Integrated Diagnostics (ID) Closed Loop Knowledge System (CLKS)

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Objective

- Develop ability for ID engineer/analyst to gain domain knowledge from integrated data stores
- Develop closed loop knowledge system where data is presented and exploited to actively influence
  - Authoring/monitoring/adjusting of smart diagnostics
  - Engineering/analyst/maintenance technician judgment
- Maximize use of current transactional databases, domain experience and past successes on aircraft/system programs
- Significantly improve sharing and integration of related information across business disciplines to enhance decision making processes
- Utilize results and lessons learned from previous Boeing ID data mining studies (2001 and 2002) to better the outcome of ID CLKS
Traditional Integrated Diagnostics

**Cone of Tolerance**
- Detect fault before Pilot
- Maintenance BIT Supplemental Tests
- Testing at these levels duplicate failures from upper levels of test.

**Aircraft**
- Identify all Failure Modes (Utilize FMEA)
- Does BIT detect & isolate all failure modes? Are supplemental tests required?
- Supplier testing and/or Organic testing addresses all failure modes?

**Organizational**
- BIT information and aircraft environmental conditions are captured by the aircraft.
- Aircraft debrief properly interprets BIT and/or Pilot observable faults.
- Provide WRA / LRU / LRM tester with fault information from the Organizational Level.

**WRA / LRU / LRM**
- Can the aircraft and/or pilot distinguish between a fault, false alarm, and normal operation?
- Does the design (Weapon System & Support System) isolate to 1 WRA / LRU / LRM? (BIT, Tech Pubs, SE, etc.)

**SRA / SRU**
- Does the design (Weapon System & Support System) isolate to 1 SRA / SRU?
- Does the design (Weapon System & Support System) isolate to a small number of components?

### Maturation
*Are the Diagnostics Performing as Designed? Test Voids? Knowledge Engineering starts providing answers!*
Why Care About ID Knowledge?

- **Mining data is mining knowledge**
  - Data mining utilizes automated search algorithms (patterns, similarities, correlations or text matching). Data results are visually presented to the user (better understanding and improved judgments).

- **Knowledge has potential**
  - Properly maintained
    - Optimized for use (IT independent)
  - Valued
    - Trying to tell us something - are we listening?
    - Look into the crystal ball - what do you see?
  - Categorized
    - Impact and message
      - Good, missing, dirty or bad data
  - Available at the point of use and to the next specialty
    - Timely and meaningful manner
    - DATA?
Previous Boeing Knowledge Study Results

- **Aircraft Program Knowledge Discovery 2001**
  - Discovered correlations between aircraft/system events
  - Identified emerging system issues/trends
  - Identified cause of part/system failure

- **Aircraft Program Data Mining Study Results 2002**
  - Identified aircraft with significant failure clustering
  - Identified recurrent faults with specific underlying relationships to aircraft parametric data
  - Identified separate nuisance fault codes for consolidation
  - Identified ideas of improving data quality for wiring faults
Knowledge Wheel
Many databases used for day to day business functions
  – But NOT a data warehouse
Transactional Sources of Data

**Fault data**
- Fault code
- System component performance
- Operational context parameters
- Flight data recording
- Flight data for single aircraft past flights
- Specific squadrons
- Bases/geographic regions
- Correlation to specific flight text
- Frequency of occurrence

**Maintenance data**
- Pilot debrief
- Procedures used
- Actions taken/parts replaced
- Time for action/personnel
- Subsystem/component test results

**Logistics data**
- Aircraft/part identification and configuration
- Aircraft part usage (sorties, hours)
- LRU/component history
- Spares disposition

**Manufacturing data**
- Lot number
- Acceptance test results
- Aircraft configuration
- Component lot number
- Maintenance actions
- Personnel experience
- I level test results
- Number/pattern of CNDs and RTOKs
Data Warehouse

- Database designed to support data mining process
  - Extract, Transform and Load (ETL Process)
Data Mining and Aircraft Failure Visualization

ID CLKS

Two Direction Feedback

Predefined
- Predictable Content

Interactive
- Analysis
- Navigation
- Data Mining

Ad-hoc
- Reporting
- Exploration & Analysis

Knowledge Discovery
- Forecasting & Optimization

User Sophistication

Interactive
- Sorting
- Filters
- Drill Through

Predefined
- Reporting

Knowledge

Exploration
- Analysis
- Navigation
- Data Mining

Exploration & Analysis
- Knowledge Discovery
- Forecasting & Optimization

Interactive
- Analysis
- Navigation
- Data Mining

Predefined
- Reporting

Knowledge Discovery
- Forecasting & Optimization

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7 P’s Visual Knowledge and Results Opportunities

**People**
- Is there a training or staff issue driving the poor diagnostics, Can-Not-Duplicate, Bench-Check-OK, etc?
- Are required entries within maintenance system filled out completely and correctly?
- Is there an opportunity to update the maintenance system?

**Process**
- Business process improvement? Is process too complicated, not accessible?
- Could a LEAN approach provide a better solution?

**Procedure**
- Does the maintenance procedure need updating or smart diagnostics updated?
- Is there a false alarm that needs masking?

**Portal**
- One web, one login, common user interface?
7 P’s Visual Knowledge and Results Opportunities (cont)

- **Prognostics**
  - If A and B are bad, then C will fail with a certain period?

- **Profit**
  - Is the knowledge discovery or change the exception or the rule?
  - Too costly?

- **Possibilities**
  - What is the data and/or the metrics trying to tell us?
  - Share the knowledge with subject matter experts from applicable business disciplines. Knowledge drives capturing of focused domain knowledge?
  - If a wiring repair maintenance action, compare job closeout WUC with text mined closeout narrative. Flag due to incorrect WUC assignment (LRU instead of wire repair). Unnecessary LRU failures which drives spares?
  - If relationships between flight parameters, generated failures and human observables exist, consider updating diagnostics accordingly?
Knowledge collaboration of related information between business disciplines improves ID influence and maturity including quality and timeliness of applicable decision making processes

- Engineering
- Diagnosis Development
- Technical Publications
- Support Equipment
- Maintenance Tools
- Field Service Representatives
- Reliability and Maintainability
- Spares
- Training
- Metrics
- Production Operations
Who benefits?

**Boeing**
- Integrated Diagnostic Engineers
  - Fast & accurate fault rule implementation
- CFRS/IMIS/AME/SMART TPS
  - Consistent ICD and rule creation
- Spares & Provisioning
  - Can more accurately predict what and when parts will fail
- Reliability & maintainability
  - Access to more accurate failure
- Field Service Reps
  - Fleet reports, trends and proactive information
- Training
  - Focused Curriculum Updates

**Customer**
- Aircraft Pilots
  - More reliable and predictable aircraft
- Maintainers at Various Levels of Maintenance
  - View of what to expect and complete aircraft history
  - Use of BIT data with Automated Test Sets (Directed TPS)
Summary

ID CLKS

- **Challenge**
  - Implement an effective method of ID knowledge use and integration across specialties
    - Provide accurate and up-to-date diagnostics
    - Reduce disruptive maintenance problems
    - Reduce cost of maintenance
    - Aid planning for support of future missions

- **Solution**
  - Develop data warehouse and utilize data mining
  - Use predictive modeling to cluster defects and define influences
  - Build on past studies and lessons learned

- **Future Benefits**
  - Enhanced domain knowledge capture, training and transfer
  - Evaluated hidden relationships and cost saving opportunities
  - Increased smart diagnostics maturation and decreased false alarms
  - Knowledge builds upon knowledge
Knowledge is Power - When properly Engineered

[Diagram with various sections including: People, Procedure, Engineering, Diagnosis, Development, Prognostics, Technical, Publications, Support, Equipment, Data Warehouse, Data Mining, Profit, Field Service Representatives, Maintenance Tools, Reliability & Maintainability, Portal, Spares, Process, Metrics, Production Operations, Engineering, Transactional Database, ID CLKS]