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Maturation and Certification of HUMS Validation of FAA HUMS AC

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Boeing Phantom Works

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FAA Tech Center, Atlantic City, NJ

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Background

Health Management is an Enabler for Safety, Availability and Affordability Improvements

- **The system at it's full maturation will allow condition based maintenance**
- **A change in maintenance process requires qualification and certification**

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Background(cont.)

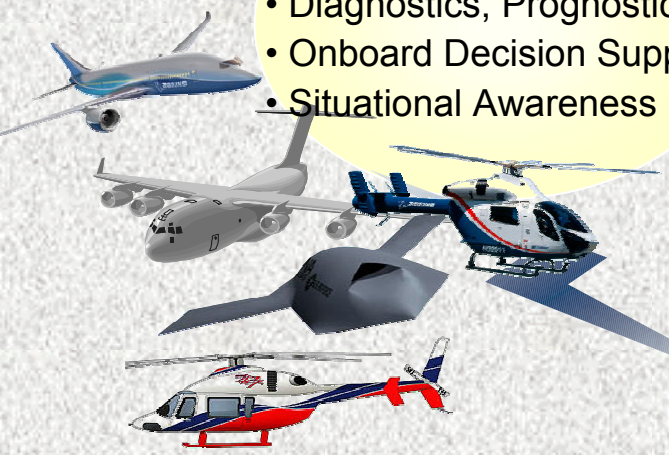
Effective Diagnostics:

- Reduced Trouble-shooting
- Reduced False removals
- Reduced Support Cost – Accident Investigation

Effective Prognostics:

- Accident Prevention – Improved Safety
- Maintenance Planning – Improved Availability

Background(cont.)

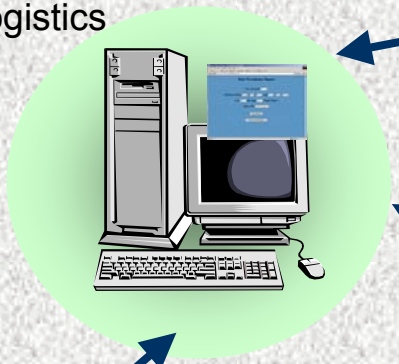


Onboard Health Management
- Diagnostics, Prognostics
- Onboard Decision Support
- Situational Awareness

Integration with Adaptive Control
- Best Performance with Degraded Systems

Logistics Network
- Spares,
- Transportation,
- Suppliers, Training, T

Ground-Based Health Management
- Diagnostics, Prognostics, Maintenance Reasoner
- Data Management
- Interface to Maintenance and Logistics



Operations / Commander Decision Aiding
- Asset Availability
- Mission Readiness
- Mission Capability

Maintenance Management System
- Scheduling
- Maintenance Aids

HUMS Elements
Candidates for Certification

1 - Hardware

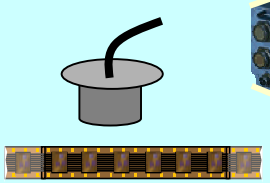
- On-board
  - Data collection and processing
  - Data storage and Download
  - Data presentation
- Off-board
  - Data Download and Hosting

2 - Software

- On-board
  - Data Acquisition, Processing, Storage and Transfer
- Off-board
  - Frame Work, Data Management and Algorithms

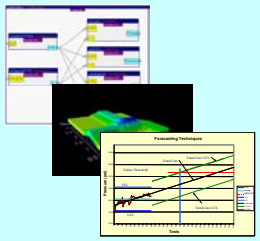
Certification
FAA Requirements

Sensors, Data Acquisition

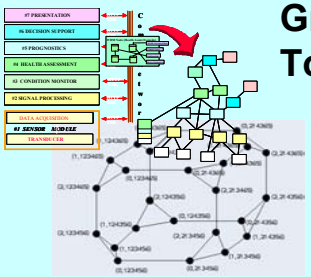


Onboard System

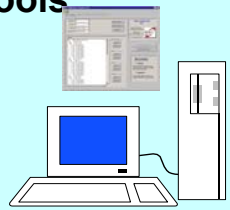
Algorithms: Diagnostic Prognostic



S/W & H/W Architecture



Off Board Ground Station Tools



Maintenance and Support System Interface

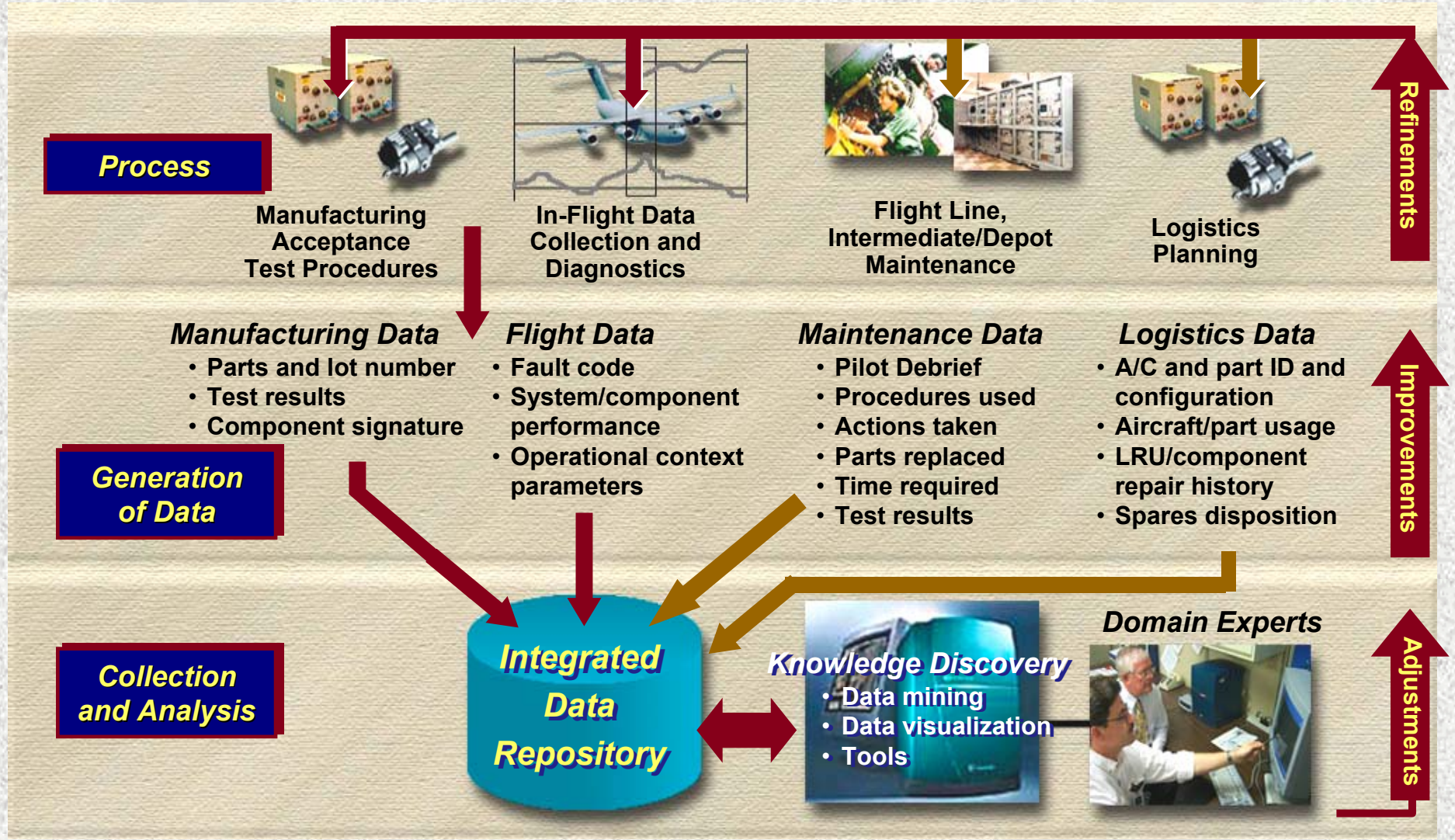
Installation

Credit Validation

Continued Airworthiness

End-to-End Certification

Certification and Health Management Development Process



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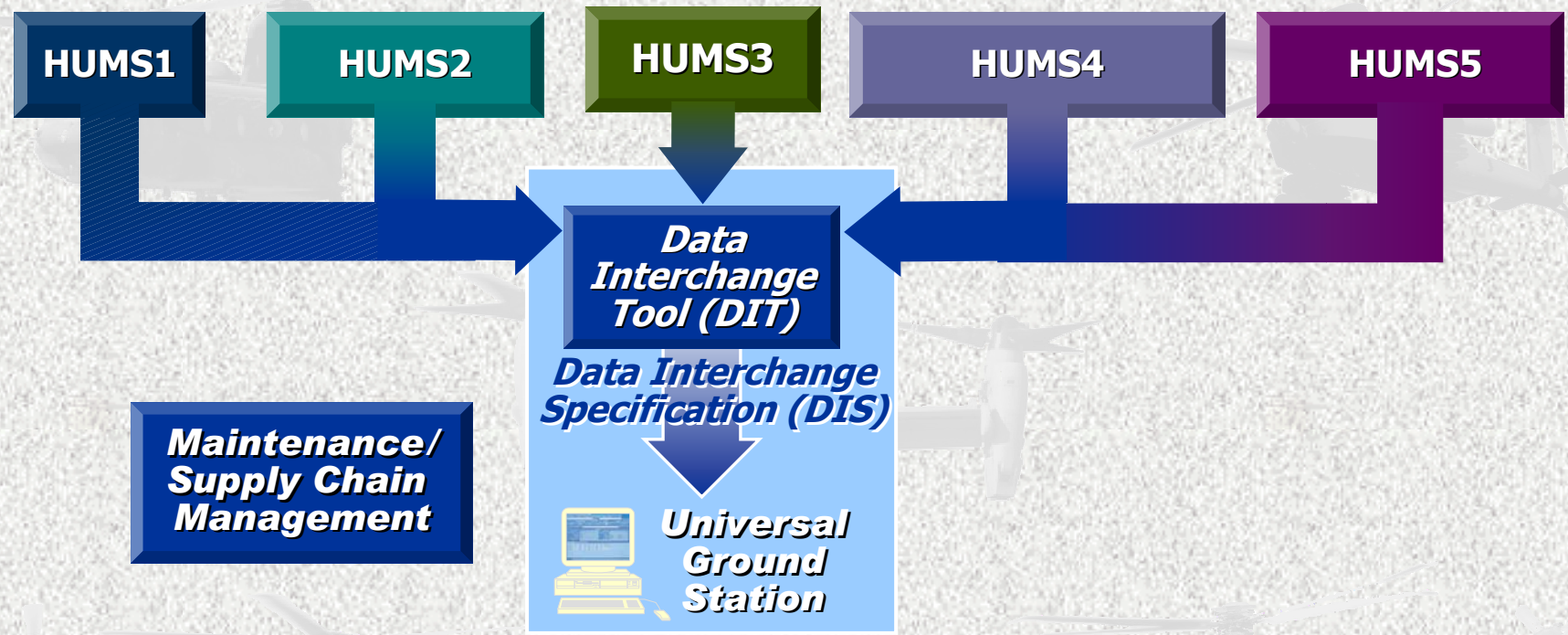
Boeing Related Projects

- RITA HUMS Technology
- Rotorcraft Damage Tolerance (RCDT)
- Structural Usage Monitoring System (SUMS)
- Transmission Vibration Diagnostics System (TVDS)

RITA HUMS Technology
Data Interchange Specification(DIS) Universal Ground Station



RITA HUMS
Universal Ground Station

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RITA HUMS Universal Ground Station

Data Administration Help

AH-64 | CH-47 | RAH-66

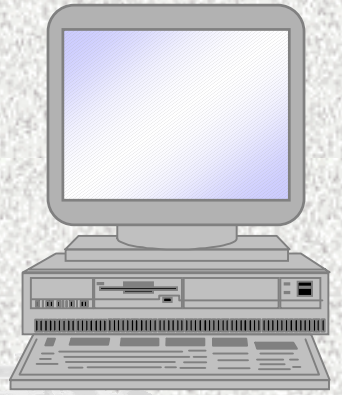
- Fleet
  - N0201
  - N0345
  - N0495
  - N0501
  - N0543
  - N1001
  - N2002
  - N3003
    - 2002-07-11 20:24:41
      - Logbook
      - RTB
      - Flight
      - HUMS

Action	Status
Validating files for the selected format	Success
Converting to DIS format	Done
Reading Logbook data file	Not Present
Reading RTB data file	Success
Retrieving flight information	Done
Aircraft Serial Number	3003
Flight GMT	2002-07-11 20:24:41-000000000
Storing RTB data	Success
Reading Flight data file	Not Present
Reading HUMS data file	Success
Storing HUMS data	Success
Processing Data	Done
Download Complete	

Aircraft Records | Fleet Records | Suporting Data | Details | Print

Start 5:12 PM

Data Presentation
Download result
DIS Files:
Log Book
RTB
Flight
HUMS



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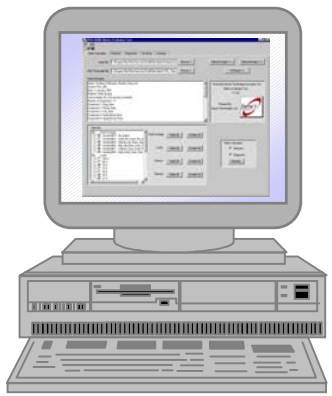
Evaluation of Diagnostics Algorithms Metrics Evaluation Tool

Motivations: **Identify Metrics to evaluate the performance and effectiveness of transmission diagnostics algorithms**

RITA Metrics Document - SAE ARP5783 (PY 2000)

RITA Metric Evaluation Tool (MET) (PY 2001-2003)

- **Threshold-setting criteria**
  - Detection rate
  - False alarm rate
- **Noise sensitivity**
- **Fault isolation/Classification**



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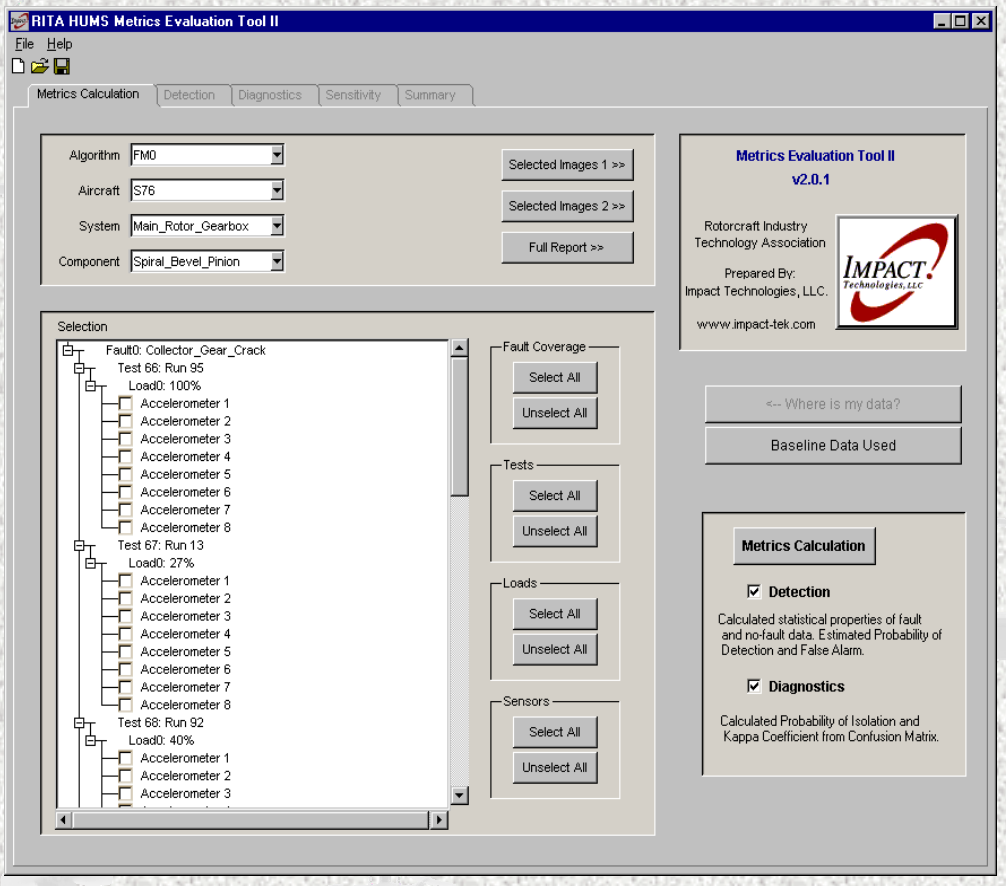
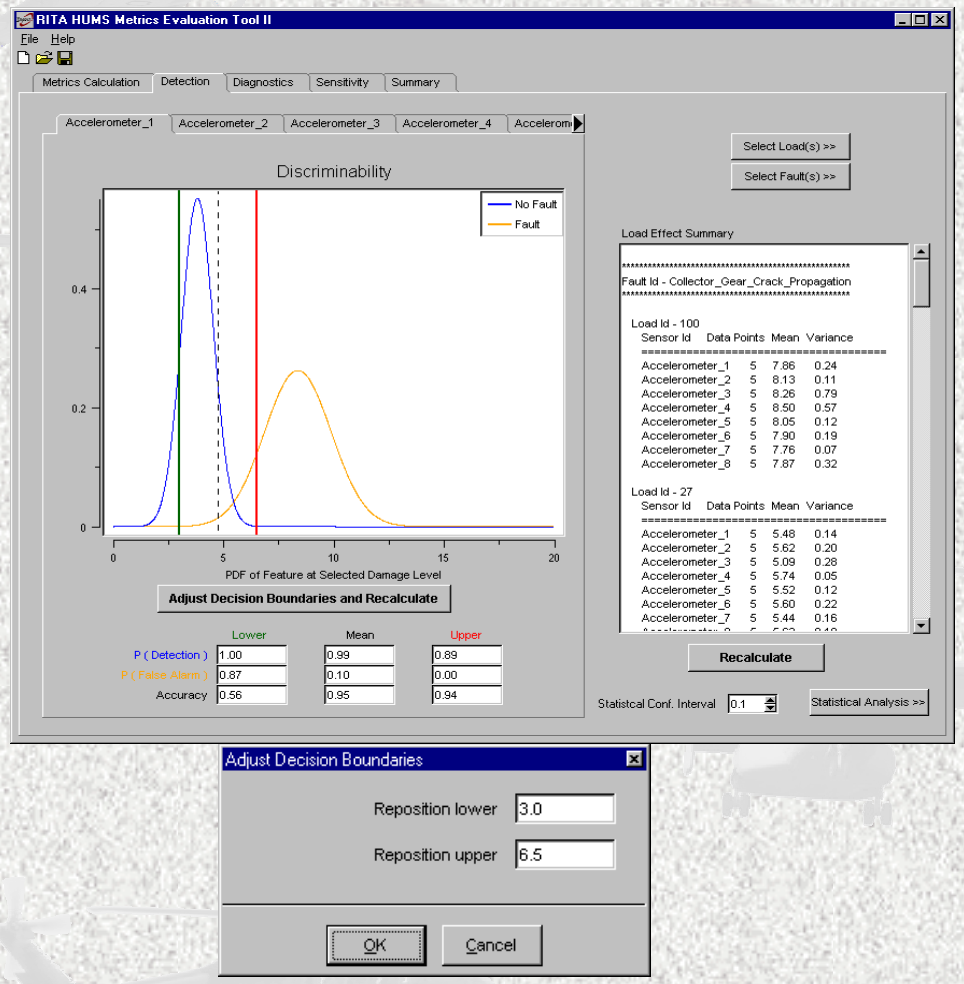
Metrics Calculation Window



- Allows user to select and unselect individual faults, features, loads, and sensors
- Hierarchical choices are dynamically generated from available data in Database
- User chooses detection metrics, diagnostic metrics, or both

MET Detection Window Threshold Setting



- Displays feature discriminability plot at normal and faulted condition
- Display results by individual sensor or as composite
- Summary sorted by load and fault conditions
- Decision threshold can be manipulated
- Resulting Probability of Detection and FA calculated

RITA HUMS MET Database Population

			Torque								
			27%	40%	45%	50%	60%	70%	75%	80%	100%
	2	Planetary Bearing Corrosion									99
F	3	Input Pinion Bearing Corrosion	22, 50	27, 55	26, 63	23, 60	37, 56	24, 61	25, 62	38, 57	30, 58
A	4	Spiral Bevel Input Pinion Spalling	17, 89	13, 85	12, 84	81	86	10, 82	83	15, 87	16, 88
U	5	Helical Input Pinion Chipping						85	86	90	91
L	6	Helical Idler Gear Crack Propagation						40	41	45	46
T	7	Collector Gear Crack Propagation	13	92		41	19	42	43	20	95
	8	Quill Shaft Crack Propagation	79	80	81	82	83	84	85	86	87
	9	No Defect	02	07	06	03	08	04	05	00	01

Microsoft Access and Oracle 8i

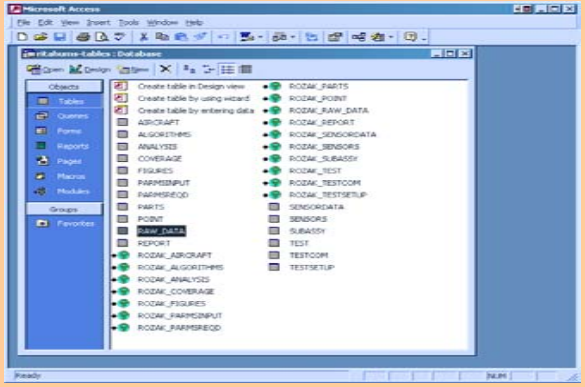
RITA HUMS DB

Westland 22 Second Data

Matlab Auto Segmentation

Visual Basic Auto Insertion

Access Database Interface



SQL Auto Data Population

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Transmission Vibration Diagnostics System TVDS

Photograph of EDM Notch

Photo of Crack Propagating from EDM Notch

Seeded Fault Test Gear Specimens

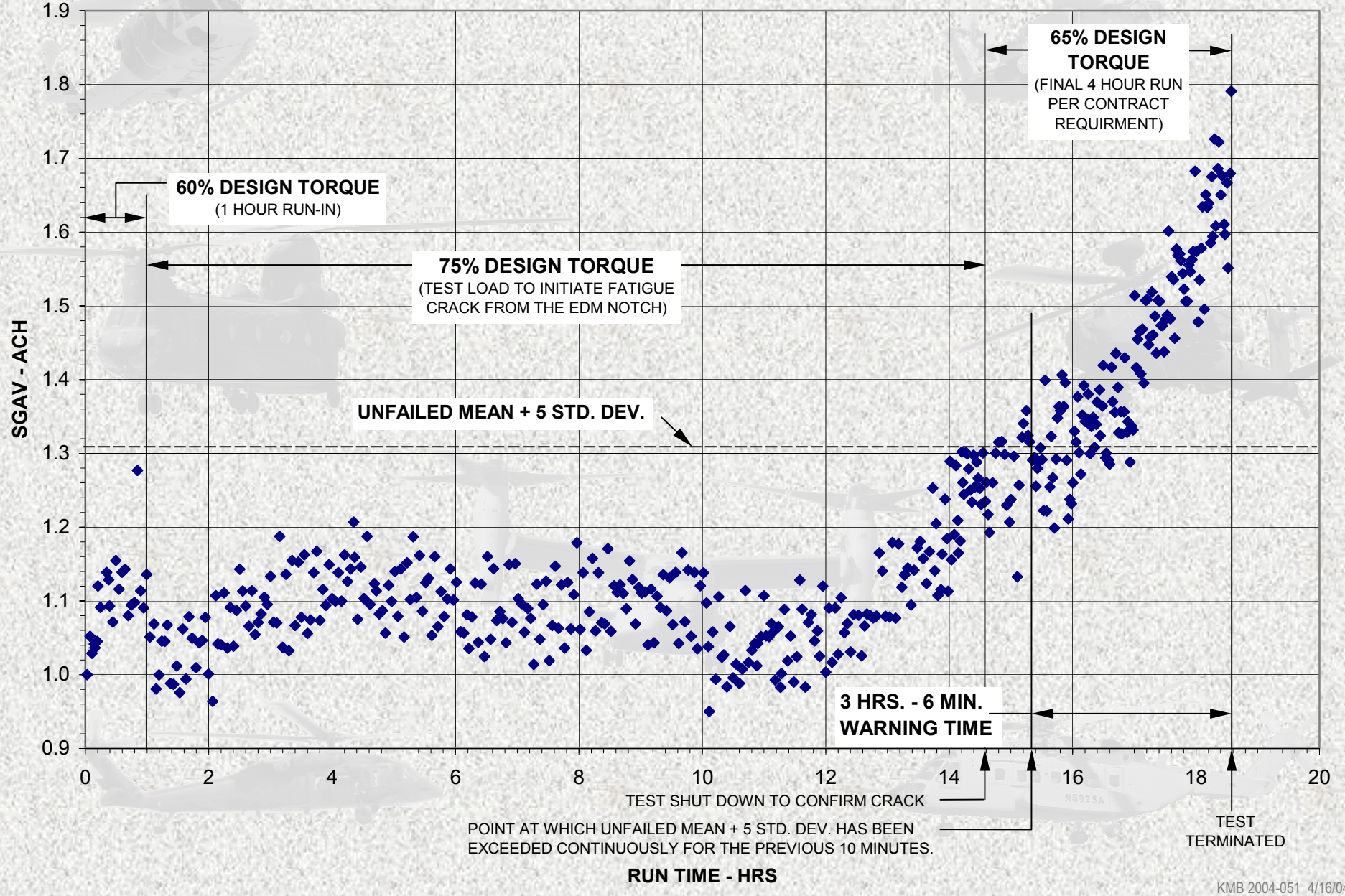
CH-47D "SEEDED – FAULT" TEST SUMMARY

Test Transmission	Machined Defect Location	Intended "Seeded – Faults"	Test Status	Warning Time (Minutes)
Combiner Xmsn	Spiral Bevel Pinion (Note 1)	Pinion Tooth Root Crack (Non-seeded Fault)	Completed	66
Engine Xmsn	Spiral Bevel Pinion Tooth Root	Pinion Tooth Root Crack	Completed	354
Combiner Xmsn	Spiral Bevel Collector Gear Tooth Root	Gear Tooth Root Crack	Completed	132
Forward Rotor Xmsn	1st Stage Planet Gear Tooth Root	Planet Tooth Root Crack	Completed	No Failure Test Terminated
Forward Rotor Xmsn	Spiral Bevel Pinion Tooth Root	Pinion Tooth Root Crack	Completed	251
Aft Rotor Xmsn	Spiral Bevel Gear Tooth	Gear Tooth Root Crack	Completed	252
Aft Rotor Xmsn	2nd Stage Sun Gear Tooth Root and internal spline Tooth Root	Gear Tooth Root Crack	Completed	53 (Note 2)
Aft Rotor Xmsn	**Spiral Bevel Pinion Lube Hole**	**Pinion Shaft Crack**	**Future Test**	
Aft Rotor Xmsn	**1st Stage Planet Gear Bore**	**Planet Gear Bore Crack**	**Future Test**	

Notes:
1. The combiner transmission spiral bevel pinion tooth bending failure had already been completed during overload testing of a non-shotpeened gear.
2. Warning time is based on post failure Mechanical System Diagnostic Analyzer (MSDA) partial analysis of recorded data (Analysis not completed).

SEEDED FAULT TEST DATA

SGAV - ACH VS. RUN TIME



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Structural Usage Monitoring System (SUMS)

- Developed and Validated Regime Recognition Algorithms.
- Developed Ground Station Processes.
- Collected In-service usage data.

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MH-47E SUMS

Development and flight test validation (1995-1998)

- Five test flights for regime algorithm validation

Field evaluation and demonstration for MH-47E fleet (1997-1998)

- 11 MH-47E aircraft, 1600 flight hours

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CH-47 SUMS(Cont.)

Fatigue Life Demonstration/Flight Data Acquisition System (FDAS) (1999)

- Three aircraft - two CH-47D, one MH-47D
- Over 200 flights and 320 hours of flight data

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Apache SUMS

- Regime Recognition Algorithm
- Software Interface
- Ground Station
- Fatigue Life Calculation
- Validation (Two flight Test Programs)

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RCDT Accomplishments/Goals

Accomplishments

- Load spectra development
- Crack growth analysis
- Characterization of material crack growth properties, and other critical areas.

Goals

- Additional work is needed.
- Certification process after additional development of the methodology

Boeing Approach

Support FAA in Validating AC by:

Ground Station -

- Maturation and Certification of a standard frame work for HUMS ground station (RHUGS)
- Integration of SUMS

Structural Usage Monitoring -

- Methodology associated with using regime recognition information and direct load measurement information to determine component retirement time

- **Rotorcraft Damage Tolerance**
  - Enhance the Methodology

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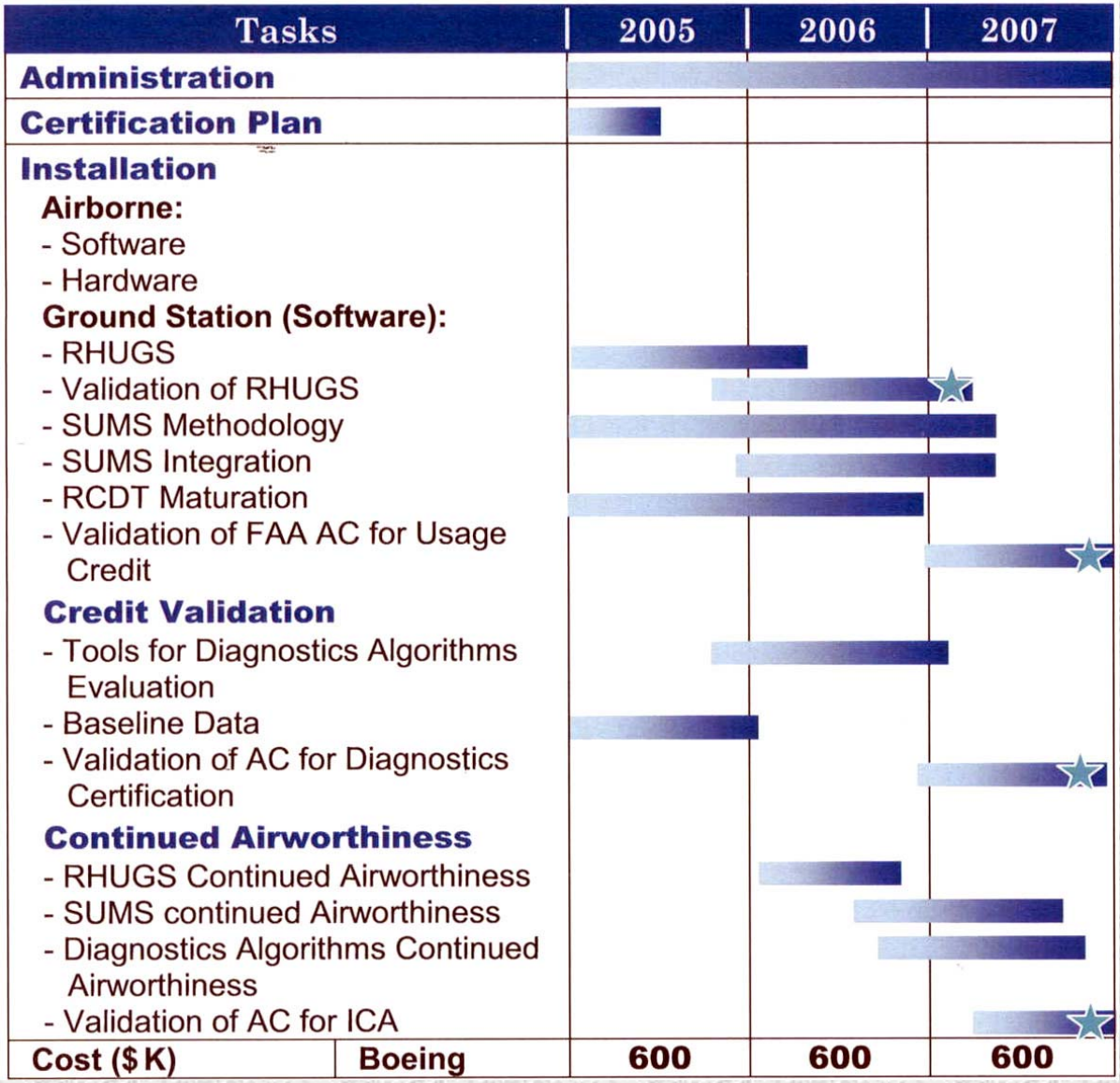
Approach
(Continued)

Certification of Diagnostics Algorithms -

- Develop tools to evaluate effectiveness of diagnostics algorithms
  - Develop baseline seeded fault data
  - Enhance RITA Metrics Evaluation Tool
  - Algorithms certification

FAA Certification Plan Schedule