STRATEGIC VALUE AND TACTICAL CHALLENGES OF IMPLEMENTING DPHM

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LOCKHEED MARTIN

BACKGROUND

- In early 2000's, Sikorsky Aircraft started incorporating health and usage monitoring as standard equipment.

- Starting with the first delivery of the S-92 Helicopter in 2004, Sikorsky established the infrastructure to collect, process and extract value from HUMS data.

- To grow capability, in November of 2011, Sikorsky purchased Impact Technologies, a small Prognostics and Health Management Company.

- Sikorsky was acquired by Lockheed Martin in November of 2016. A byproduct of the acquisition was the sharing of Diagnostics, Prognostics and Health Management (DPHM) tools, processes, methodologies, and lessons learned across Lockheed Martin.

LM Product Family

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IMPLEMENTING DPHM

Successful implementation of DPHM is a function of good upfront Systems Engineering

- **High-level value proposition** needs to be established, e.g., new maintenance paradigm, reduced operational cost, improved availability, mission-centric focus, etc.

- **Key DPHM elements** required to produce value need to be present. Be careful of over specifying; system should grow/mature with time

- **Integrated system**: data/information streams need to be connected and appropriate tools/apps must be in place to utilize the information.

- **Manage expectations**: some capability will require data/time to yield benefits

- **Staying committed**: changing leadership shouldn't derail DPHM value maturation

Sikorsky Helicopter DPHM Enterprise

Army CBM+ Initiative

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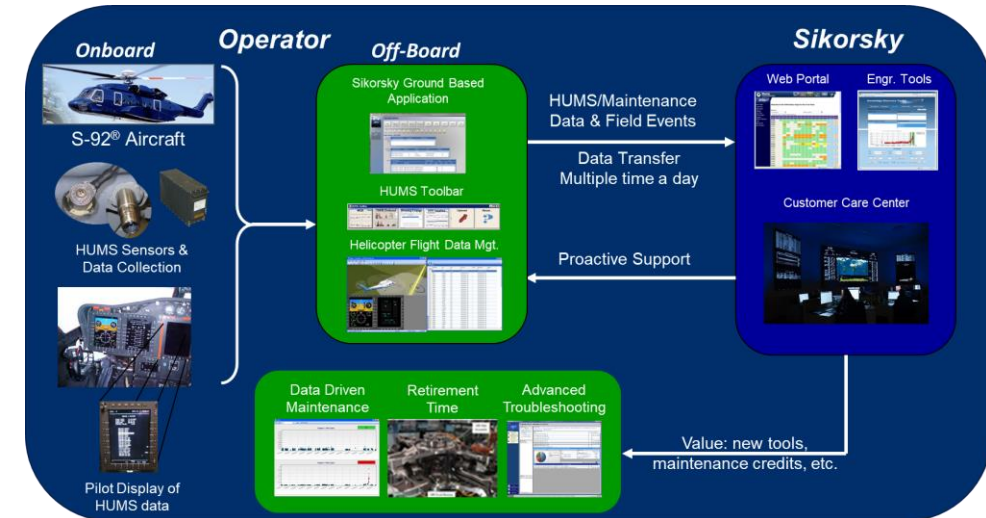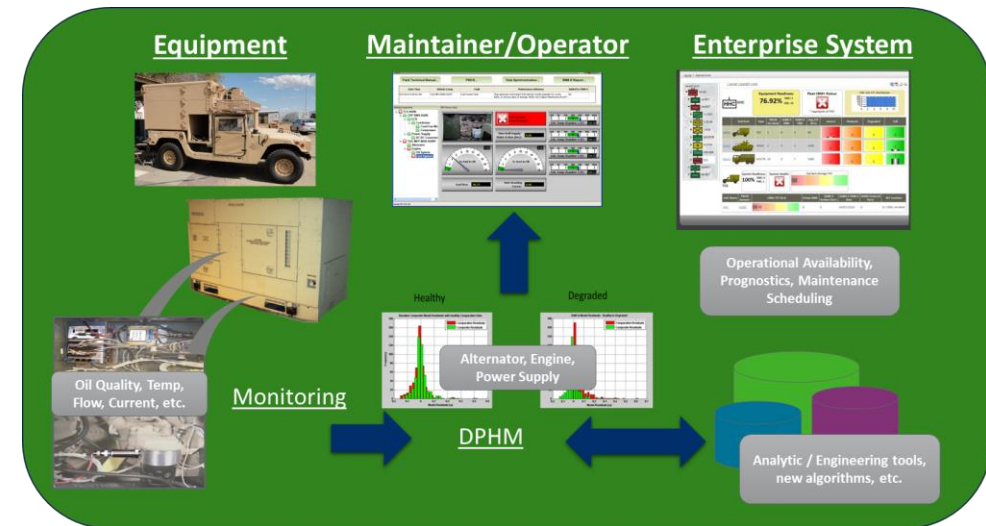
HIGH-LEVEL DPHM VALUE PROPOSITION

If **Asset Availability** is of paramount importance, DPHM can help
- Complex systems are very expensive to make ultra reliable
- Things do happen; over-maintaining is not the solution
- Knowing in advance when and where parts are required is essential

If **Operational Efficiency** is important, DPHM can help
- Perform maintenance only when required (UBM, CBM, etc.)
- Focus troubleshooting, eliminate random part swapping
- Asset information drives real-time mission analysis – can it be done

If **Life Cycle Cost** is important, DPHM can help
- Optimize Provisioning and Logistics Management (timely data)
- Replace only failed component, not next higher assembly

If **Managing Risk** is important, DPHM can help
- Early detection of anomalies
- Identify "root cause" and which assets are at risk
- Enhance safety through utilization of risk management and decision
  support tools

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VALUE OF HEALTH STATE AWARENESS

- **Degraded performance**, such as an engine running inefficiently and consuming more fuel than required, can substantially increase operational cost.

- **Monitoring Condition** reduces unscheduled maintenance, improves maintenance planning, and ensures parts are available when required.

- **Visual Inspections** that require disassembly can be eliminated through the incorporation of algorithms that reliably detect condition.

- **Rapid Support** of field issues can be accomplished through the release of software modules that monitor and trigger alerts.
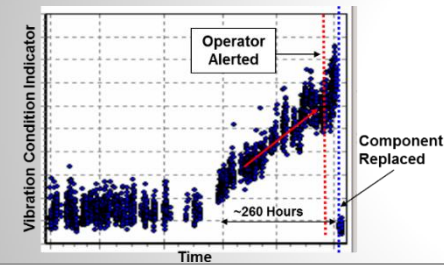
Operating Efficiency
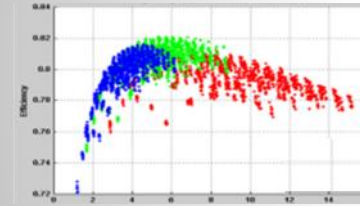
Engine Power Efficiency

Power loss can result from operating in harsh environments, running at inefficient states consumes more fuel, simple engine wash can restore power

Condition Based Maintenance

Gearbox Bearing Degradation

Relative trend allowed incipient fault to be identified 260 flight hours before removal. Part removed before chip detection, minimizing collateral damage

New PHM Based Apps/Tools

HUMS Toolbar

Rapidly support field issue through the release of data driven health state awareness apps

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VALUE OF UNDERSTANDING ANOMALIES

- Important to define metrics that clearly identify operations which drive maintenance and/or identify risk.

- Identifying and managing anomalies early enhances availability and potentially safety.

- Flight hours is base metric for helicopters but doesn't take into account operational and/or environmental conditions.

Fleet Takeoff/Landing
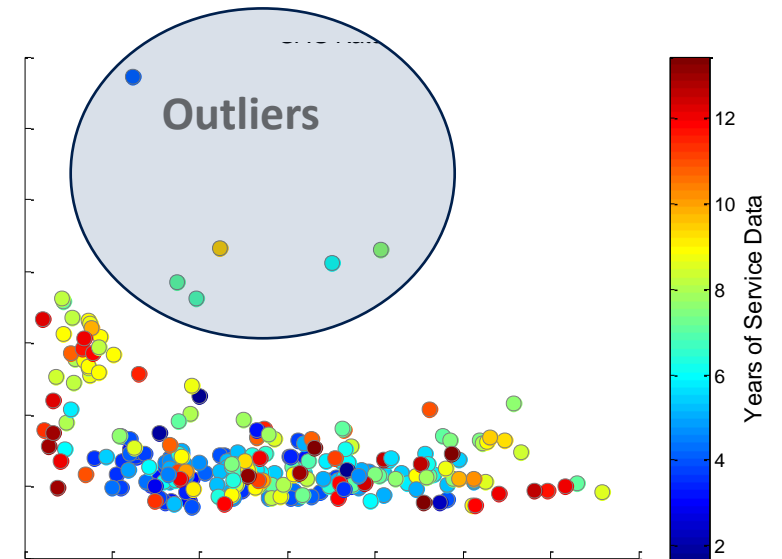
Adjusting Behavior Based on Usage Data

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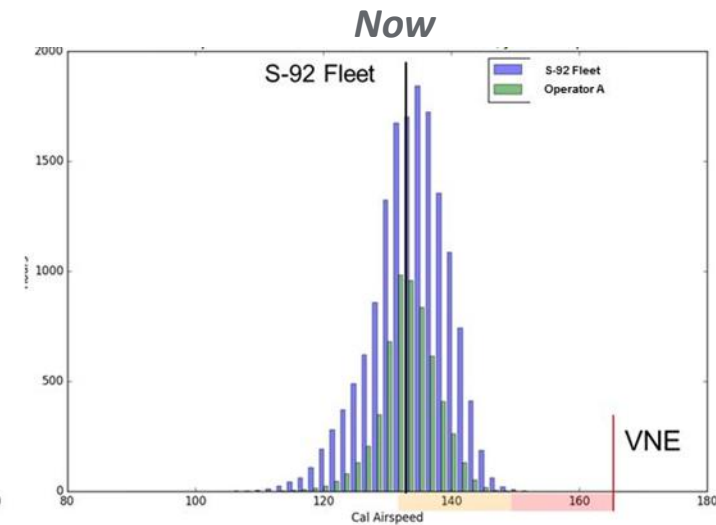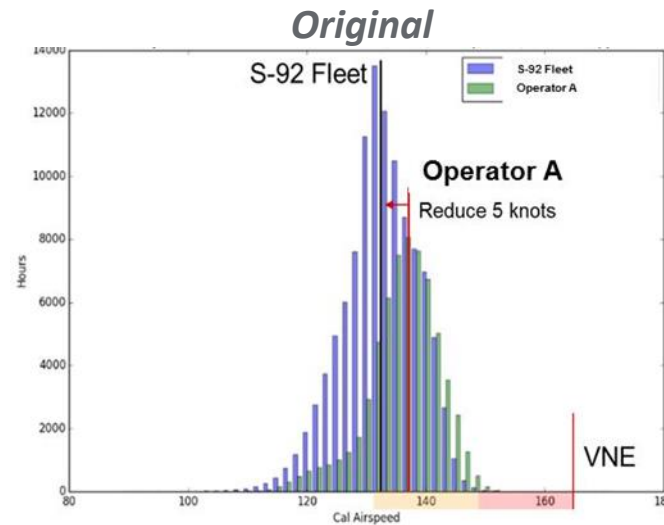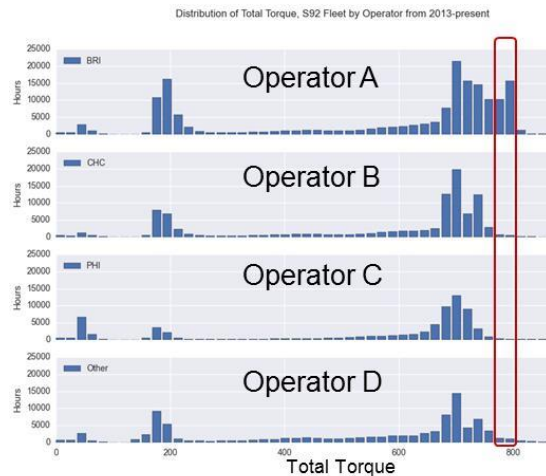
IMPORTANCE IN HAVING THE RIGHT TOOLS

Keys to extracting value from data

- Automatic data ingestion, scrubbing, analysis and alerting
- Visualization tools with simple and intuitive user interfaces
- Fusion of different data sources (Mx, R&M, DPHM, etc.)
- Advanced Data Analytics, Machine Learning and Artificial Intelligence tools

Data Visualization Tools

Multi-Variant Analysis & Alerting Tools
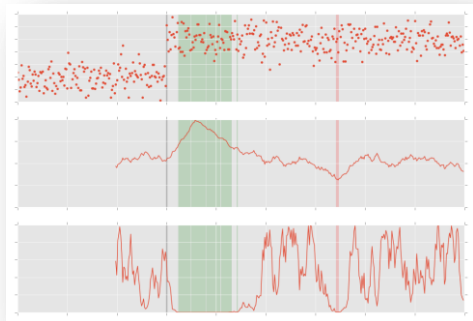
Fleet Evaluation Tools
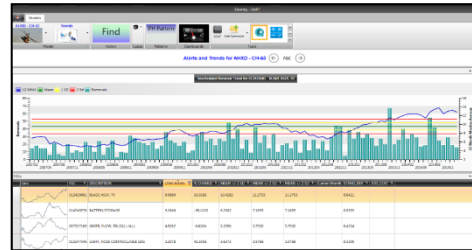
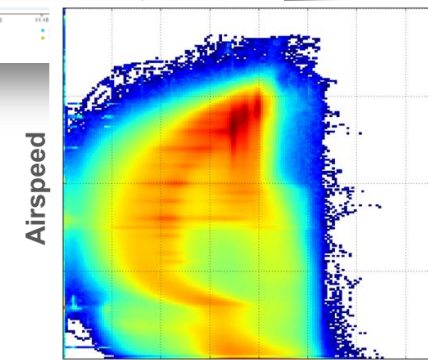**Advanced Data Mining Tools**

Advanced Data Analytics

Artificial Intelligence & Machine Learning

Validation Tools

Reported / Calculated

A picture is worth a thousand words

Airspeed / Torque

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TACTICAL CHALLENGES

- New versus Legacy systems

- Business Case, defining/proving the value proposition

- Cost of validation; mitigated by controlled introduction to service

- Manufacturers commitment to integrated DPHM systems

- Proprietary issues with Operators, OEM, suppliers, etc.

- Potential liability concerns

- Digital data thread, easily flowing the correct data from the asset to all the stakeholders

- Data analysis and decision support tools

- Configuration management and Parts Tracking

US Air Force CBM+ Program for legacy aircraft

Tracking Part
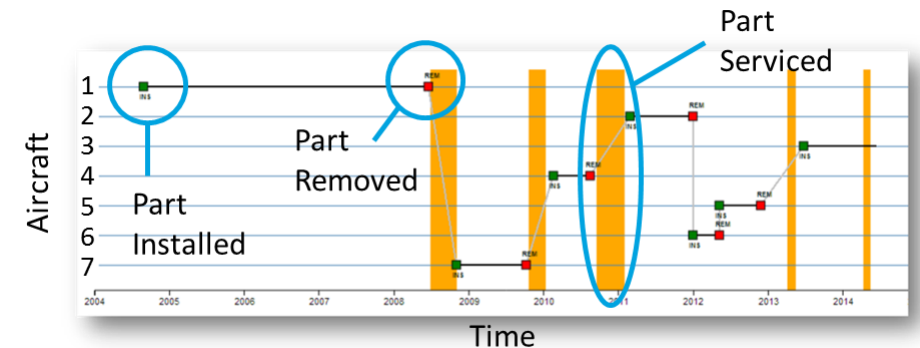
ALL TACTICAL CHALLENGES ARE SOLVABLE USING A CRAWL, WALK, RUN APPROACH AND BY SIMPLIFYING/PRIORITIZING CHALLENGES

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FUTURE: INTEGRATING DPHM OUTPUT IN AUTONOMOUS SYSTEMS

Autonomy is rapidly being integrated into various platforms
- Pilot assist: reduced workload
- Optional pilot, fully autonomous
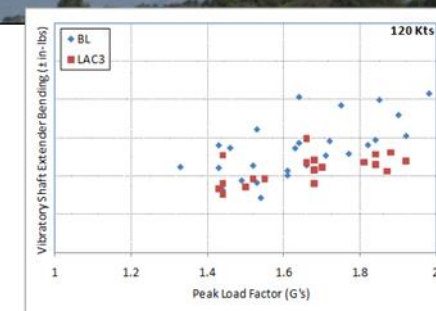- Autonomy kit for rapid integration
- Next step is integrating DPHM

CHALLENGES

Accurately detecting, quantifying & reporting of health state awareness data

Real-time execution of health adaptive controls

Civil & Military Certification Challenges

Army RASCAL Flight tests

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