The 8th Annual Conference of the PHM Society

phmsociety

Panel Discussion on:

Fielded Systems

6-Oct-2016, 1:15-3:00 PM MDT

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Introducing Today's Panel

Chair:

- Andy Hess, Hess PHM Group

Panelists:

- Steve Holland, General Motors
- Tim Felke, Honeywell
- Pete Carini, UTC
- Gary Larivee GDLS-C

Steve Holland

- Currently, Research Fellow, Vehicle Health Management at GM Global R&D
- 40+ years of experience at GM in R&D and Manufacturing Eng./Robotics
- Chief Technologist: applying PHM technologies to GM vehicles (10 yrs)
- Previously R&D Director: application of PHM to improve GM plant throughput (4 yrs)
- Bachelors/EE from Kettering & Masters/CS from Stanford
- PHM Board of Directors & Member of PHM International Scientific Committee
- SAE Member: HM-1 IVHM Standards & IVHM Steering Committee
- Professional Engineer & IEEE Fellow

steven.w.holland@gm.com

IVHM Capability Levels for Aerospace/Automotive

Draft

SAE Level	Vehicle Health Capability	Narrative Description	Participation in Repair Actions	Key Data Resources	Availability of Logged &/or Real-Time Data	Use of Supporting Models	IVHM System Characteristics
Manual Diagnosis & Repair Process performed by Technician							
0	Limited On-Vehicle Warning Indicators	Service actions for scheduled maintenance or when Operator notices problems or is alerted by indicator lights or simple gages.	**Operator/Driver & Service Tech**	On-Vehicle Measurements & Observation	N/A	Paper-based Manuals	Only Manual Diagnostic Tools & No Condition-Based Services
1	Enhanced Diagnostics Using Scan Tools	Service techs gain added diagnostic insight using automated scanners to extract vehicle operating parameters & diagnostic codes	Operator/Driver & Service Tech	**On-Vehicle & Service Bay/ Depot Tools**	Logged Diagnostic Codes & Parameters available to Service Tech	Paper-based Manuals	On-Board Diagnostics Available
2	Telematics Providing Real-Time Data	Service techs gain real-time vehicle data via remote monitoring of vehicle to more completely capture issues	Operator/Driver, Service Tech & Remote Support Center Advisor	On-Vehicle, Service Bay / Depot & Cloud Data	**Telematic Data Available to Service Tech with Diagnostics Info**	Paper-based Manuals	On-Board & Remote Data Available
Diagnosis & Repair Augmented by Prognosis & Predictive Analytics							
3	Component Level Proactive Alerts	Operator and service techs are provided with component health status (R/Y/G) before problem occurs . Limited condition-based maintenance	Operator/Driver, Service Tech & Cloud-Based Services	On-Vehicle, Service Bay & Cloud Data	Telematic Data Available to Service Tech with Diagnostics Info	**Addition of Component-Level Health Models**	Component-Level Health Predictions
4	Integrated Vehicle Health Mgmt.	Operator and service techs are provided with system or vehicle level health indicators before problems occur with remaining useful life estimated. Condition-based maintenance	Operator/Driver, Service Tech & Cloud-Based Services	On-Vehicle, Service Bay & Cloud Data	Telematic Data Available to Service Tech with Diagnostics Info	Addition of Vehicle-Level Health Models	**Vehicle-Level Health Management**
5	Self-Adaptive Health Mgmt.	Self-adaptive control to extend vehicle operation and enhance safety in presence of potential or actual failures	Operator/Driver, Service Tech & Cloud-Based Services	On-Vehicle, Service Bay & Cloud Data	Telematic Data Available to Service Tech with Diagnostics Info	Addition of Vehicle-Level Health Models	**IVHM Capability Integrated into Vehicle Controls**

GM's Prognostics Press Release @CES Jan 4, 2015

Chevrolet Opens New Chapter for Driver Assurance
Customers will soon drive vehicles that can predict future service needs

DETROIT – Chevrolet is using advanced connected vehicle technology to give customers an unprecedented level of assurance in their vehicles later this year. This industry-leading prognostic technology can predict and notify drivers when certain components need attention – in many cases before vehicle performance is impacted.

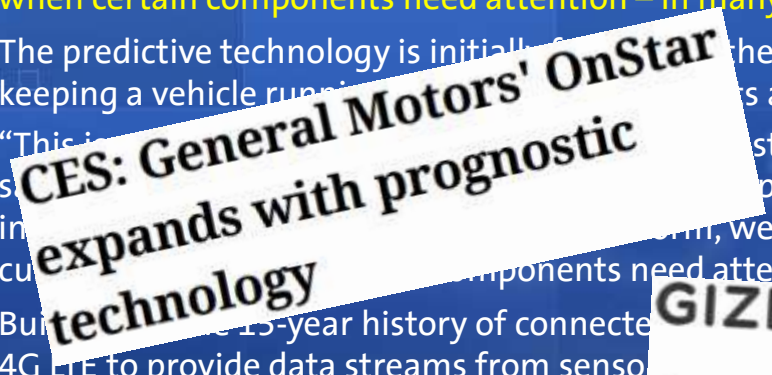
The predictive technology is initially [redacted] the battery [redacted] motor and fuel pump, all critical to starting and keeping a vehicle runn[redacted]s and co[redacted]ed to be added in future model years.

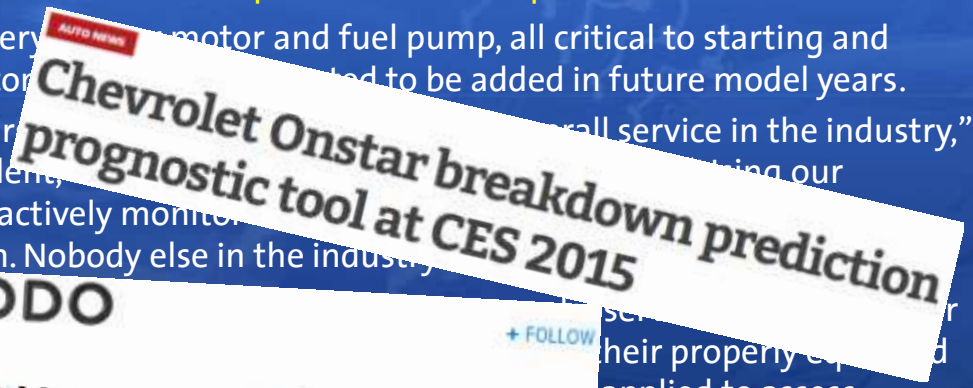
"This i[redacted]stomer [redacted]rall service in the industry," s[redacted]president, [redacted]ing our in[redacted], we can actively monito[redacted] cu[redacted]mponents need attention. Nobody else in the industry [redacted]

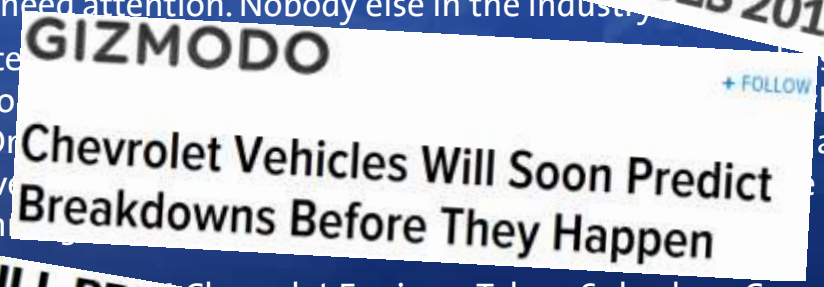
Bu[redacted]e 15-year history of connecte[redacted]r 4G LTE to provide data streams from senso[redacted]their properly [redacted] vehicle in this service, the data is sent to Or[redacted] applied to assess w[redacted]ain conditions could impact ve[redacted] sent to the customer via e[redacted]ide alerts or th[redacted]

This [redacted] Chevrolet Equinox, Tahoe, Suburban, Corvette, Silverado and Silverado HD models [redacted] more Chevrolet vehicles throughout the 2016 model year.

Prognostic capability is the latest advancement in a suite [redacted] that will keep Chevrolet custom[redacted] informed from the first day of ownership through many years into the future.







GM

VEHICLE HEALTH MANAGEMENT

GM's 2nd Press Release – May 9, 2016

Chevrolet Now Offers Customers Ability to 'See' the Future
Industry-first OnStar Proactive Alerts set to redefine routine maintenance

DETROIT – What if the company that built your car or truck could warn you about a potentia ... ad? Chevrolet is the only automaker to offer this predictive technolog ... y-first OnStar ser

Similar to how Boeing 787 ... erting them of ... g problems bef ... next?

... x can now op ... hicle's ... wearing out ... n- ... ence.

"C ... hen you ... eral ... M

Pre ... ns and determine the

Proactive Aler ... tion of vehicles that

"Accuracy is ... ng for a condition we ... ship."

Proactive A ... vrolet vehicles. In

Of the com ... attery can lose 3 ... – instead of

"A few compan ... expecta ... r, we hope to


FIXED OPS JOURNAL

BEING PROACTIVE

General Motors innovation could rewrite service business

RICHARD TRUETT

Imagine a customer arriving at a dealership's service drive with the diagnostic work completed, the faulty part identified and the warranty repair approved before a service writer even greets the driver.

You don't have to imagine it. It's happening.

This spring, General Motors quietly introduced a new feature for its OnStar connected car technology called Proactive Alerts. The program's goal, says

critical systems in the vehicle," Holland says, "things that have a lot of electrical content."

Once a problem is detected that requires service, the driver has about two weeks to schedule a service appointment, Holland adds.

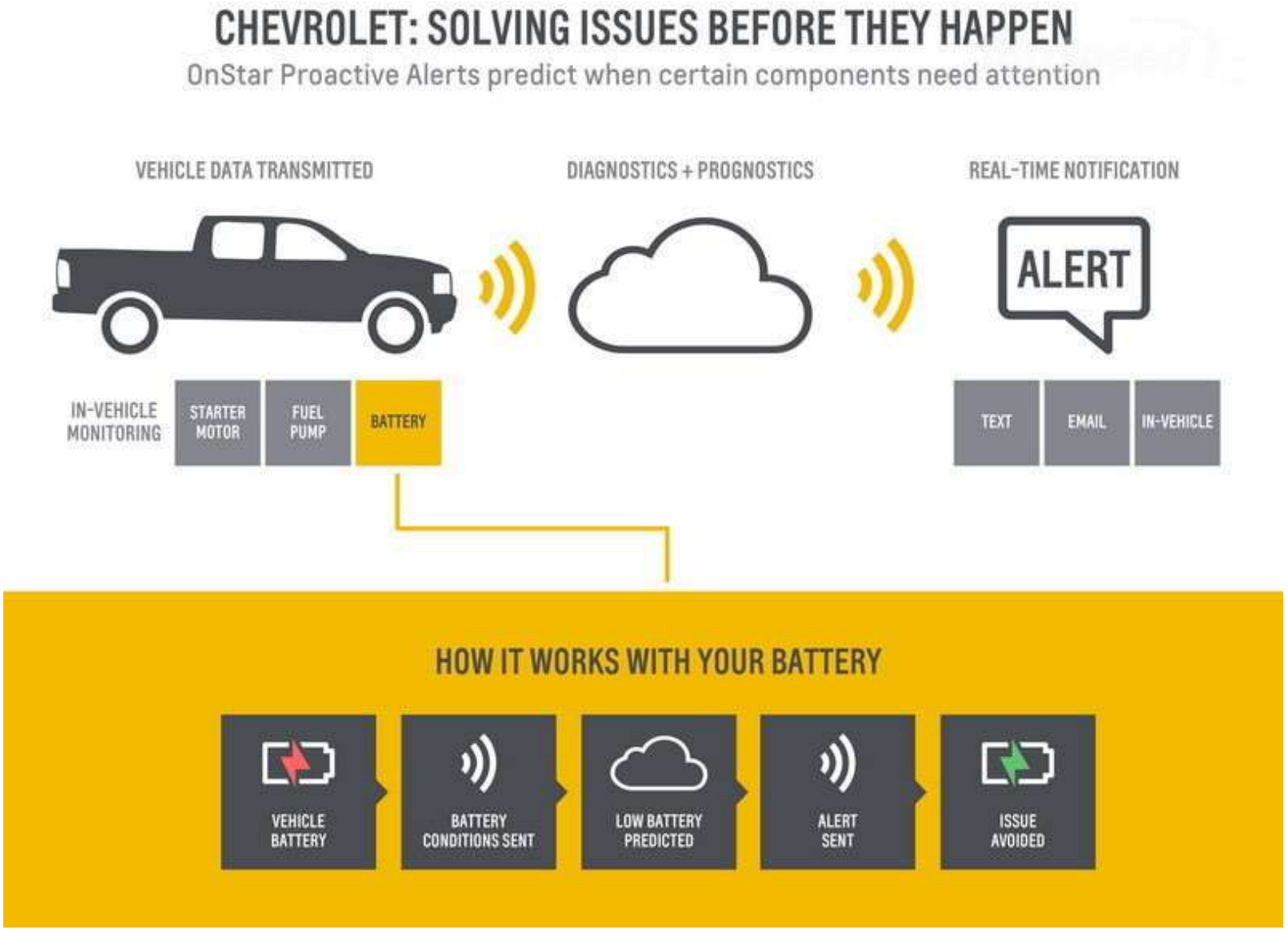
"That's early enough so that the customer has time to deal with it before they suffer the inconvenience of having a problem

"There are a lot of similar services, but no one offers the depth or breadth of services that OnStar offers."

DAVE SULLIVAN, analyst, AutoPacific

GM

- Everything wears out over time
- Customer's life is disrupted, when his/her vehicle needs repair unexpectedly
- The solution - Vehicle Health Management (VHM)
  - Alert before failure happens
  - Transform an emergency repair to planned maintenance
  - Enhance ownership experience - a delight to customers
- Introducing OnStar™ Proactive Alerts - a new customer care service


CHEVROLET: SOLVING ISSUES BEFORE THEY HAPPEN
OnStar Proactive Alerts predict when certain components need attention
VEHICLE DATA TRANSMITTED
DIAGNOSTICS + PROGNOSTICS
REAL-TIME NOTIFICATION
ALERT
IN-VEHICLE MONITORING
STARTER MOTOR
FUEL PUMP
BATTERY
TEXT
EMAIL
IN-VEHICLE
HOW IT WORKS WITH YOUR BATTERY
VEHICLE BATTERY
BATTERY CONDITIONS SENT
LOW BATTERY PREDICTED
ALERT SENT
ISSUE AVOIDED

Where are we today on OnStar™ Proactive Alerts?

- Launched on
  - 2016 Chevrolet Equinox
  - 2016 Chevrolet Tahoe
  - 2016 Chevrolet Suburban
  - 2016 Chevrolet Corvette
  - 2016 Chevrolet Silverado
  - 2016 GMC Terrain
  - 2016 GMC Yukon
  - 2016 GMC Sierra
  - 2016 Cadillac Escalade
- Currently cover three critical components
  - battery, starter, fuel pump
- Will be extended to more GM vehicle programs and cover other critical vehicle components over time

Tim Felke

- 30+ years of experience in Condition Based Maintenance (CBM) and Integrated Vehicle Health Management (IVHM)
- Currently; Engineering Fellow, Honeywell IVHM Systems
- Previously;
  - Senior Technical Manager for Honeywell's Common IVHM Architecture
  - Technical Lead for Deployment of IVHM in Automotive Applications
  - Data Architect for US Army's Platform-Soldier, Mission Readiness System
  - Technical Lead for Diagnostics and Fault Model Development of Central Maintenance Computer (CMC) for Boeing 777 and 787 Aircraft

tim.felke@Honeywell.com

Honeywell Integrated Vehicle Health Management (IVHM) History

Flight Control Maintenance Diagnostics System

Platform Soldier Mission Readiness System

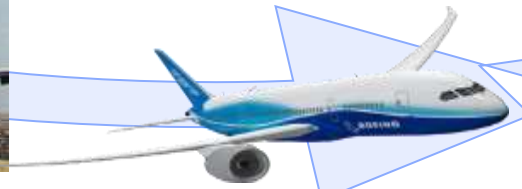
Primus Epic® Central Maintenance& Aircraft Condition Monitoring

Health & Usage Monitoring (HUMS)

Zing™ Vehicle Diagnostics

CEV Orion Systems Management & Abort Determination

777 Central Maintenance & Aircraft Condition Monitoring



787 Crew Information & Maintenance System

Automotive – Integrated Vehicle Health Management (IVHM)

Honeywell Fielded Systems:
Central Maintenance Computing Systems

777: Monitors 85% of AC systems

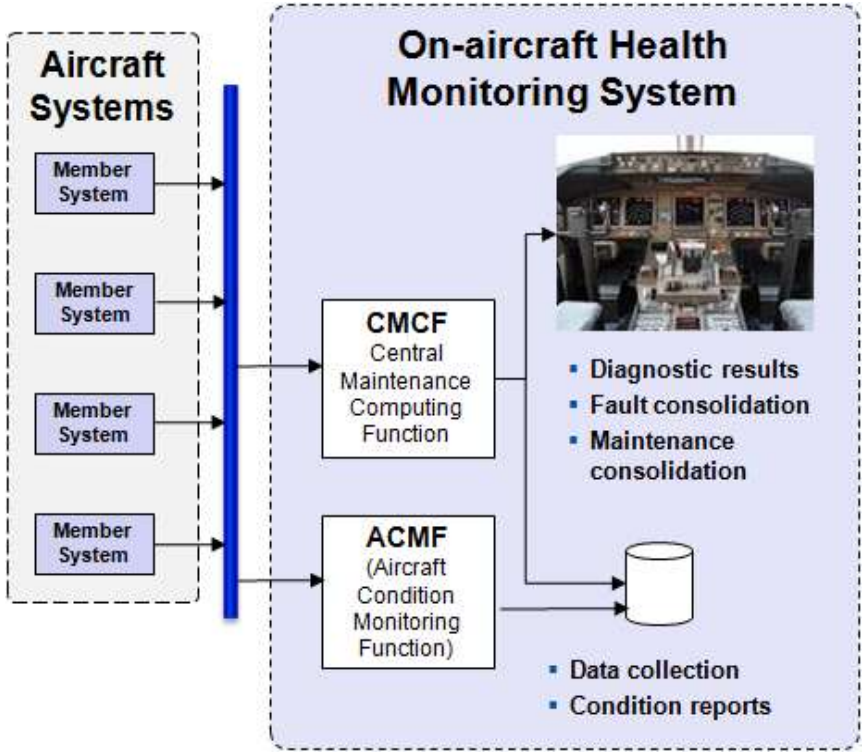
- 80% Reduced NFFs
- 50% Reduced Repair Turn Time
- >99% Dispatch reliability

787: 65,000 parameters monitored

- 150 systems, 1100 ECUs
- Advanced Diagnostic Modeling
- 30% DMC savings projected vs.767-300
- Includes Cyber Security Features

Business and Regional Jets

- 15 Major OEMs
- Nose to Tail Coverage for CMCF and ACMF



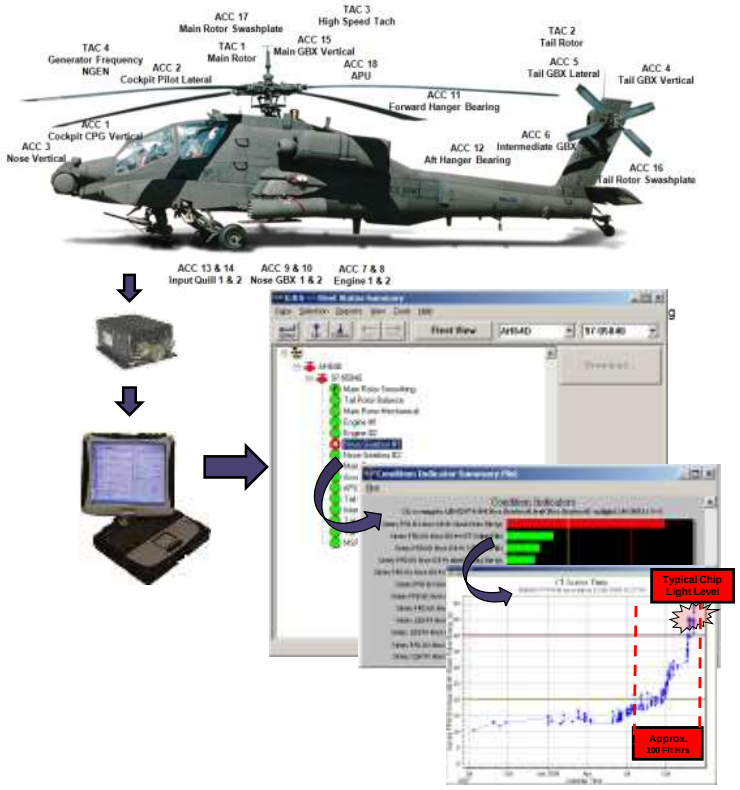
Honeywell Fielded Systems:
Helo Health & Usage Monitoring

Vibration Monitoring and Analytics:

Rotor Track and Balance

- 95% reduction in aborts for vibration
- $102M in IVHM savings over 26 months
- Readiness Increased by 5-8%
- Class A mishaps reduced 9-12%
- Parts Costs per FH Reduced 12-22%
- Maintenance reduced by over 2950 mh

HUMS = Safety, Lower Cost, Higher Readiness

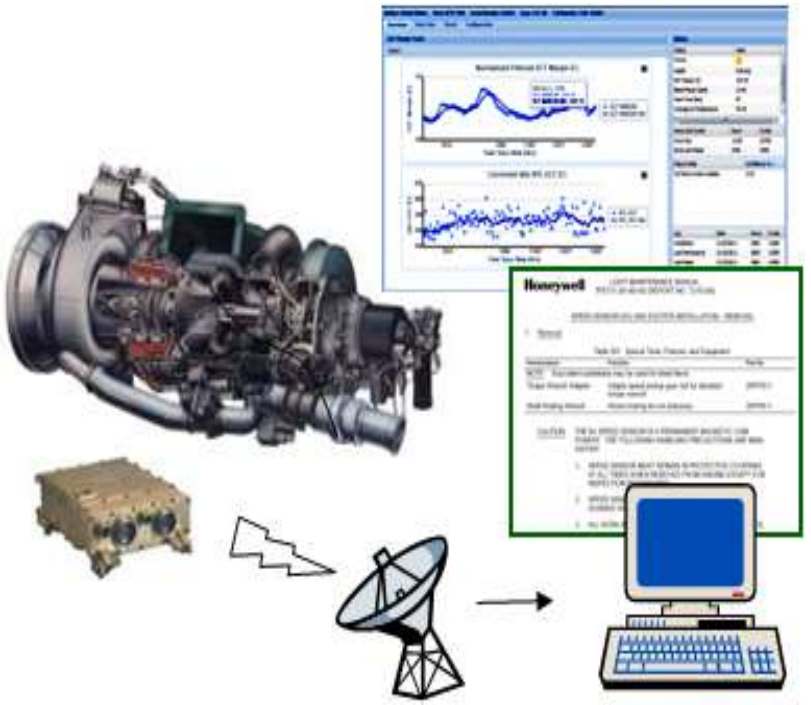


Honeywell Fielded Systems:

Auxiliary Power Unit Trend Monitoring

APU Health Prediction

- 4500 APUs Monitored
- On-wing time: 75% improvement
- Eliminate maintenance inspections
- Web-based tool gathers APU sensor data
- Real-time, in-flight data transmission
- $1.2M annual maintenance cost savings/vehicle



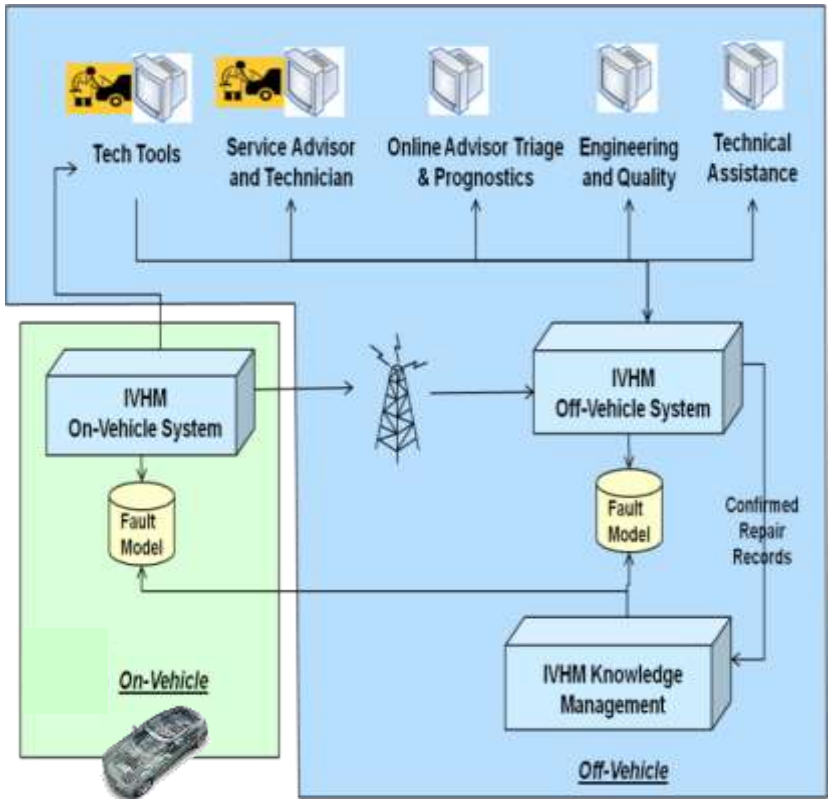
Honeywell Fielded Systems:
Automotive Model Based Diagnostics

Adapting IVHM for Ground Vehicles

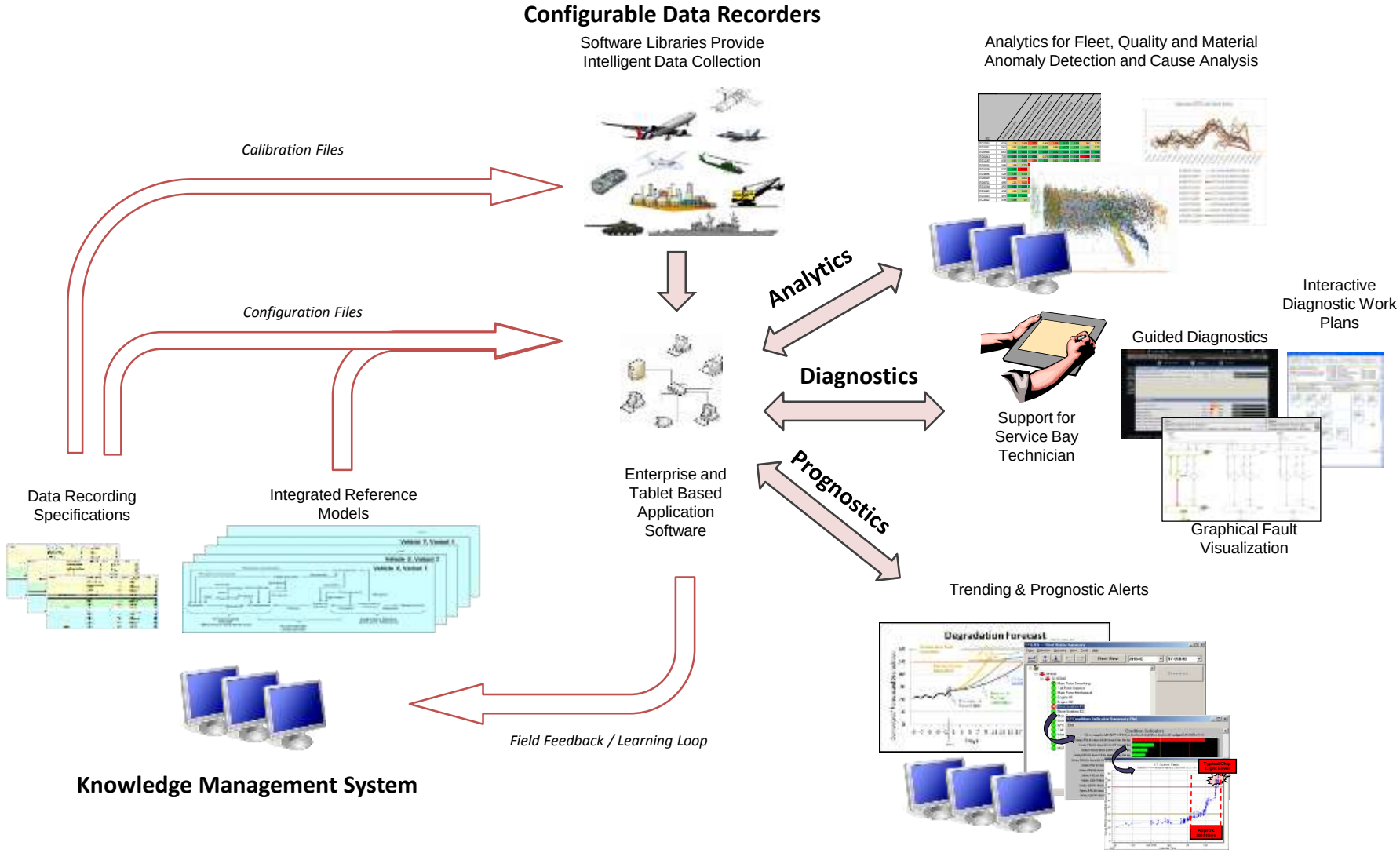
- Low cost diagnostic modeling
- Deal with high variation
- Improve Diagnostic Accuracy
- Reduced NTFs
- Reduce Intermittent Faults

Warranty Cost Savings (Projected)

- 50% reduction in unnecessary repairs
- $100M+ annual warranty cost savings



Honeywell IVHM System Overview



Dealing with Fleet Variation:
Problem Statement

- Sources of Variation
  - Market / Usage Driven Product Variation
  - Evolution of Requirements (Regulatory, Safety, Efficiency, Customer Preference)
  - Versions: Evolution of Implementations (to address new requirements, reduce cost, improve reliability)
  - Variants: Introduction of new system / part as an alternative to an old one.

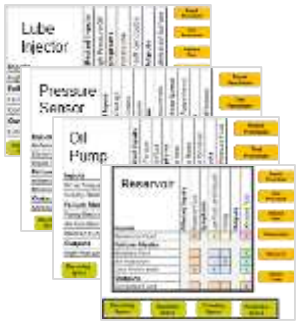
- Effects of Variation on Asset
  - Changes to BOM, Failure Modes, Functions and expected Symptoms
  - Changes to Failure Occurrence Rates
  - Changes to Failure / Symptom CoOccurrence Rates
  - Changes to Parametric Reporting Messages
  - Changes to Fault Reporting Messages

- Effects of Variation on IVHM System
  - Changes to IO and Decode Functions
  - Changes to Fault Detection Algorithm Parameters and Trip Points
  - Changes to Fault Isolation Logic
  - Changes to Changes to Fault Prediction Algorithm Parameters and Trip Points
  - Changes to Maintenance Procedures
  - Changes to Logistics and Parts Management

Dealing with Fleet Variation:
Solution Summary

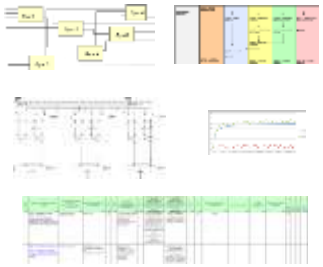
- Minimize Changes to Software, Have Variation Handled by the Reference Model
- Maximize Use of Design Data in Model Integration Process
- Produce Separate Reference Models for Each Major Variant (e.g., Model-Year)
- Use Effectivity Tags within Reference Model to Encode Minor Variation within a Major Variant (e.g., Service Bulletins, Part Changes, etc.)

Component Models (Re-Usable), Include:
- ***Processing Model***
- ***Fault Model***
- ***Advisory Model***



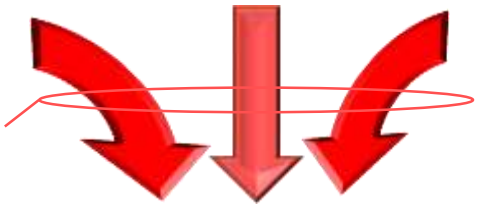
Interface Models (Re-Usable)

Design Data (Per Program)

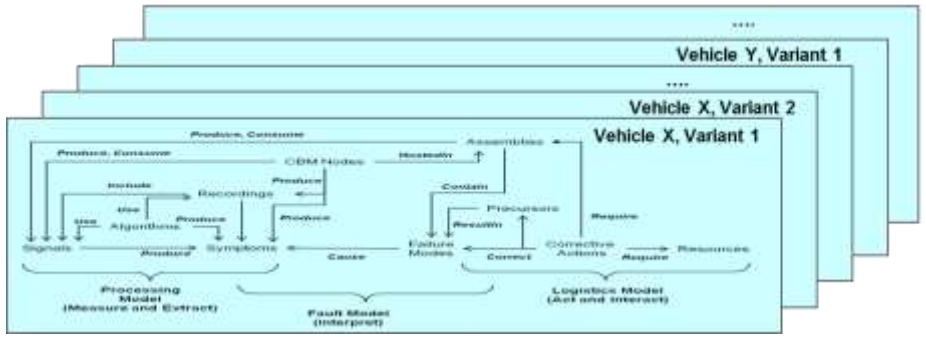


BOM, Schematics, FMEA, ICD's, UML, Models, Algorithms, etc.)

Model Integration Processes



- ***IRM is Produced for Each Major Platform Variant***
- ***Includes Effectivity Information to Ensure Accurate Results***






PHM Society - Fielded Systems Panel

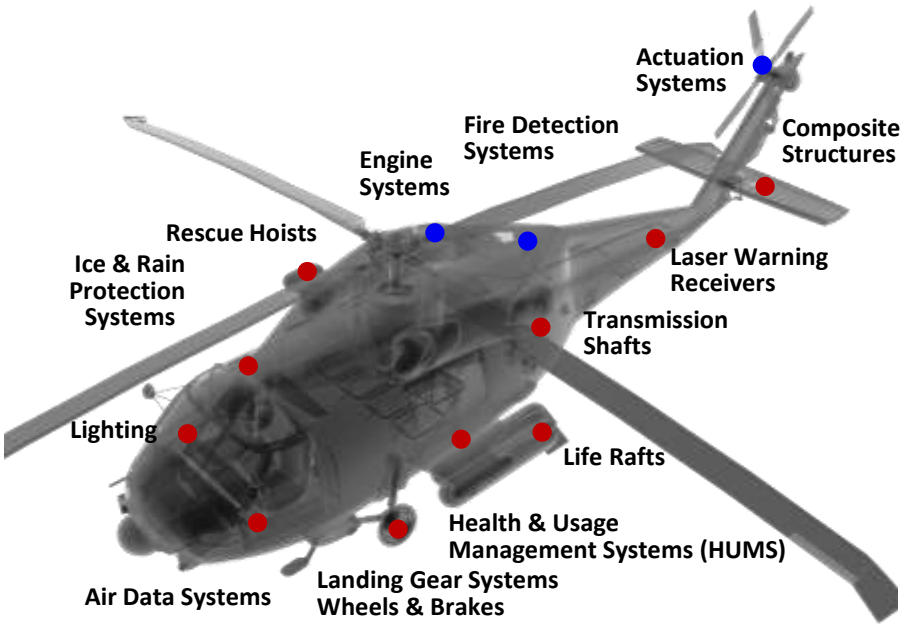
Pete Carini, Engineering Platform Chief
PHM & SHM

10/6/2016

UTC AEROSPACE SYSTEMS

Hamilton Sundstrand / Goodrich Integration

Product portfolio



Legacy Goodrich

Legacy Hamilton Sundstrand

One company

UTC Aerospace Systems

HUMS History

1990 2000 2010

V-22

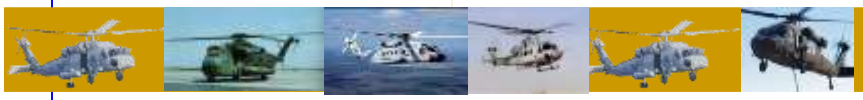
V-22 Refresh

VSLED

H-60B HIDS, A-109 Rega, CH-53E EOA

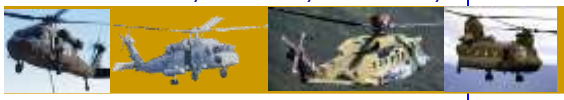
KT-1

H-60B, CH-53E, S-92, UH-1Y/AH1-Z, MH-60, UH-60A/L



MPU

UH-60A/L/M, MH-60, CH-148, CH-47D, CH-53K



IVHMU

S-76D, Bell 525

VIGOR

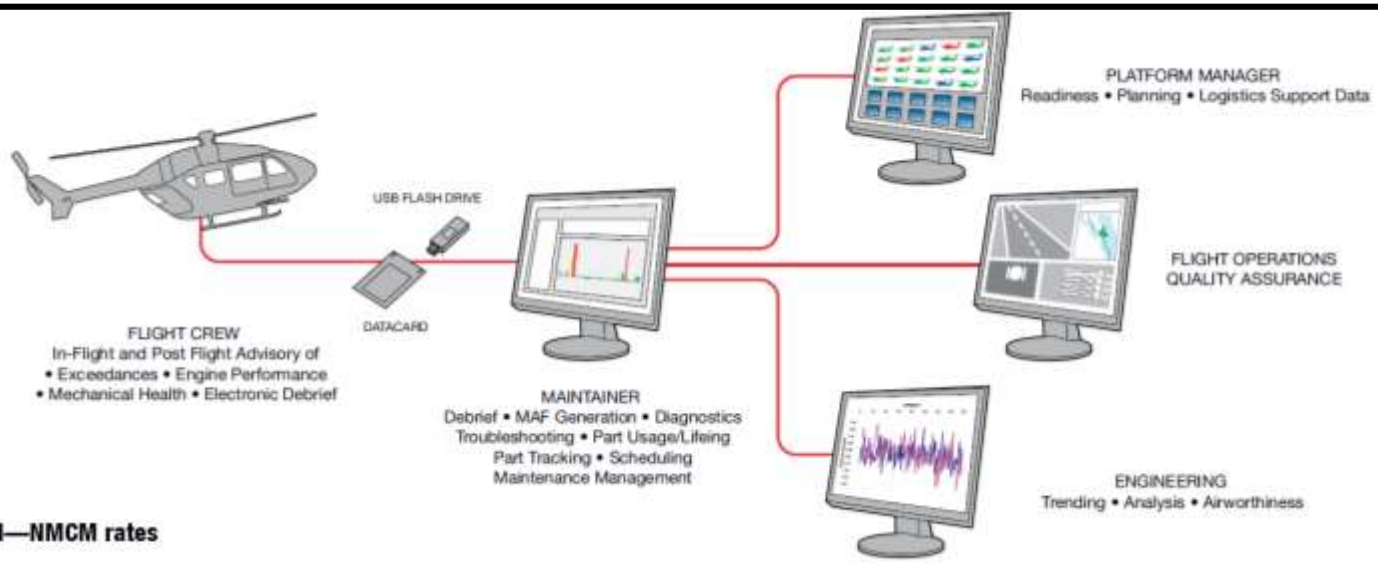
CH-47F

RSIM

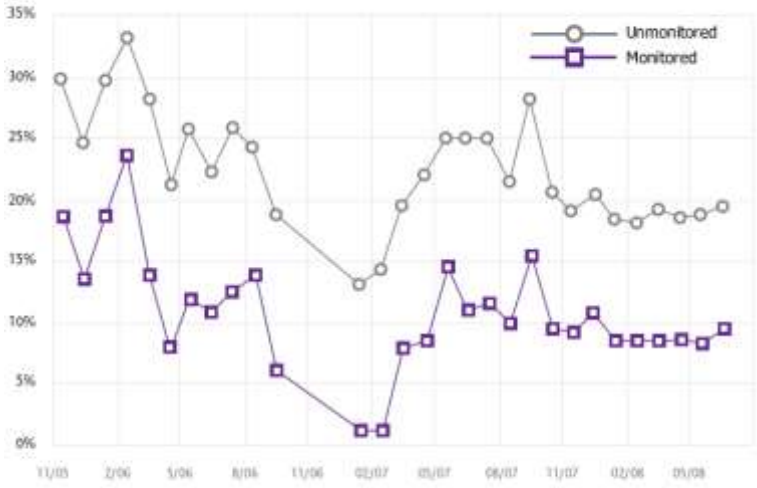
HUMS Functions

- **Parametric Data Recording**
- **Rotor Tuning**
- **Shaft Balancing**
- **Vibration Diagnostics**
- **Mechanical Diagnostics**
- **Event Detection**
- **Exceedance Detection**
- **Operational Usage**
- **Regime Recognition**

HUMS Successes



UH-60L ACFT deployed—NMCM rates



The U.S. Army recognized a reduction in Non-Mission Capability Maintenance rates of 10% for aircraft deployed into combat operations

Maintenance Reductions

Unscheduled MMH/FH	-52%*
Mission Aborts MMH/FH	-48%*
Total MMH/FH	-17%*

* Actual data from U.S. Army Deployed UH-60 Black Hawk helicopters

In the first one-year deployment of 38 aircraft equipped with UTC Aerospace Systems HUMS in an Army battalion, the battalion executed 27% more missions than a non-equipped sister battalion with the same mission profile. The HUMS-equipped battalion set a new Army record for the most missions accomplished in a one-year period, never missing or aborting a mission due to mechanical problems.

V&V Lessons Learned

- **Everything works as designed until it is tested. At the point where it is tested, it fails as designed.**
- **We should not seek to "*pass the test*" but rather aspire to "*fail to break*" the system.**
- **It is by exposing the flaws and limitations in a system that we can improve the systems we build.**

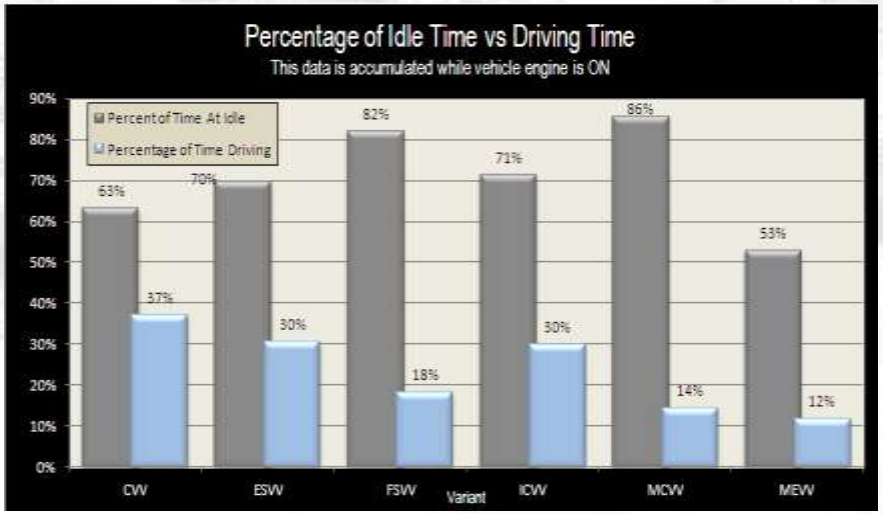
CBM – US Army Stryker


THE THINGS THAT HELP PREDICT ARE LOOKING AT THE TITLE,COVER AND CHARACTERS, ALSO READING THE FIRST PART OF THE BOOK.
Chester's Masterpiece
PICCOLLAGE

GDLS Lessons Learned

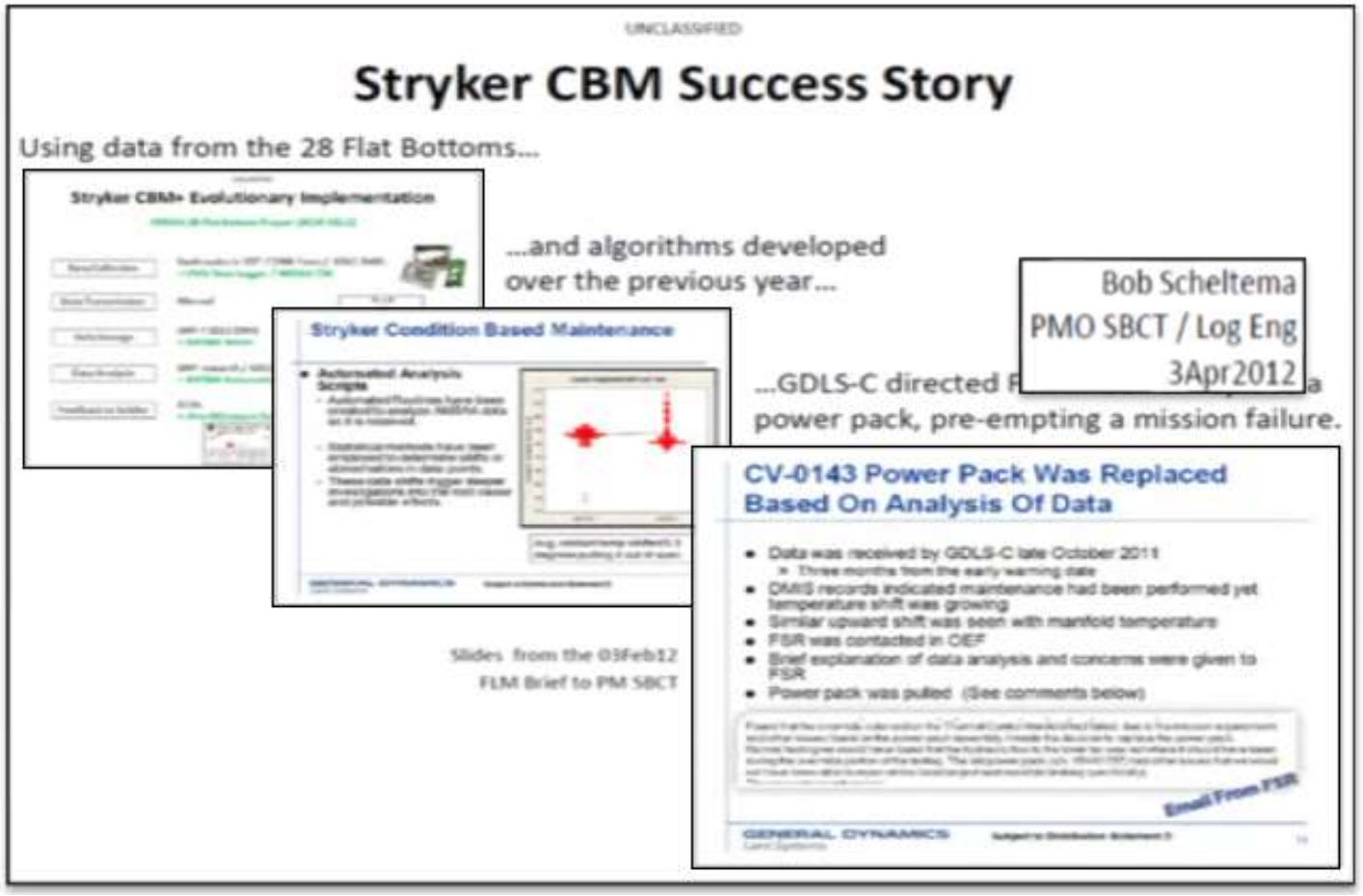
Cost of Entry

- Average miles / hours driving and at idle
- Average speed attained while vehicles in use
- Average fuel consumption while driving and at idle



- PVT testing maintains approx. 60% engine load for duration of day - In theatre engine load rarely exceeds 60%
- PVT test requires constant vehicle movement - In theatre vehicle is idle ~ 70 % of mission

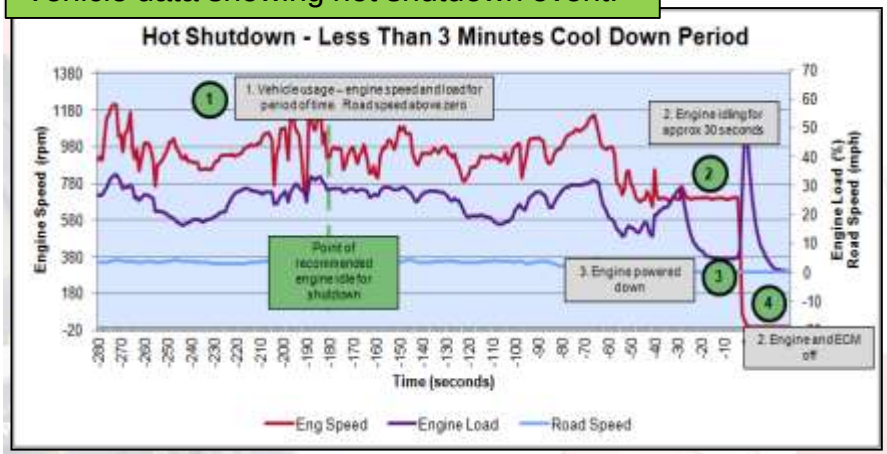
CBM Driven Investigations – 28 OEF
Condition Indicators Lead to Preventive Maintenance

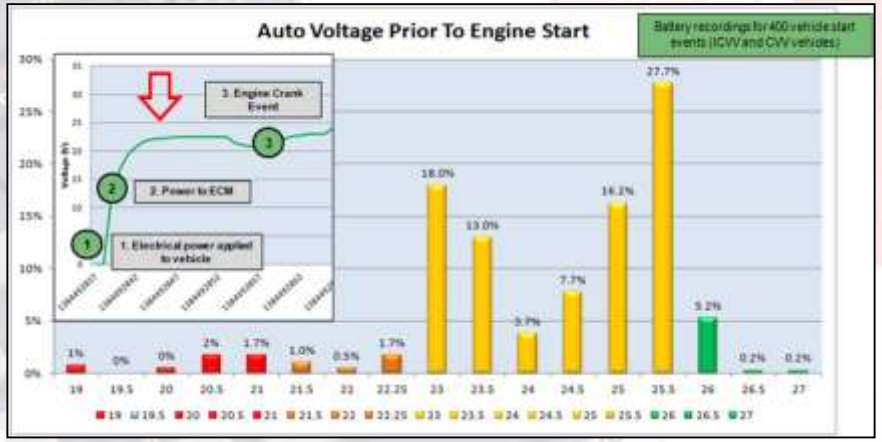


GDLS Analysis Findings:

Vehicle Usage

Vehicle data showing hot shutdown event.





Vehicle data showing immediate electrical power shutdown.