Integrated Vehicle Health Management

IVHM CAPABILITY LEVELS ARE DEFINED IN SAE INTERNATIONAL RECOMMENDED PRACTICE JA6268

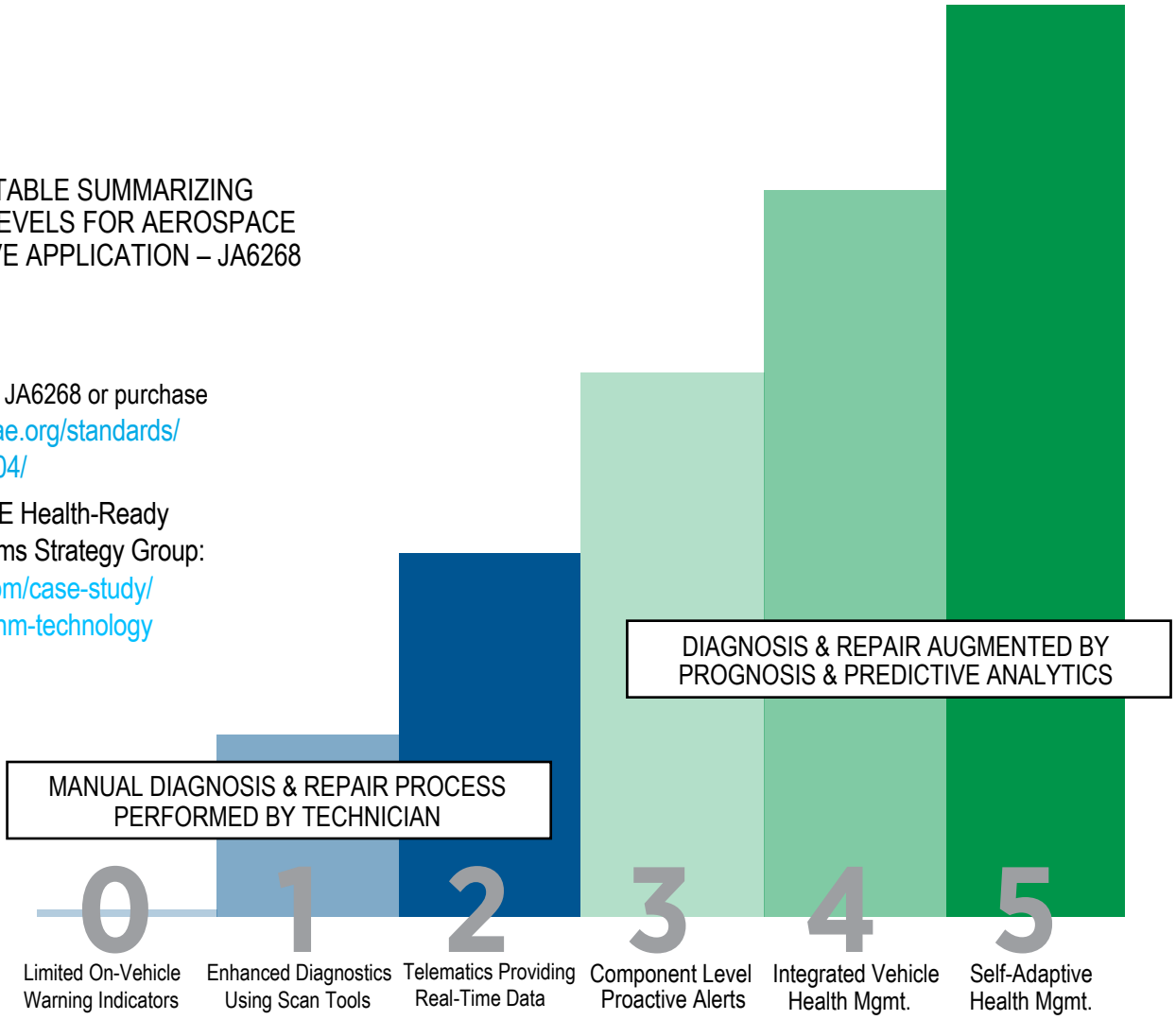
With the goal of providing common terminology for Integrated Vehicle Health Management Systems, SAE International's recently published standard JA6268: "Design & Run-Time Information Exchange for Health-Ready Components," includes a harmonized classification system and supporting definitions that:

- Identify six levels of IVHM system capability from essentially "no automation" to "self-adaptive health management".
- Base definitions and levels on functional aspects of technology.
- Describe categorical distinctions for a step-wise progression through the levels.
- Are consistent with current industry practice and future directions.
- Eliminate confusion and are useful across numerous disciplines (engineering, legal, media, and public discourse).
- Educate a wider community by clarifying for each level what role maintenance technicians have in performing vehicle repairs.

OVER FOR A TABLE SUMMARIZING CAPABILITY LEVELS FOR AEROSPACE & AUTOMOTIVE APPLICATION – JA6268

Learn more about SAE JA6268 or purchase a copy: https://www.sae.org/standards/content/ja6268_201804/

Learn more about SAE Health-Ready Components & Systems Strategy Group: https://www.sae-itc.com/case-study/unlocking-potential-ivhm-technology



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SUMMARY OF SAE INTERNATIONAL'S CAPABILITY LEVELS FOR AEROSPACE & AUTOMOTIVE APPLICATIONS

Published in April 2018, SAE international's JA6268 was created to help reduce existing barriers to the successful implementation of Integrated Vehicle Health Management (IVHM) technology into the aerospace and automotive sectors. It is motivated by the need to facilitate the introduction of enhanced IVHM functionality relating to supplier-provided components to better meet the needs of end users and government regulators in a cost effective manner.

The report's six capability levels for IVHM span from no automation to self adaptive health management. A key distinction is between level 2 & 3, where prognostics and predictive analytics are brought to bear to significantly enhance the capabilities of the system.

These levels are descriptive rather than normative and technical rather than legal. The capability levels illustrate increasingly sophisticated approaches for diagnosis and prognosis, but do not imply that all companies will implement the levels in this exact order. For example, individual companies may choose to implement specific capabilities for given subsystems based on real-world constraints but not apply the same to the entire vehicle. Elements indicate minimum rather than maximum system capabilities for each level. A particular system may have multiple IVHM features such that it could operate at different capability levels depending upon the feature(s) that are engaged.

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**

Key definitions relating to JA6268 include (among others):

Diagnosis is the process of determining the root cause of a problem once a failure has occurred …that is, what part replacements or repair actions are necessary to fix the problem. Diagnostic Trouble Codes (DTCs) or Built In Tests (BITs) are used to capture symptoms of possible faults which have been detected and which could be useful in diagnosis.

Prognosis is the process of estimating remaining useful life in order to predict failures. This estimation is based on (1) monitoring state of health during the onset of specific failure modes and (2) executing fault progression models until they reach a future failure threshold. A sufficiently early prediction allows for possible mitigating action to take place. Health reporting codes are issued based on onboard symptoms or evidence and can provide warnings of necessary service action in order to avoid an imminent failure mode.

Integrated Vehicle Health Management refers to the unified capability of a system of systems to assess current or future state of member system health and integrate that picture of system health within a framework of available resources and operational demand (as defined by SAE's IVHM Steering Committee.)

Contact: SAE INTERNATIONAL +1.724.776.4841 • Global Aerospace Standards +1.248.273.2455

Because Vehicle Health Management (VHM) system capabilities vary from product to product, SAE International's recommended practice, JA6268[1], defines six levels of health management capability (identified as level 0 to 5) for aerospace and automotive OEMs, their suppliers, and government regulators to describe a vehicle's health management sophistication. An important paradigm shift occurs between Levels 2 and 3, where vehicle diagnosis and repair processes are augmented with prognosis and predictive analytics. The commonly used progression to characterize analytics ranges from (a) descriptive (that is, classification only) to (b) predictive (that is, ability to forecast or predict coming events) to (c) prescriptive (that is, both the forecast of coming events and actionable advice on how to address it). This also aligns with moving up the hierarchy from input ***data*** alone transformed into useful ***information***, and then to ***knowledge***, and ultimately to a prescribed ***action.***

Level 0: Limited On-Vehicle Warning Indicators
Vehicle maintenance actions are prompted by either scheduled maintenance intervals or when the vehicle operator is alerted by indicator lights, simple gauges or observes a performance issue.

Level 1: Enhanced Diagnostics using Portable Maintenance Aids
Vehicle is equipped with on-vehicle diagnostic software (e.g., OBD, BIT, HUMS). Maintenance technician gains added diagnostic insight using portable maintenance aids or scan tools to extract vehicle operating parameters and/or diagnostic codes (e.g., DTC, BIT, CI, or HRC) that were calculated and retained on-board specifically to enhance the diagnostic process.

Level 2: Remote Health Monitoring
Vehicle is equipped with data link to transmit diagnostic health indicators and operating parameters to maintenance technicians or to a central support center. Maintenance technician gains added diagnostic insight (in advance) without having to physically be there. In addition, the data can be used to monitor real-time performance or to capture performance history over time for subsequent analysis.

Level 3: Component Level Proactive Alerts
Vehicle operator and maintenance technician are provided with component Proactive Alert Identifiers (PAI) as alerts of impending problems, possibly listing severity (Red/Yellow/Green), along with estimated component Performance Life Remaining (PLR) or Remaining Useful Life (RUL) and recommended remediation actions.

Level 4: Vehicle Level Health Management
Operator and maintenance technician are provided with cross-system or vehicle-level health indictors before problems occur, along with estimated critical function Performance Life Remaining (PLR) or Remaining Useful Life (RUL) and recommended remediation actions.

Level 5: Self-adaptive Health Management
VHM capability is integrated with vehicle control functions to provide autonomous, real-time, self-adaptive control and optimization to extend vehicle operation and enhance mission completion and/or safety, in the presence of component or system degradation.

[1] https://www.sae.org/standards/content/ja6268_201804/