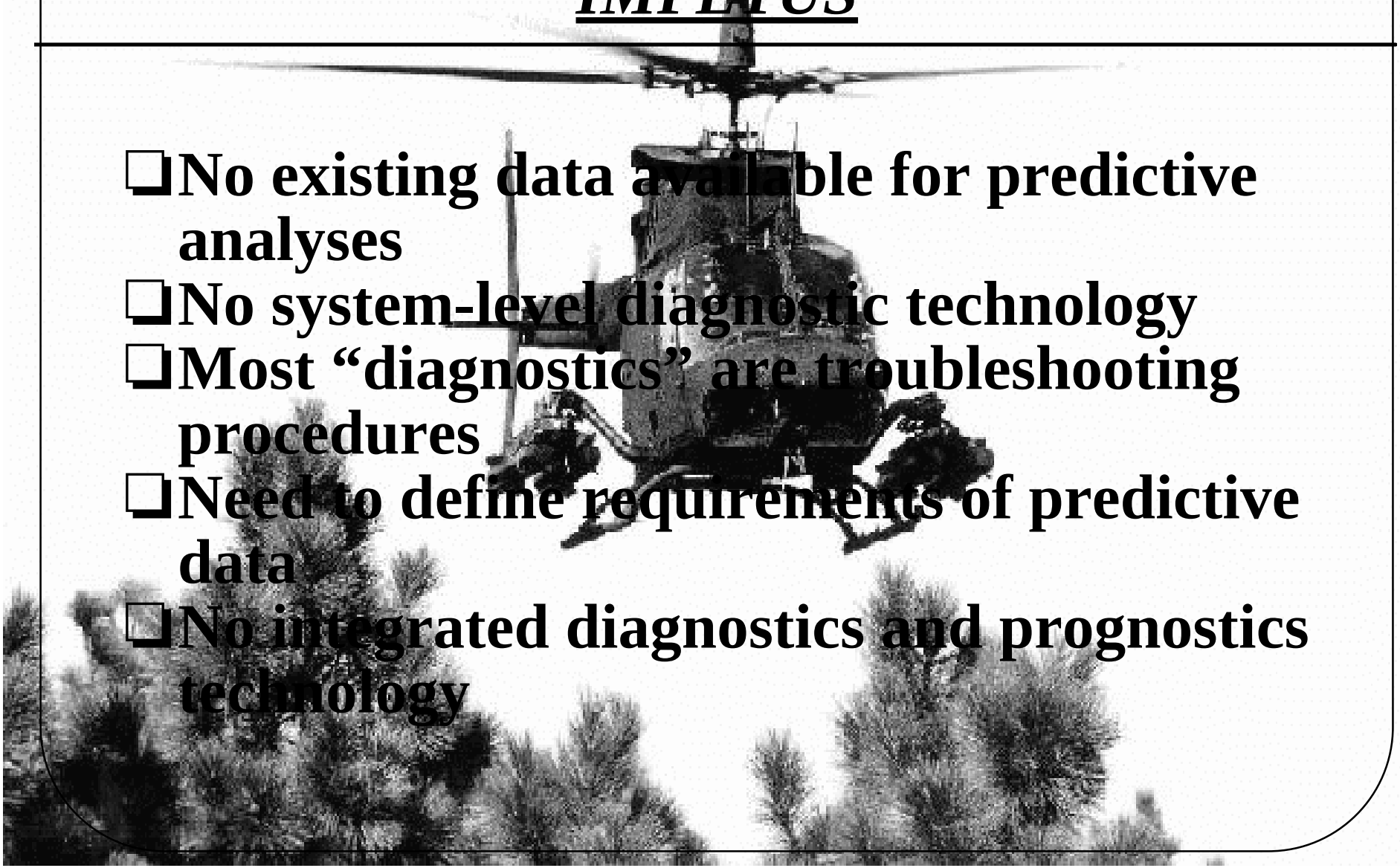


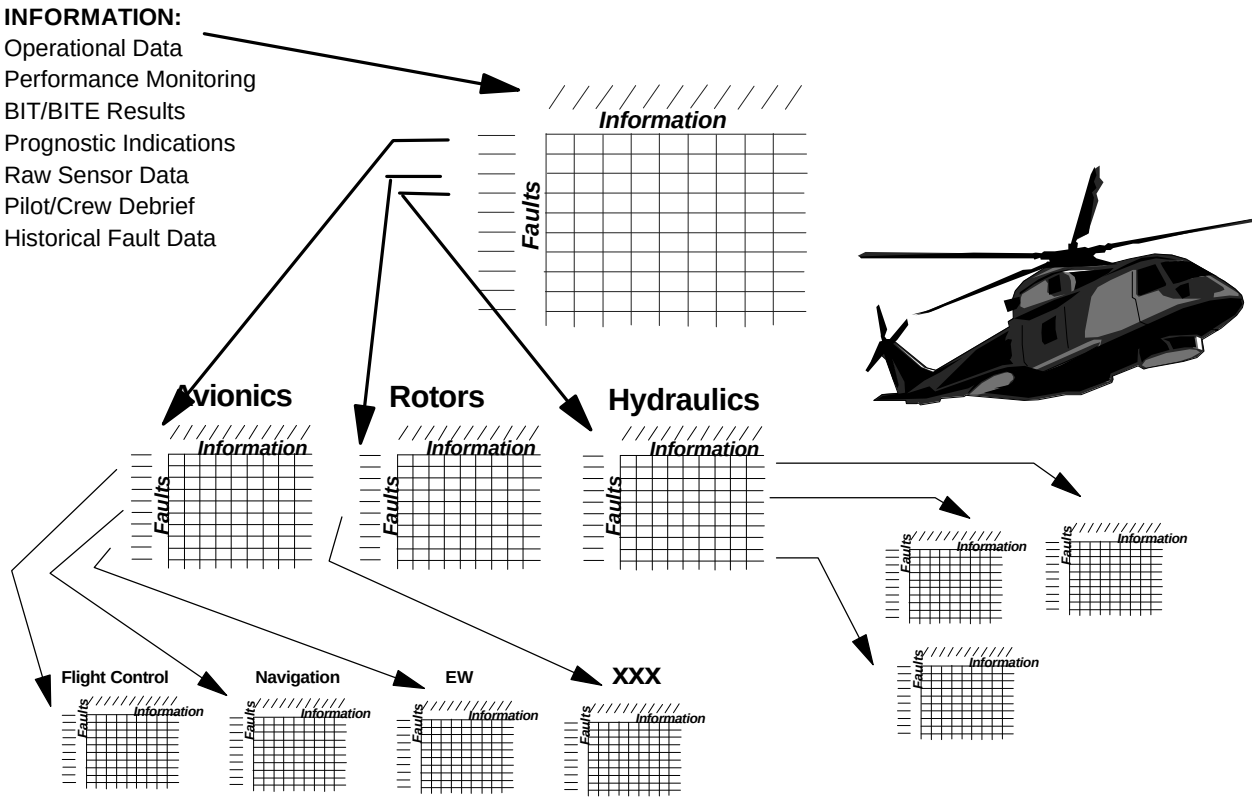
- No existing data available for predictive analyses
- No system-level diagnostic technology
- Most “diagnostics” are troubleshooting procedures
- Need to define requirements of predictive data
- No integrated diagnostics and prognostics technology

Why A Prognostics Framewo

- **Point Solutions too Expensive; Risky (Outcome unsure)**
- **Generic, Tailorable Approach will save time, money, and program-specific funds; fastest way for Army to converge on Prognostics capability**
- **Information to be provided to operational & maintenance crew should be normalized/standardized across Army systems**
- **Prognostic Mechanisms at various stages of maturity; system-level implementations are non-existent**
- **Need to Tie-in to logistics infrastructure is critical (e.g., IETM, logistics planning, mission planning, spare parts provisioning)**
- **Prognostics should be integrated with Diagnostics to provide a total "Health Management Capability"**

Why This Approach?

Diagnostician uses a design-based model of fault/symptom relationships to isolate faults



- **Open architecture; generically applicable**
- **Single knowledge base for embedded and off-line**
- **Software structure is extendible**
- **Hierarchical approach enables *system integration***
- **Can be used for legacy systems and new designs**

What is the Prognostics Framework?

- A *generic,* structured information architecture and tools to implement Prognostics by supporting
  - PMs in application of Prognostics
  - Operational Crew in Situational Awareness
  - Maintainers in Optimal Logistics Support
- Integrates current LIA TEDANN Program
- Can be applied to existing and new weapon systems
- Can be embedded or off-board
- Enables PMs to *Converge* on Prognostics as technology evolves
- Makes maximum use of existing Sensor/BIT data
- Automatically logs Historical Data

HTI

TEDANN

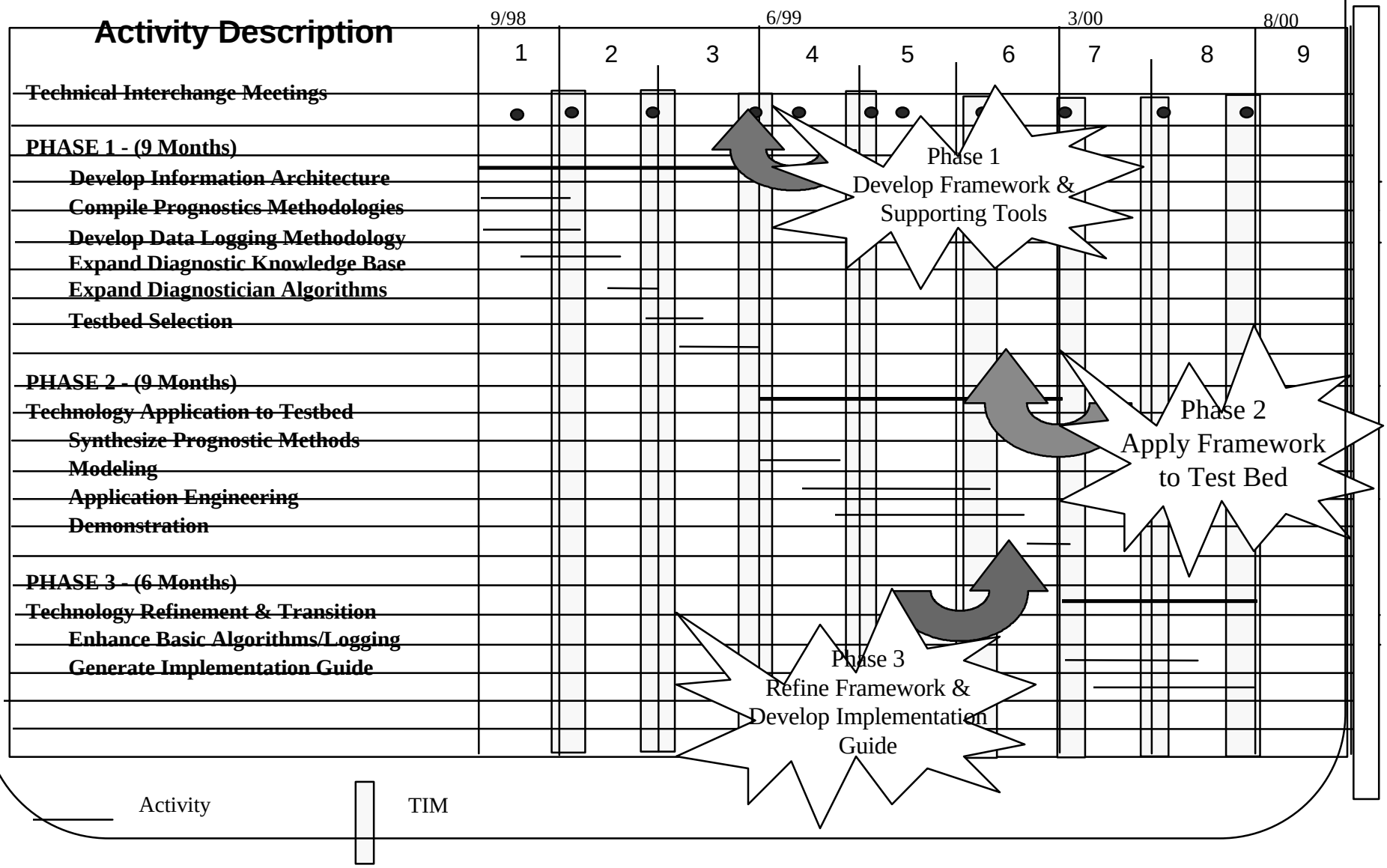
FAMPS

PFSA

Approach Makes Sense! Supports Army Policy Direction and Initiatives:

RML, Operational Readiness, Reduced Logistics Footprint, Force XXI, AAN

Prognostics Framework Schedule



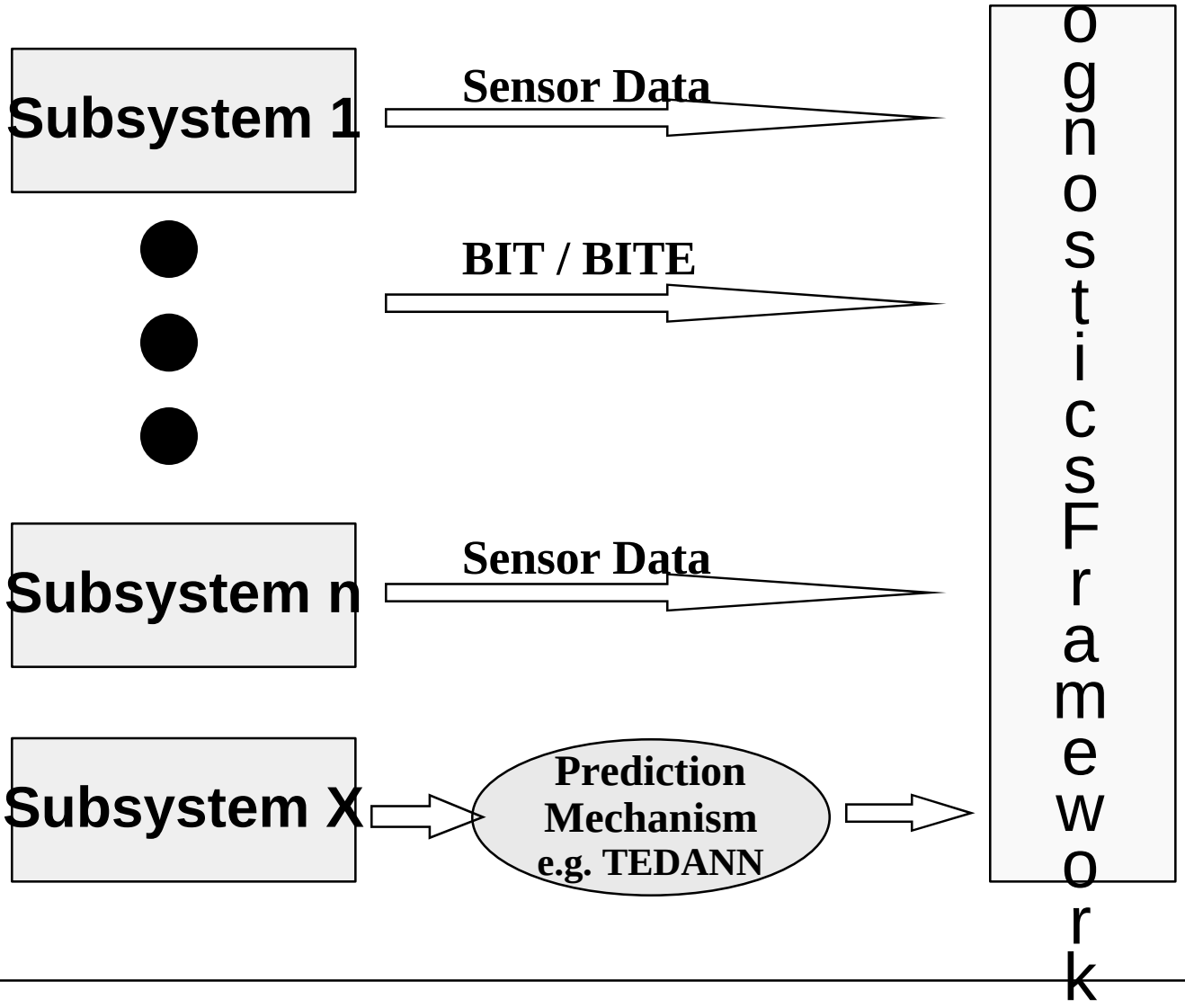
Prognostics Framework Architecture

Prognostics Framework
Complements Other Prognostics Efforts

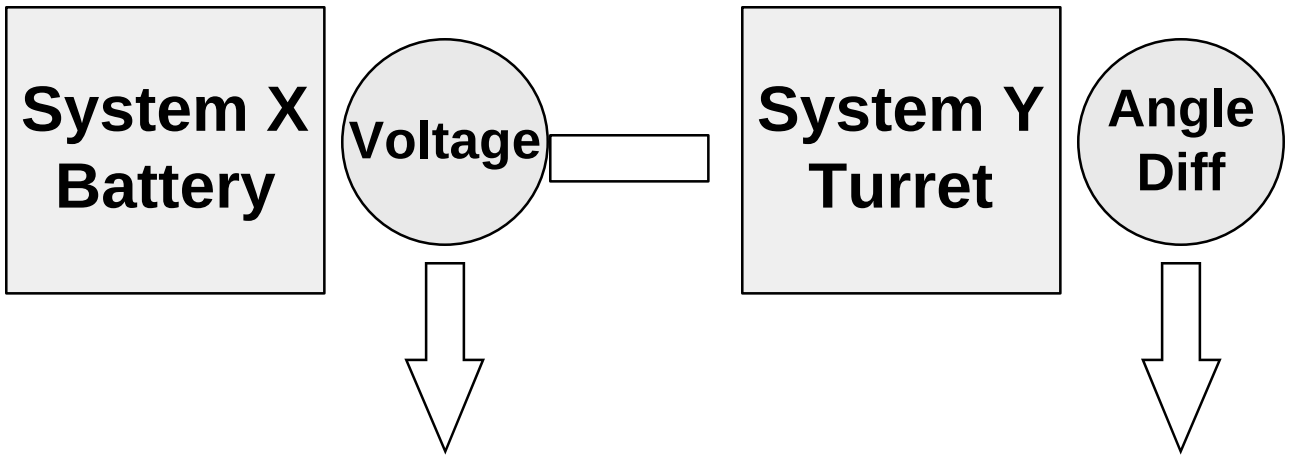
- Integrates Diagnostic/Prognostic Mechanism Outputs From Many Subsystems
- Provides Supplemental Prognostics
- Provides Diagnostic Analyses
- Ties-in to logistics infrastructure
- Prepares Information for Use By Both Operator & Maintainer

Prognostics Framework

Integrates Data From Many Subsystems



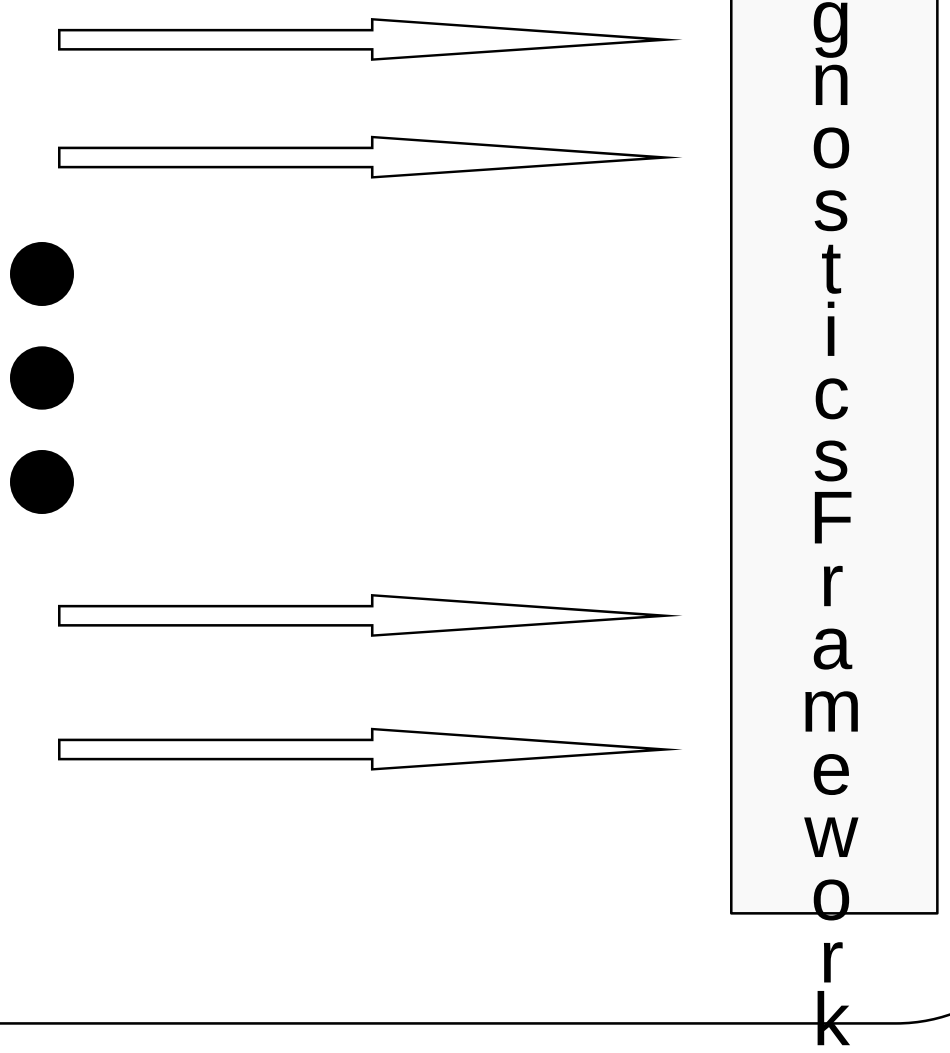
Prognostics Framework
Integrates Data From Many Subsystems



Prognostics Framework
(Relationships Between Systems)

Voltage Low	**and**	**Angle Failure =**	**Bad Battery**
Voltage Ok	**and**	**Angle Failure =**	**Bad Turret**

Prognostics Framework
Provides Diagnostics and "Supplemental" Prognostics Analyses



Prognostics Framework

Supports Operations and Maintenance

Prognostics Framework

Missions

Mission Possible or Not
Predicted Mission Success or Failure

Operations

Functions Available/Unavailable
Predicted Function Times To Failure

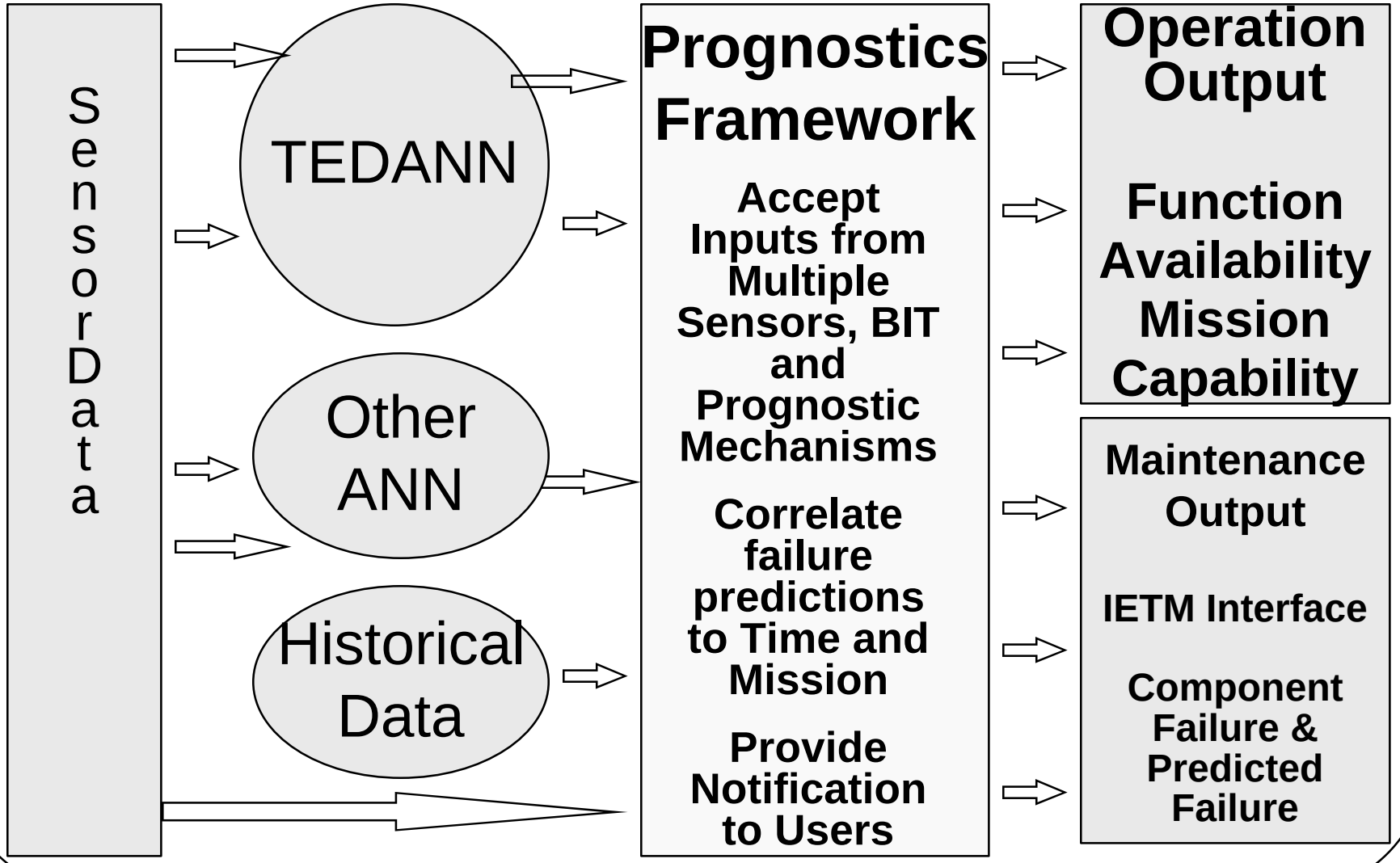
Maintenance

Components Requiring Repair
Components Needing Repair Within Time Period X
Spares & Tools Required for Fix

Bottom Line: ***Increased Operational Readiness & Battlefield Situational Awareness***

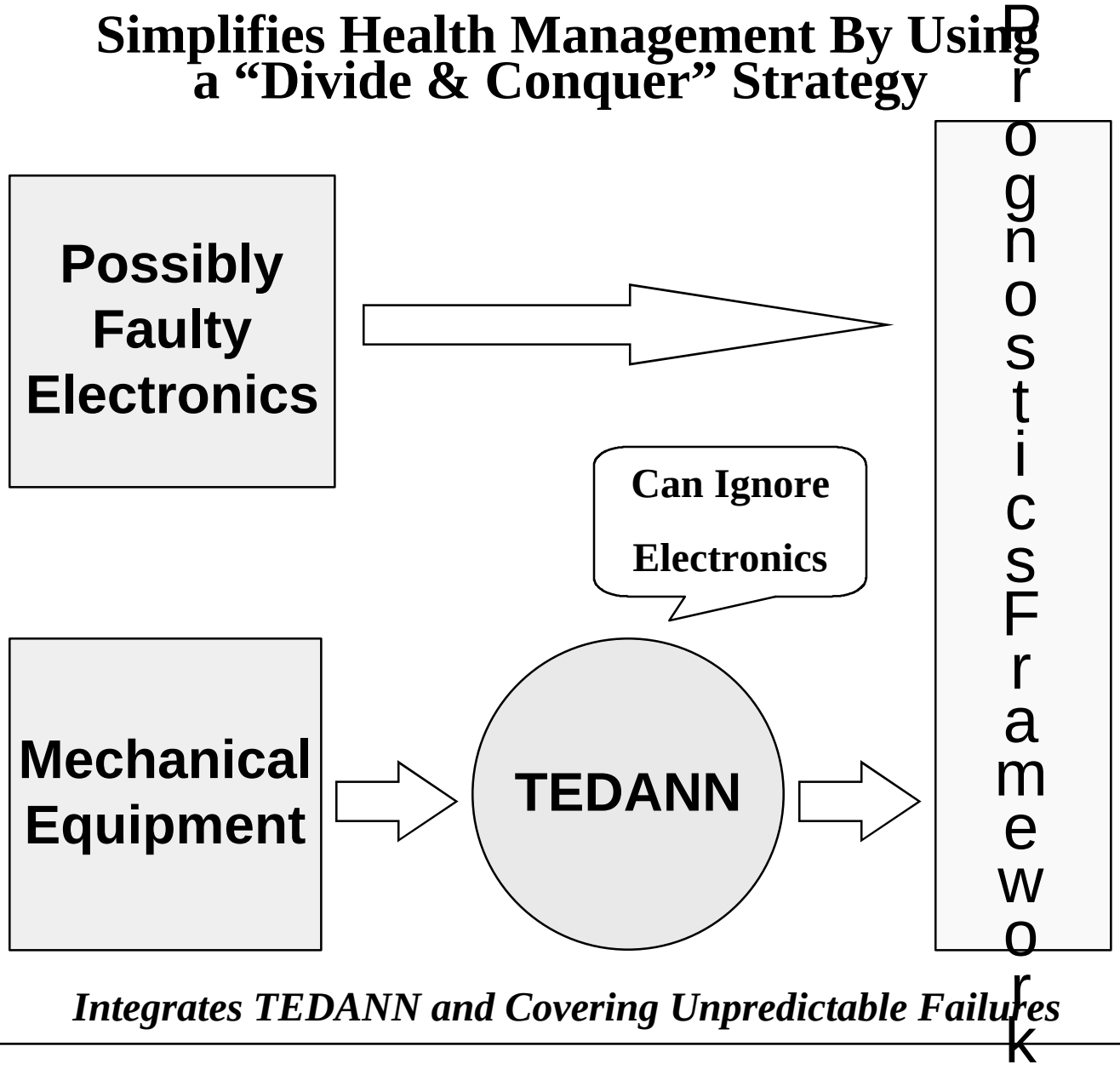
Prognostics Framework

Integrates Prognostics Mechanisms and Interprets Results For Users



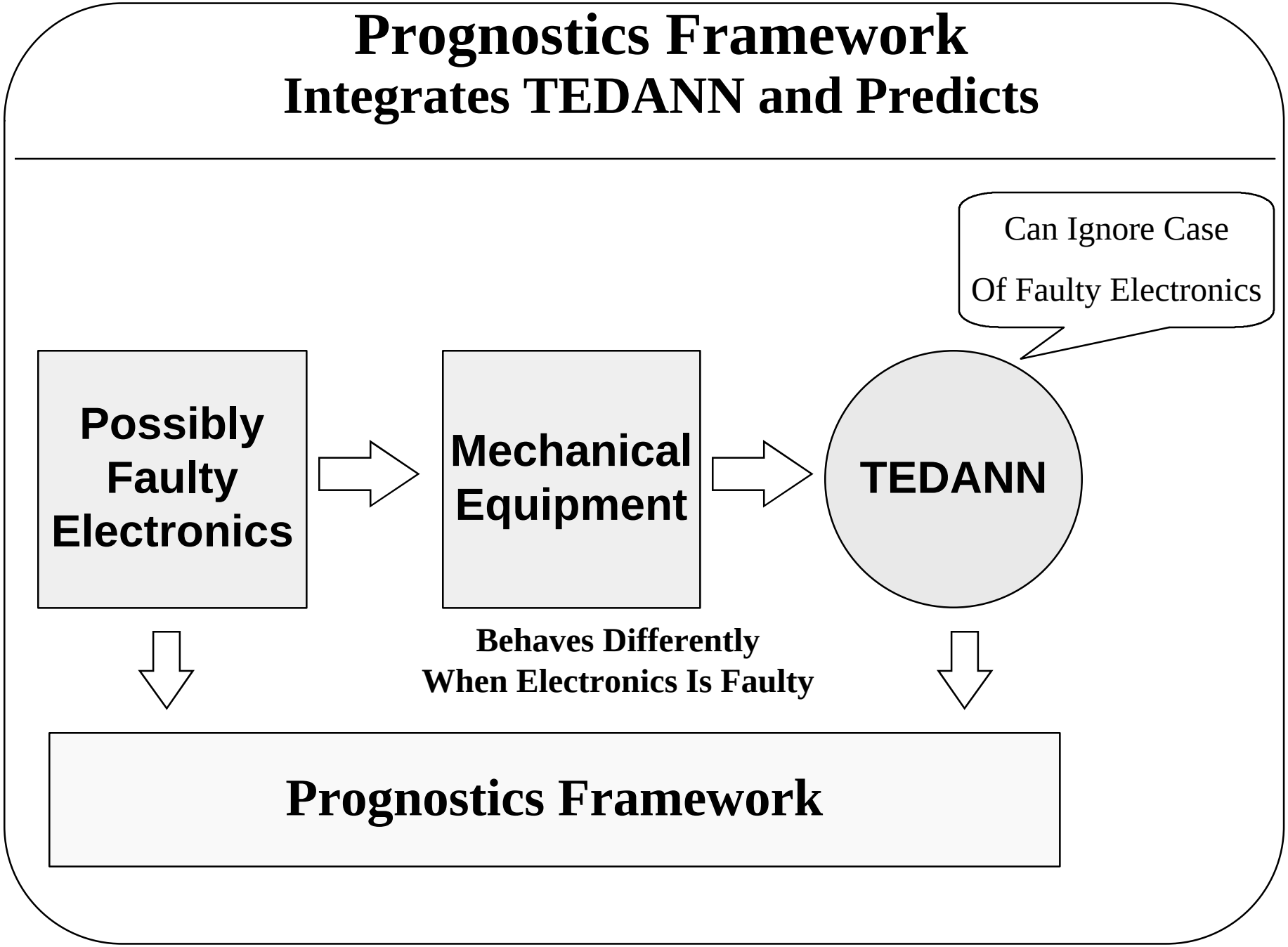
Prognostics Framework

Simplifies Health Management By Using a "Divide & Conquer" Strategy



Integrates TEDANN and Covering Unpredictable Failures

Prognostics Framework
Integrates TEDANN and Predicts

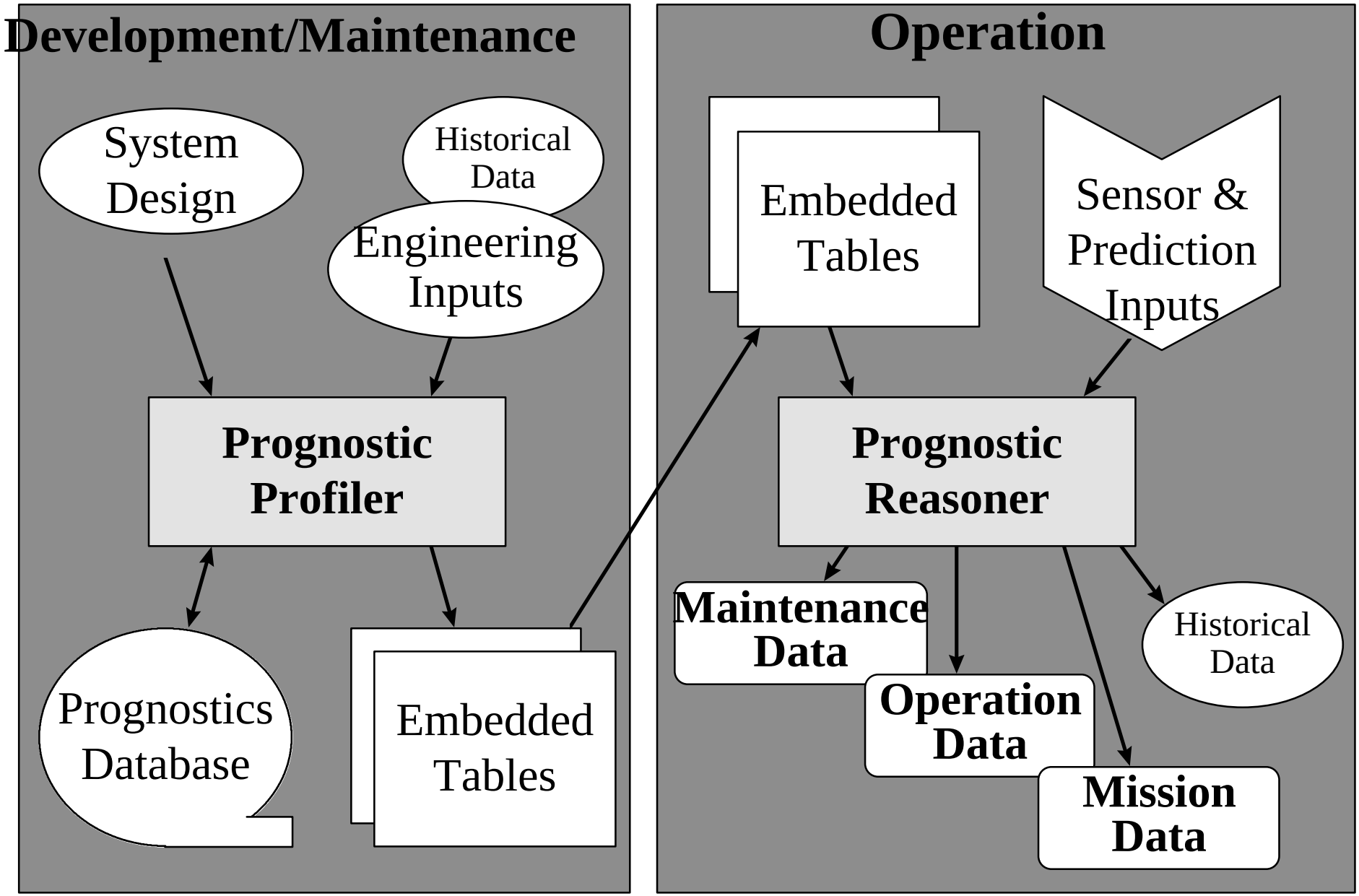


Prognostics Framework Design Approach

Prognostics Framework
Design Goals

- **Provide a Generic Solution to Prognostics Implementations**
- **Open Architecture allows complementing and enhancing Existing and Future Prognostics Mechanisms**
- **Minimize Cost of Development and Maintenance of Prognostics Framework Applications**

Top Level Prognostics Framework Design



Prognostics Framework

Prognostics *Profiler* Software Module

<u>Purpose</u>: Support both development and maintenance of an operational Prognostics Framework System.

<u>Design Goals</u>: Provide Services for developing and maintaining an operational Prognostics Framework System that are easy to understand and to use.

<u>Approach</u>: Provide developer interfaces that are similar to the Diagnostic Profiler in feel but extending support to prognostics.

Prognostics Framework

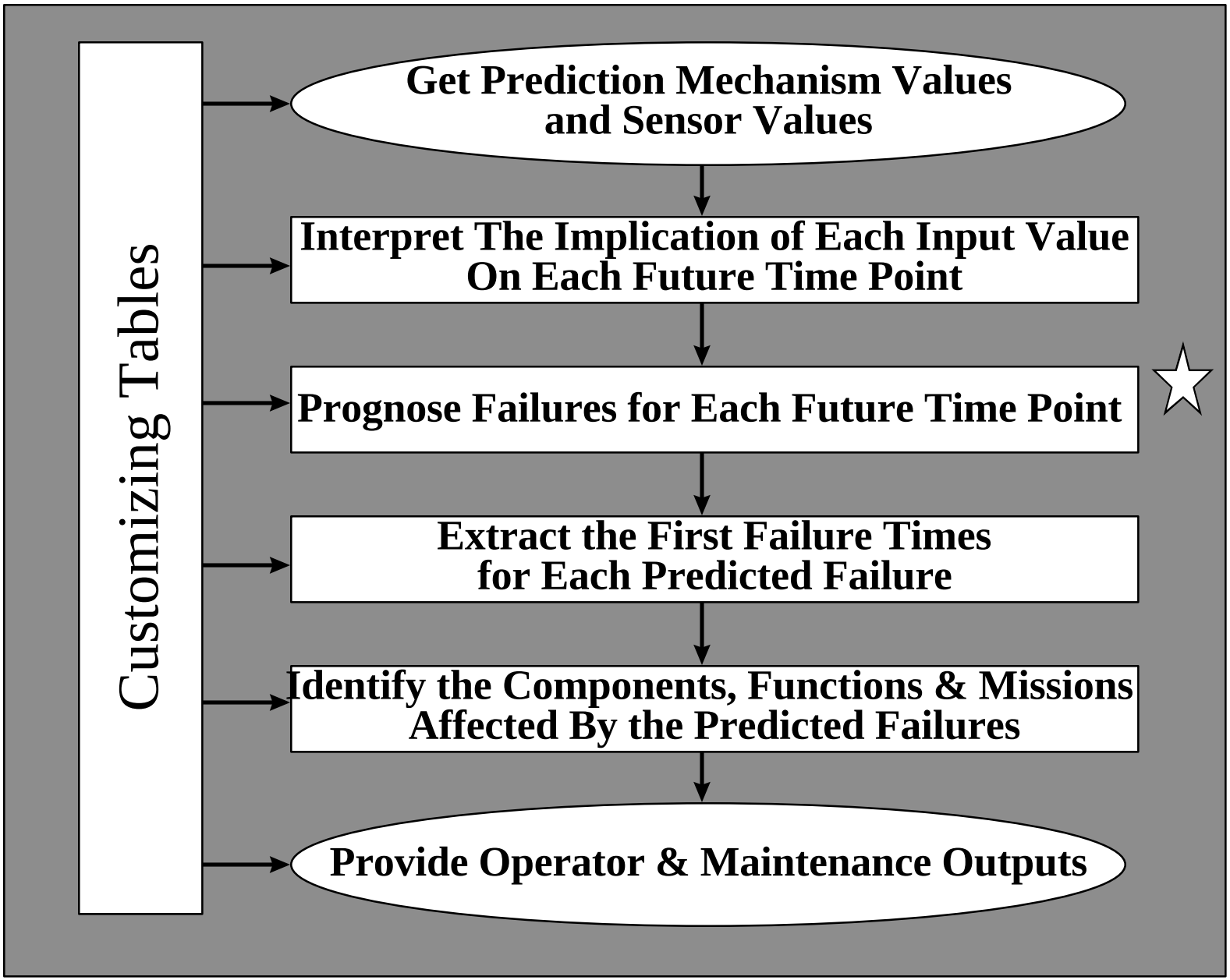
Prognostics *Reasoner* Software Module

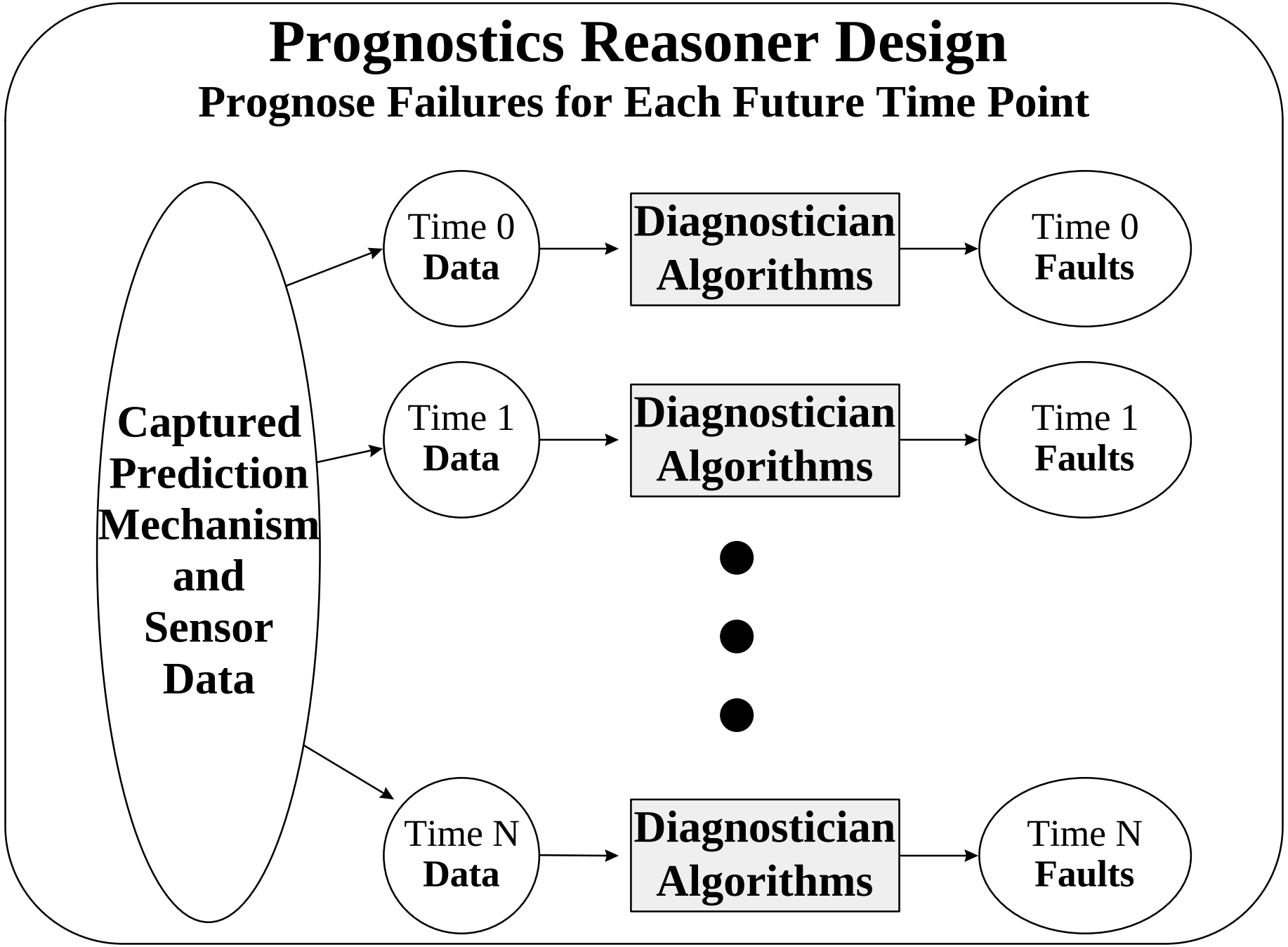
Purpose: Analyze the test and prediction inputs and provide results that are understandable from the mission and maintenance point of view whenever those results are needed

Design Goals: Provide software that (1) can be embedded on a weapons platform, (2) can be tailored using the Prognostics Profiler, and (3) acquires, analyzes, and interprets input data for the use of maintainers, operators, and mission planners

Approach: Provide algorithms based on a three dimensional fault-symptom-time matrix and other tables to acquire data, analyze the results, and generate outputs

Prognostics Reasoner Block Diagram

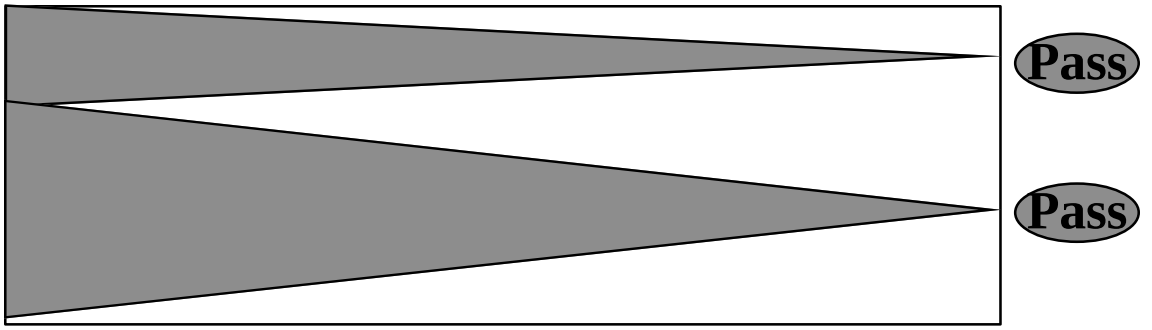



Prognostics Reasoner Design
Prognose Failures for Each Future Time Point
Captured Prediction Mechanism and Sensor Data
Time 0 Data
Time 1 Data
Time N Data
Diagnostician Algorithms
Diagnostician Algorithms
Diagnostician Algorithms
Time 0 Faults
Time 1 Faults
Time N Faults

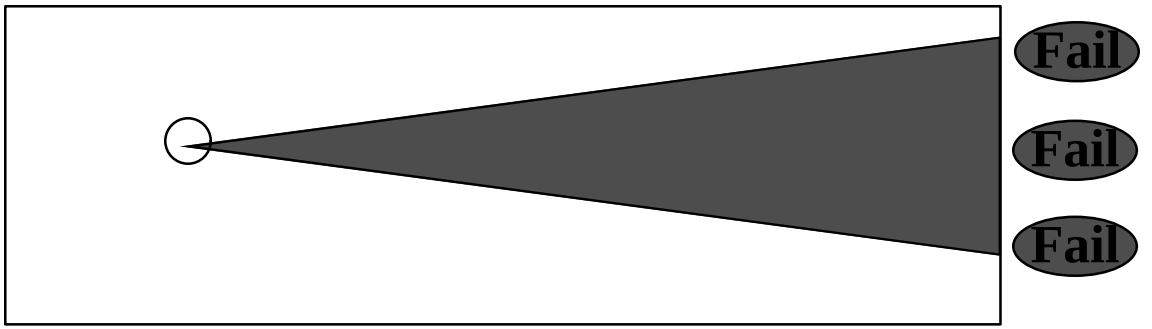
Prognostics Reasoner Design

Diagnostician Algorithms - Cones of Evidence

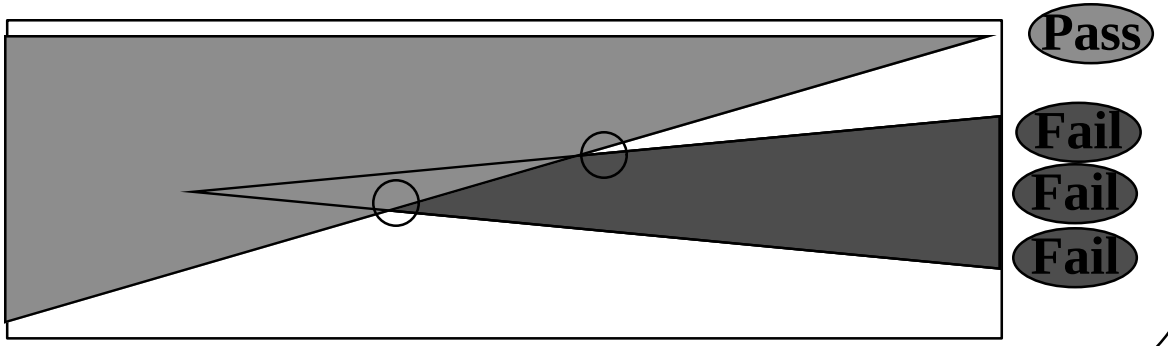
Pass Data Clears Some Faults



Failure Data Is Explained By Faults



Pass & Fail Data May Identify Multiple Faults



Prognostics Mechanisms Survey Results

Prognostics Framework

Research & Development Efforts

- **Machines and Systems: Tanks, rotorcrafts, Navy ships, process and power plants, Joint Strike Fighter, obstacle guidance, etc.**
- **Development works: Sensors, Health and Usage Monitoring, Condition Based Maintenance (CBM), Mission Readiness, obstacle Guidance Systems**
- **Types of Prognostics: Turbine engines, rotor stability, system vibrations, gears, shafts, power plants, wind tunnel compressors, etc.**

Prognostics Framework

Current Major R&D Efforts

- **Turbine Engines: PNNL; ARL (D)**
- **Helicopter gearbox prognostics: Princeton and Boeing/Office of Naval Research (ONR) (E)**
- **CBM for Intelligent Ship: Pen State/ONR (D)**
- **Obstacle avoidance: Univ. Southampton & UK Dept. of Defense (R/E)**
- **Power plants Intelligent Data Acquisition & CBM: PAC & PROSIG (U)**
- **Wind tunnel compressors automated reasoning expert system: AMES Research Center (D)**
- **Power transmission systems (MURI IPD): Penn State/ONR (R)**
- **Statistical Network Modeling (ModelQuest): AbTech/Rome Labs (U)**

PROGNOSTICS FRAMEWORK
DELIVERABLES

- **Generic Model Structure for Predictive Analysis**
- **Prognostics Framework Development Tool and Implementation Guide**
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- **Prototype Prognostics Framework on a Testbed subsystem**