The Health-Ready Components and Systems (HRCS)Consortium and IVHM

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FOUNDATIONAL DOCUMENT: SAE JA6268

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SURFACE VEHICLE/AEROSPACE RECOMMENDED PRACTICE	JA6268™	APR2018
	Issued 2018-04	
Design & Run-Time Information Exchange for Health-Ready Components		

RATIONALE

This Surface Vehicle & Aerospace Recommended Practice was created to help reduce existing barriers to the successful implementation of Integrated Vehicle Health Management (IVHM) technology into the aerospace and automotive sectors by introducing health-ready components. Health-ready components are augmented either to monitor and report their own health or, alternatively, ones where the supplier provides the integrator sufficient information to accurately assess the component's health via a higher-level system on the vehicle. The principal motivation for health-ready components is to facilitate enhanced IVHM functionality in supplier-provided components that better meet the needs of end users and government regulators in a cost-effective manner. Underlying this motivation is the assumption that market forces will drive the need to achieve IVHM's benefits, which will in turn drive new requirements that suppliers must ultimately meet. This recommended practice has two primary objectives: (1) to encourage the introduction of a much greater degree of IVHM functionality in future vehicles at a much lower cost, and (2) to address legitimate intellectual property concerns by providing recommended IVHM design-time and run-time data specification and information exchange alternatives in an effort to help unlock the potential of IVHM.

WHAT IS A HEALTH-READY COMPONENT?

- Health-ready components monitor their own health or condition. For example, an automobile starter could monitor these parameters:
    1.) Cranking speed
    2.) Current draw
    3.) Bendix engagement time
    4.) Environmental conditions
    5.) Vibration
- Instead of a **"Check Engine"** light, a prognostic algorithm could derive Remaining Useful Life (RUL) and inform the driver to return for service within two weeks.
- If there is high accuracy in the prognostic (99%) can save diagnosis time and lower cost of the repair.

WHAT IS A HEALTH-READY COMPONENT?

- Alternatively, the part could provide information to a higher-level system on the vehicle (or combination of both) such as the entire starting system. The system could monitor:
    1.) Starter
    2.) Battery
    3.) Ignition system
    4.) Fuel system

- Information sharing should be ***machine-readable*** and standardized for interoperability

- *This is key to unlocking the potential of Integrated Vehicle Health Management (IVHM)*

SAE VEHICLE MAINTENANCE/IVHM CAPABILITY

(VEHICLE LEVEL)

(SOURCE: SAE JA6268)

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	All pre-1980 automotive vehicles
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	Introduction of microprocessor-based controls & OBD 1980-1995
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	Introduction of GM Onstar telematic services 1996-2014 (OBD II)
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	Introduction of Onstar Proactive Alerts post-2015
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	Necessary enabler for future Autonomous & Active Safety Vehicles
5	Self-Adaptive Health Mgmt.	Self-adaptive control and optimization 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	Long-range vision

SAE AUTONOMOUS VEHICLE & IVHM CAPABILITY (VEHICLE LEVEL)

(SOURCES: SAE J3016 & JA6268)

Illustrating autonomous vehicle capability

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Illustrating vehicle IVHM capability

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 and optimization 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

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DEFINING TERMS…

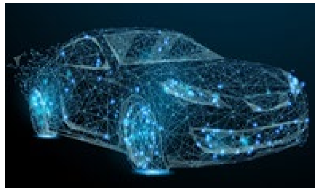
Diagnosis:

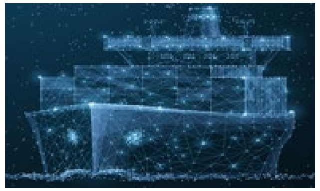
Process of determining the root cause of a problem once a failure has occurred …that is, what part replacement(s) or repair action is necessary to fix the problem
(today's world in automotive)

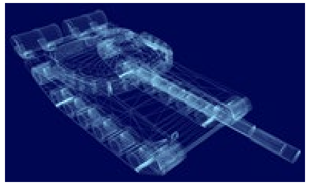
Prognosis:

Process of predicting the onset of a potential failure mode BEFORE the failure has occurred …while the component is still operating within specs & with sufficient advance notice to avoid the problem (RUL)

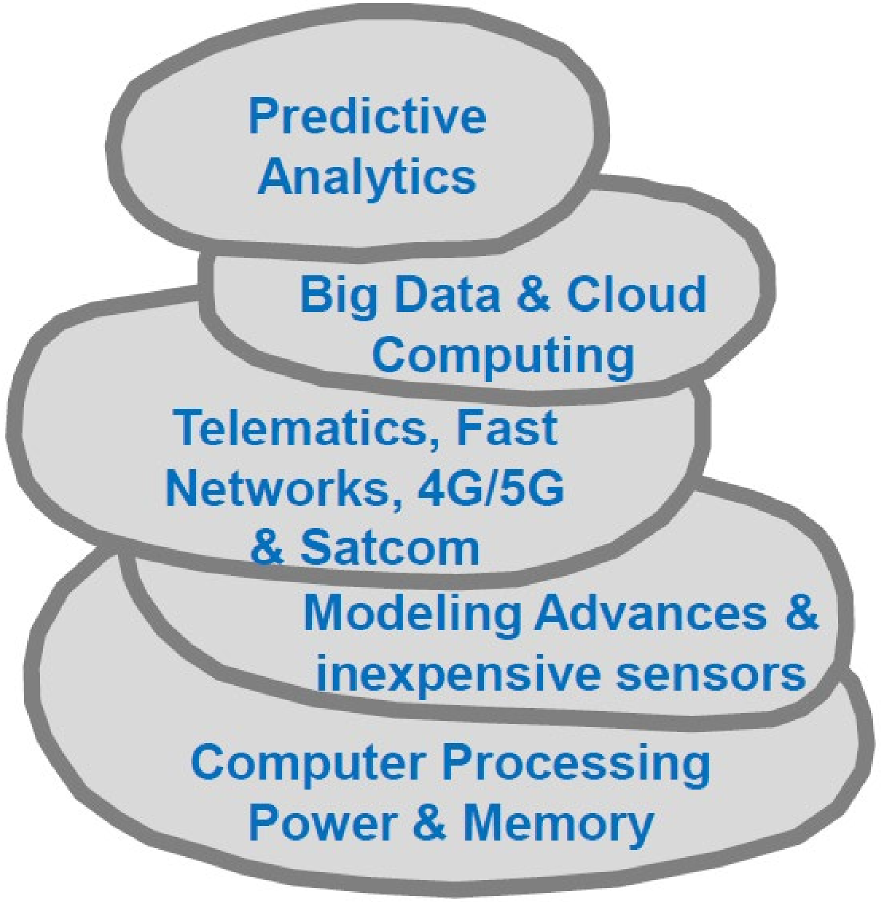
Caveat: This distinction is *very* significant technically but is mostly lost on the public







TECHNOLOGICAL ADVANCES CREATING A NEW PARADIGM



Prognostics were enabled by stacking a series of technological advances

- Trend toward electrification (p/s, p/b, fan, landing gear)
  - lighter, more efficient, built-in signaling capacity
- …***but*** business and social systems need to evolve
  - data ownership?
- ***…but*** we need better real-time performance, scalability, and sustainability

HRCS FOCUS: *MOBILITY* (BUT CAN ALSO BE APPLIED TO FIXED-BASE EQUIPMENT)

Current Members:

Bell Aerospace

Global Strategic Solutions

General Motors

Garrett Motion

VHM Innovations

***Volvo GTT** (Group Trucks Technology)*

IVHM IN SPACECRAFT

Spacecraft: *Fédération Aéronautique Internationale:* Must reach an altitude of at least 100km (Kármán line)

- First spacecraft: German V-2 reached 189km in June 20, 1944

- First orbital spacecraft: Russian Sputnik 1 reached orbit on October 4, 1957

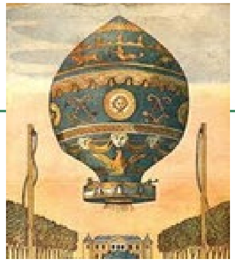
- First human spaceflight: Russian Yuri Gagarin April 12, 1961

- First lunar landing: Americans Neil Armstrong and Buzz Aldrin July 20, 1969

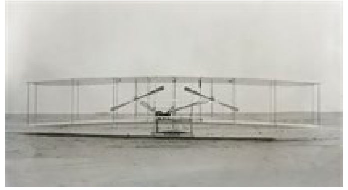
- First GPS satellite constellation 1978

- First IVHM 1978-1984 GPS constellation
  - NRTE (non-repeatable transient events preceded failures, thought to be random)

IVHM IN AIRCRAFT



- First flight: Frenchman Montgolfier September 19, 1783
  - *Hand signals, signs, and torches*



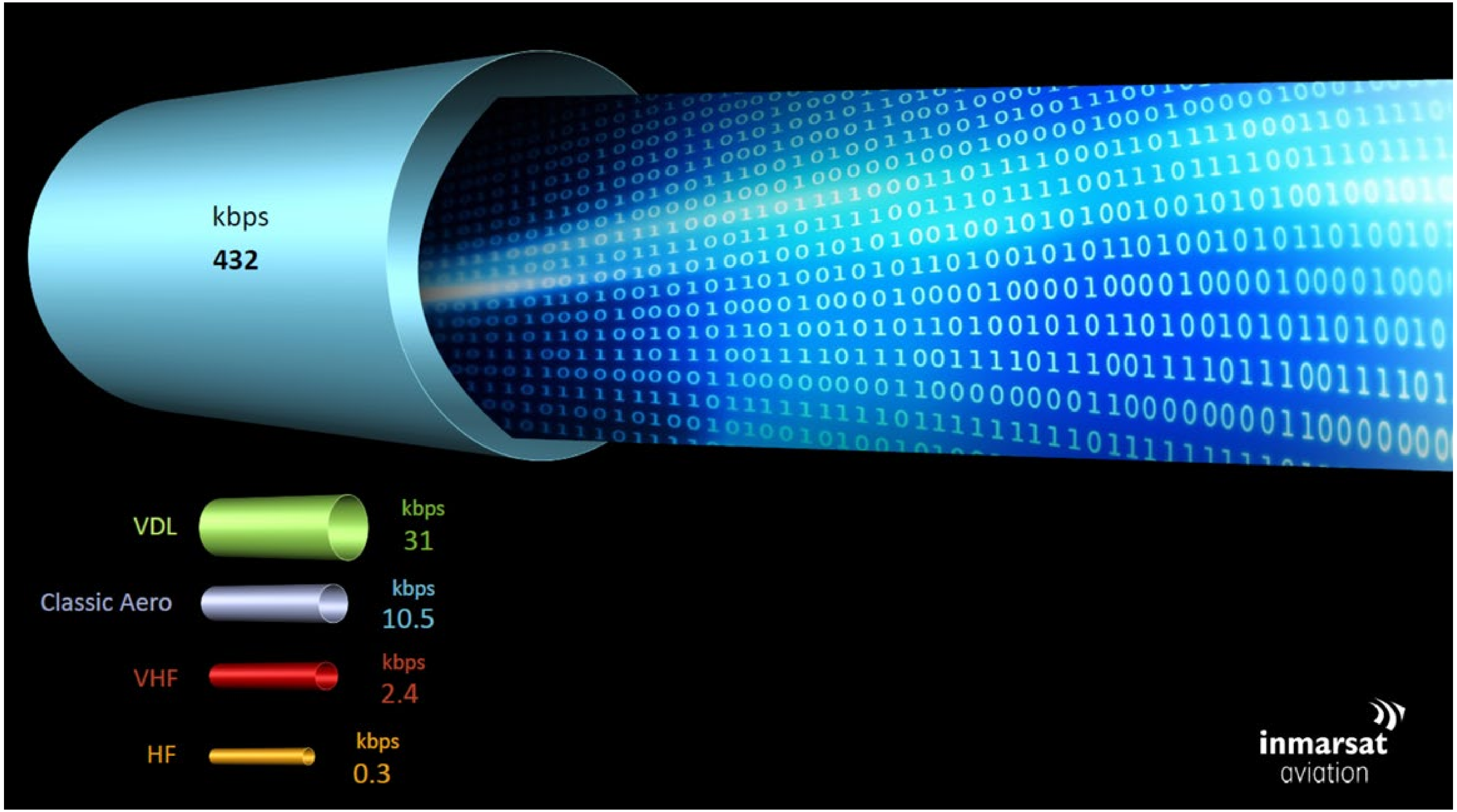
- First heavier than air flight: American Orville Wright in Kitty Hawk, NC December 17, 1903
  - *Two-Way radio 1915*

- First transatlantic crossing: American Charles Lindberg New York to Paris May 21, 1927
  - *Radar- Mid-1930s*

- First commercial jet transatlantic crossing October 4, 1958
  - *Air Traffic Control (ATC) System Mid-1950s*
- First communication by Airlines Communications Addressing and Reporting System (ACARS) 1978
  - *Improvements in safety, efficiency, and air traffic management*

- Other systems Ku, Ka, L-Band, Wifi, 4G/5G, etc. enable ***Connected Aircraft***
  - *Real-time data monitoring, big data, predictive analytics, improved operations*

COMMUNICATIONS PIPE (SOURCE: MARY MCMILLAN- INMARSAT)



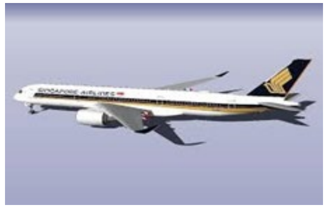
IVHM IN AIRCRAFT

- Over 50% of operators were using data analytics to compete in 2019
- 10-40% reduction in maintenance costs
- 25% cost reduction in remote maintenance

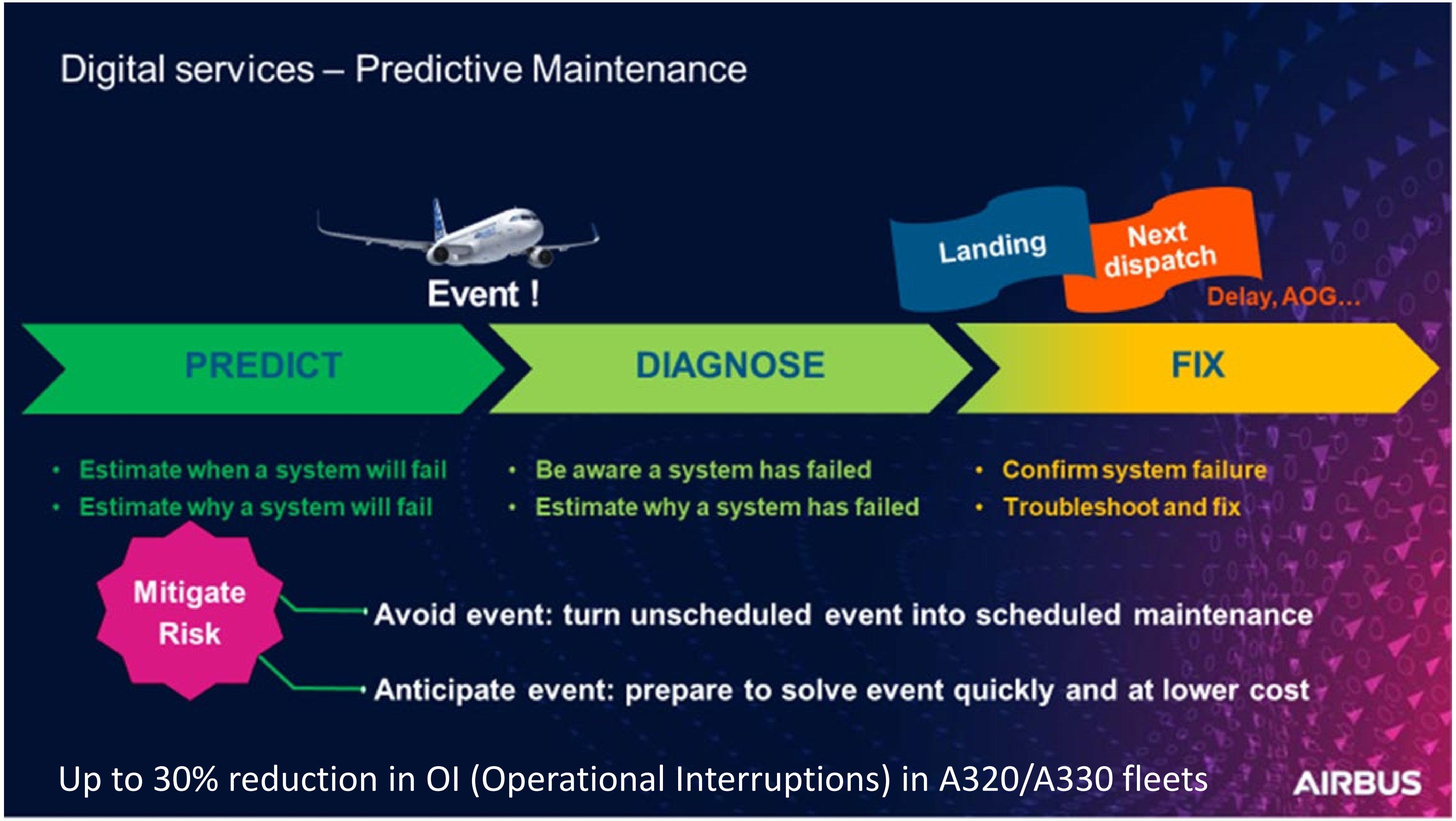
A320: 400 parameters 50MB
A320: 24,000 parameters 12GB

A330: 1500 parameters 200MB
A330: 40,000 parameters 30GB

A350: 600,000 parameters 1TB 6,000 sensors



PREDICTIVE MAINTENANCE (SOURCE: JEAN-FRANCOIS ST. ETIENNE- AIRBUS)

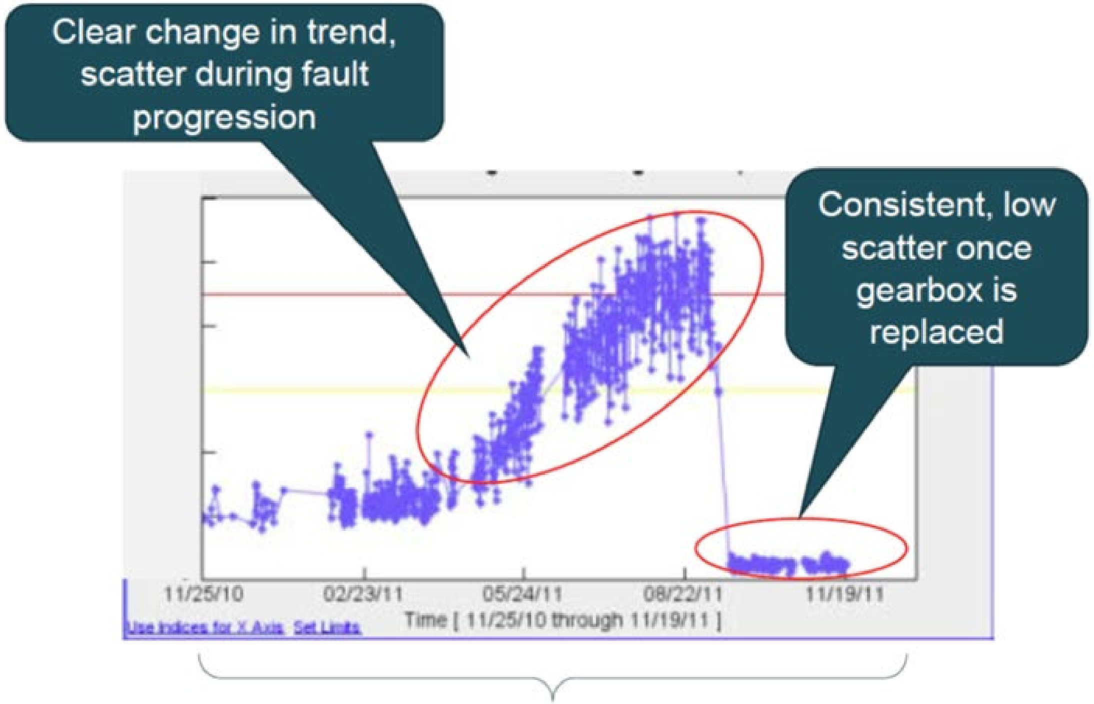


BELL IVHM IMPLEMENTATION (SOURCE: BRIAN TUCKER- BELL AEROSPACE)

Big Data Application

Finding Anomalies in Vibration Data

- Thresholds
  - based on fleet characterization
- Automated trend detection



Time period = 1 year

HRCS DATABASE: 3 REGISTRATION STAGES
(NOTE: COMPONENT/SUBSYSTEM LEVEL)

Ladder-like structured Stage Registrations for easy entry and upgrades when ready. No proprietary information will be requested or listed.

Stage 1: *Functional Self Assessment*

Stage 2: *Failure Modes Assessment*

Stage 3: *Detailed Design Assessment*

Note:

- *Stage 1 is a low barrier to entry provisional registration. All Stage 1 information will be recorded in online HRCS Registry.*
- *Stages 2 & 3 are enhanced by seeking an OEM/ integrator to validate the more detailed supplier-provided assessments. Stage 2 & 3 completion will be noted in HRCS Registry.* ***This additional (potentially proprietary) data will not be loaded into the registry.***

DATABASE THREE REGISTRATION STAGES

(NOTE: NOW AT THE COMPONENT/SYSTEM LEVEL)

Health-Ready Components & Systems (HRCS) Registry (Beta)

Health-Ready Components Registry

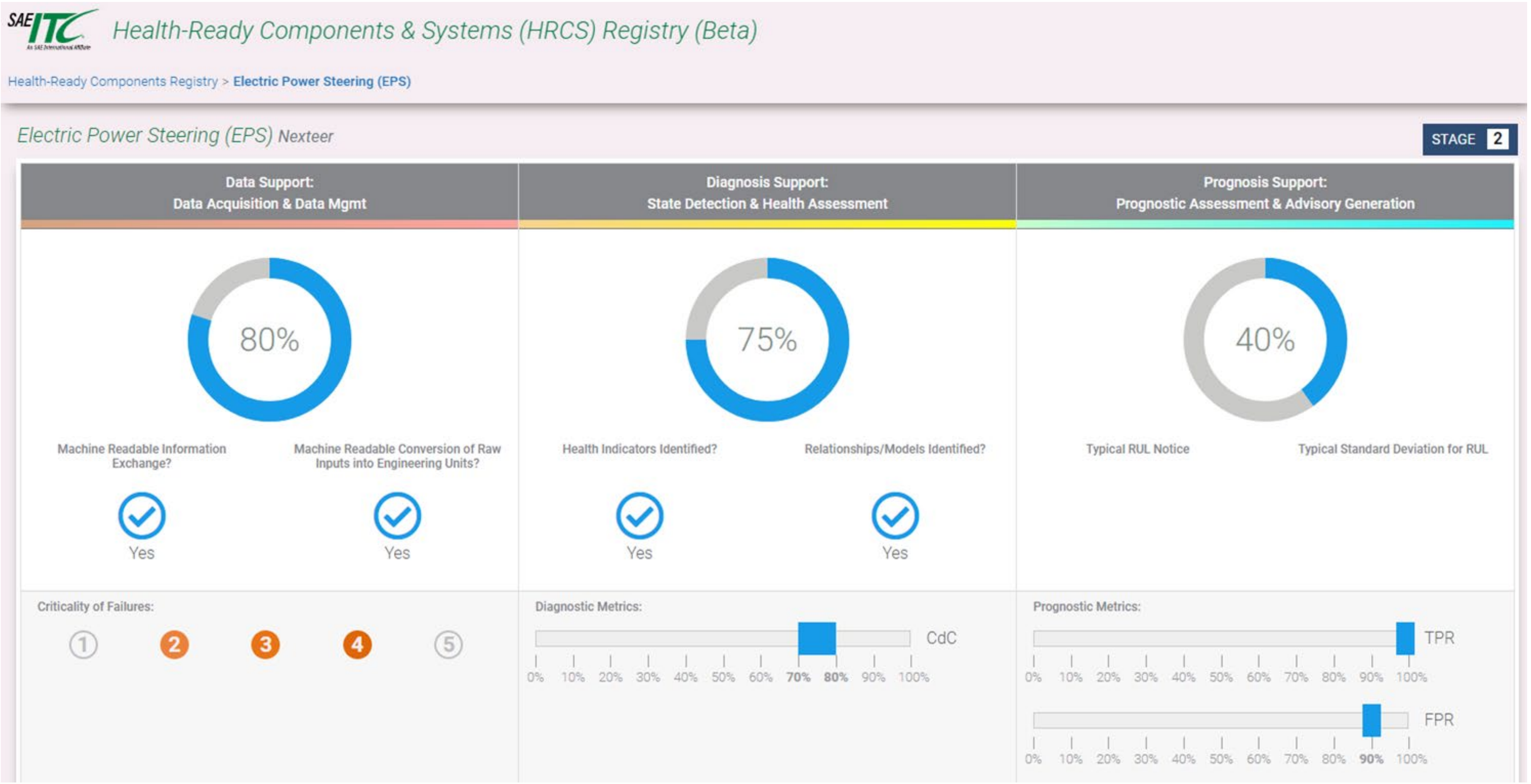
Health-Ready Components Registry

SHOW 25 ENTRIES FILTER BY: SEARCH:

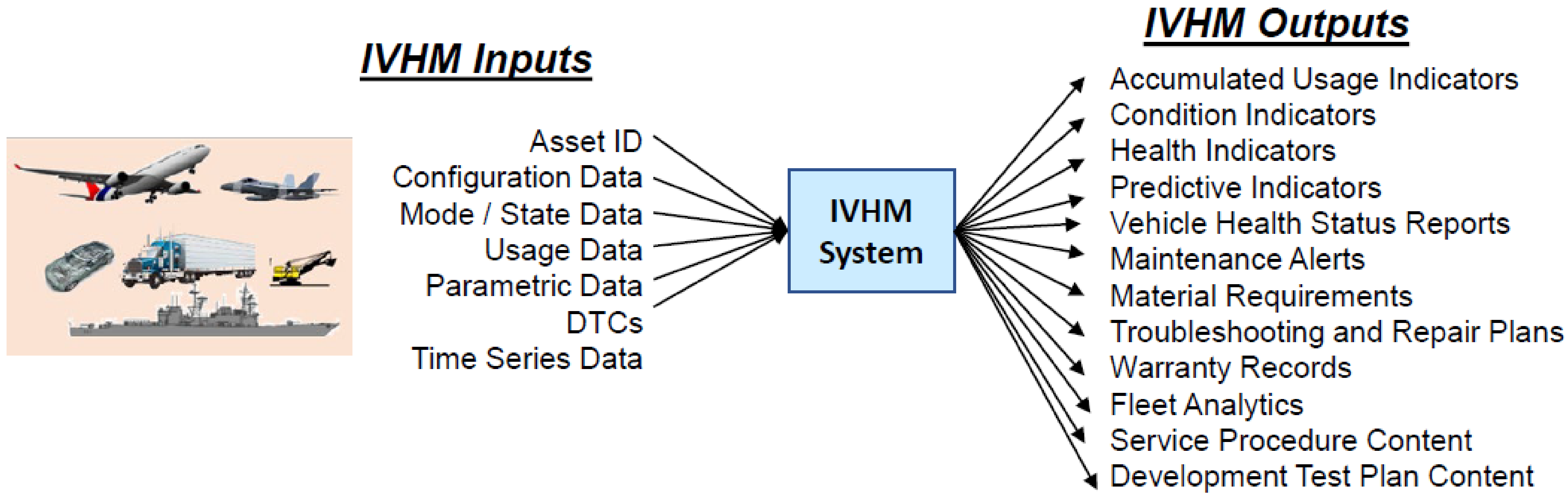
Part Name	Supplier Name	Sector	Certification Stage	Machine Readable Info Exchange	Machine Readable Conv of Inputs to Eng Units	Criticality of Failures	Data Acquisition & Manipulation Coverage	Health Indicators ID'd	Relationships/ Models ID'd	Diagnostic Metrics	State Detection & Health Assessment Coverage	Typical RUL Notice	Typical RUL Std Dev	Prognostic Metrics	Prognostics Assessment & Advisory Generation Coverage
Electric Power Steering (EPS)	Nexteer Automotive	Automotive	2	✓	✓	1 2 3 4 5		✓	✓	70% - 80% CdC				99% TPR 90% FPR	
Turbocharger with Electic Boost (eTurbo)	Garrett	Automotive	1	✓	✓	1 2 3 4 5		✓	✗	10% - 20% NTF (NFF) AMBIGUITY GROUP SIZE 1.7		30 Days	10.0 Days	91% TPR 0.10% FPR	
Turbocharger with Varible Nozzle Turbine- 5001S	Garrett	Automotive	1	✓	✓	1 2 3 4 5		✓	✗	20% - 30% NTF (NFF) AMBIGUITY GROUP SIZE 2.0		60 Days	10.0 Days	85% TPR 0.15% FPR	
Turbocharger with Varible Nozzle Turbine - 5003S	Garrett	Automotive	1	✓	✓	1 2 3 4 5		✓	✗	20% - 30% NTF (NFF) AMBIGUITY GROUP SIZE 2.0		60 Days	10.0 Days	85% TPR 0.15% FPR	
Turbocharger with Varible Nozzle Turbine - 5006S	Garrett	Automotive	1	✓	✓	1 2 3 4 5		✓	✗	20% - 30% NTF (NFF) AMBIGUITY GROUP SIZE 2.0		60 Days	10.0 Days	85% TPR 0.15% FPR	

Previous 1 Next

HRCS DATABASE LISTING DETAIL



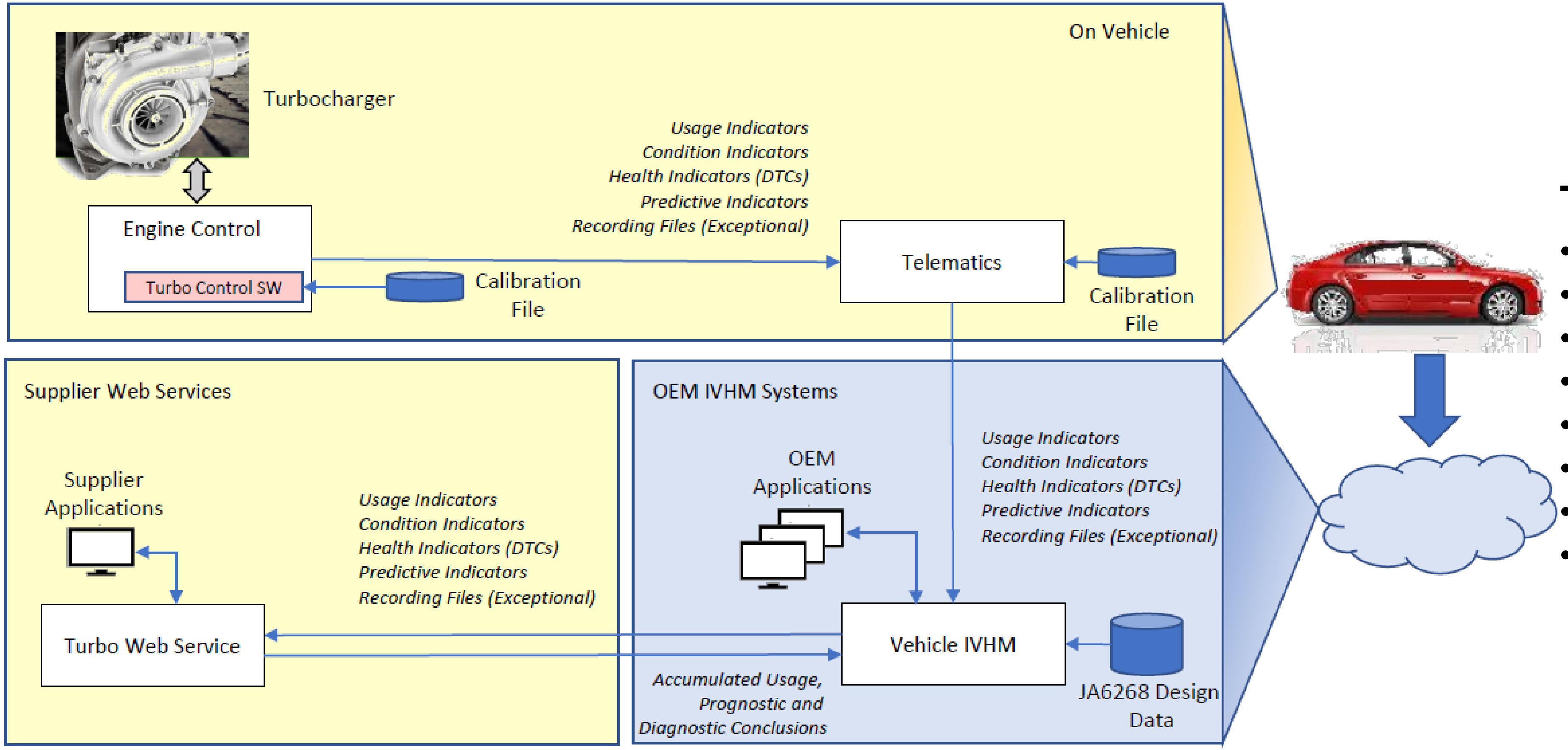
INTEGRATED VEHICLE HEALTH MANAGEMENT (IVHM)



In Summary: IVHM provides value by monitoring the health of asset and recommending a (near) optimal sequence preventative and corrective actions.

IVHM Primary Challenge: How can we build a system with sufficient accuracy with a cost that is significantly less than the value it provides.

EXAMPLE APPLICATION OF JA6268 FOR A TURBOCHARGER



Turbocharger Parameters

- Speed of turbocharger (rpm)
- Exhaust gas inlet temperature
- Exhaust gas outlet temperature
- Wastegate position
- Oil pressure
- Oil temperature
- Knock sensor
- Engine rpm

JA6268 is used to standardize design-time data submittals, web service APIs, and run time messages

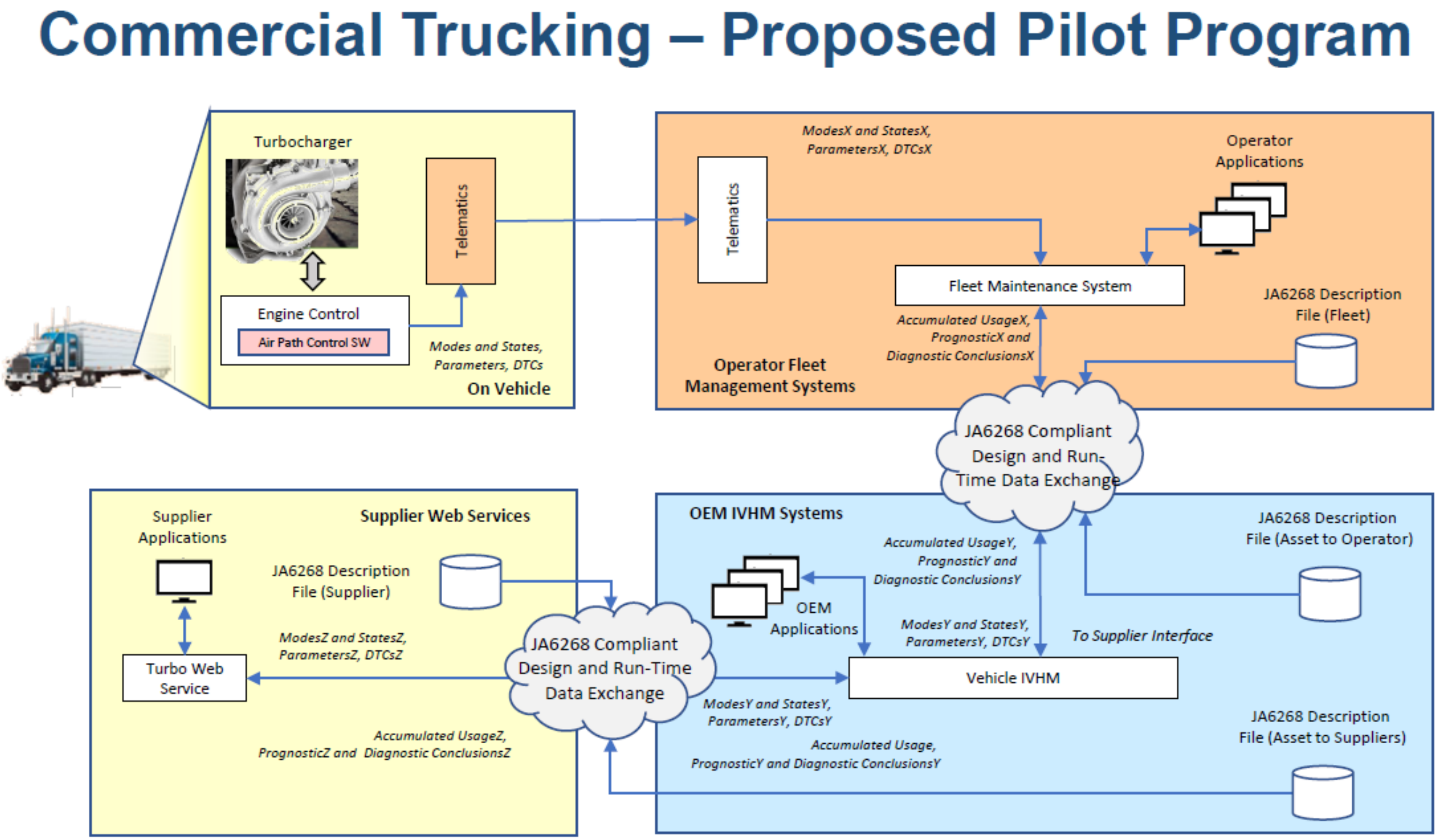
HRCS- ATA (AMERICAN TRUCKING ASSOCIATION) PILOT PROJECT

Lead Organization: SAE ITC HRCS Consortium & ATA's Technology and Maintenance Council (TMC)

- Confirmed participants:
  - Volvo GTT (tractor)
  - Garrett Motion (turbocharger)
  - Platform Science (telematics)

- Other interested parties:
  - UPS/Schneider/FedEx/Southeastern (fleet operators)
  - Great Dane (trailer)
  - ABS supplier?

HRCS- ATA (AMERICAN TRUCKING ASSOCIATION) PILOT PROJECT

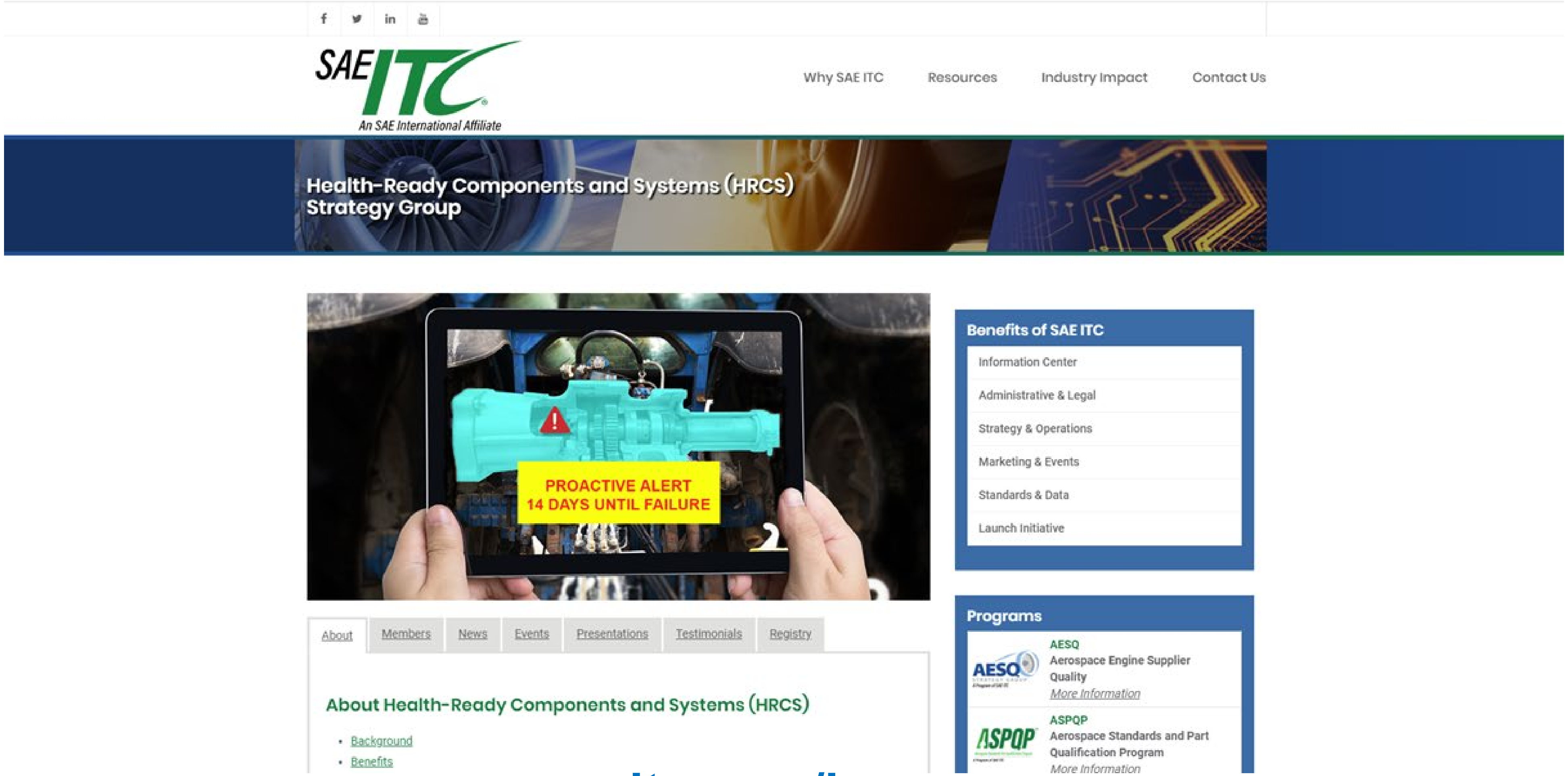


Pilot will demonstrate how JA6268 and HRCS support the integration of IVHM data and functionality between participants

OTHER PILOT PROJECTS IN DEVELOPMENT

- ***General Motors:*** Exploring a steering related project
- ***Bell Aerospace:*** In partnership with Astronics using electrical signals from their power distribution system as input parameters
- ***HRCS Templates:*** Development directed by the HRCS Executive Committee and supported by sector specialists
  - Base level parts with master and sector templates
  - Standard signals defined, proprietary signals only shared between supplier and OEM
  - Will be available in the HRCS database
  - Templates can be updated and refined

HEALTH-READY COMPONENTS AND SYSTEMS



www.sae-itc.com/hrcs

Questions?

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Thank You