AIAC14 Fourteenth Australian International Aerospace Congress

Autonomic and Sense and Respond Logistics: Evidence from the USA and UK

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Abstract

Autonomic and Sense and Respond Logistics are a continuum of logistics support that, in military terms at least, connects the 'foxhole to the factory to the foxhole'. The concept has expanded from its origins in the avaition industry to become an integrated element of a range of civilian enterprises and network centric, military operations.

Equipment Health Monitoring Systems have existed for decades. One such system was developed for jet engines in the F-15 and F-16. The Engine Monitoring System consisted of the Engine Diagnostic Unit (EDU) and the Ground Diagnostic Unit (GDU). The EDU monitored and recorded the operating conditions of the aircraft systems. Once the aircraft had completed its mission and had landed, the EDU was connected into the GDU and the data was downloaded so that it could be analysed. This paper presents developments in Autonomic and Sense and Respond Logistics from the USA, UK and Australia.

Keywords: Autonomic Logistics, Sense and Respond Logistics, Aviation logistics, Combat Service Support, Logistics continuum, Military Integrated Logistics Information System

Introduction

Until recently, platform-based, logistics applications required data to be physically downloaded and transferred between systems so that analysis could estimate the status of key components. In both the Automated Logistics (AL) and Sense and Respond (S&R) systems, prognostics has been added to monitoring functions. That is, the electronic/electromechanical suite located in the aircraft or vehicle obtains metrics from sensors throughout the asset and compares them to preset standards using algorithms, in order to predict the status/longevity of the part or unit. This real time prediction aspect is a relatively new logistics development facilitated by the real-time communication of data while the platform is in operation.

While the (Australian) Military Integrated Logistics Information System (MILIS) proposes to extend the reach of supply chain information to sub-unit level, it falls short of crossing the gap to link HUMS (platform-based data) into the logistics continuum to provide end-to-end visibility of Combat Service Support (CSS).

This paper will review evidence from recent military applications of Autonomic and Sense and Respond Logistics in the United States Marine Corps, the United States Army and the military in the UK as well as the multinational Joint Strike Fighter (JSF/F-35) program. It will state the case for application of Autonomic and Sense and Respond Logistics to the ASLAV, the Australian variant of the US Light Armored Vehicle (LAV), and Bushmaster platforms, in a similar fashion to those employed in the US and the UK, as starting points to provide end-to-end connectivity of the logistics continuum as well as a source of accurate and up-to-date CSS information for the various levels of command.

The evolution of HUMS

The Australian Warfighter does not have access to complete logistical data that would impact on the tactical aspects of immediate operations. For instance, questions such as: what is the current and projected ammunition and fuel usage of critical vehicles?; can that helicopter make another mission based on actual maintenance required as opposed to flight time limitations?, require answers best provided by accurate and timely information. These capabilities are available and we will insight into some of the current initiatives in the United States (U.S.) and the United Kingdom (U.K.) as well as some programs in the commercial sector.

Health and Usage Monitoring Systems (HUMS) have existed for decades. One such system was developed for jet engines used in the F-15 and F-16. The Engine Monitoring System (EMS) consisted of the Engine Diagnostic Unit and the Ground Diagnostic Unit. The EDU recorded the operating conditions and any anomalies. Once the aircraft was on the ground, the EDU was connected into the GDU and the data was downloaded so that it could be analysed. This same concept was transferred over into the automotive arena and the diagnostic system now used on the family car. But even here, the car has to be taken to a shop and hooked up and the data downloaded for analysis. The HUMS data is not available "real time" to the entire system. This is the current situation within the Australian Defence Force (ADF). While the various services in the U.S. and the UK have HUMS made data availability from all platforms, in real-time, to the complete logistics system, a primary goal. The ADF does not appear to share the same concept of tactical logistics visibility.

Evidence from the USA and UK

U.S. Defense Examples

Two programs in the U.S. are Autonomic Logistics (AL) and Sense and Respond Logistics (S&RL). Both of these concepts make HUMS data available, on-board, and through external links, as inputs to the wider logistics system, while the platform is in operation. Autonomic Logistics was developed by the Lockheed Martin Corporation (LMC) specifically for the Joint Strike Fighter (JSF/F-35) program. It uses sensors integrated into the various components of the

aircraft to generate HUMS data (including prognostics) which is transmitted back to base and to the Autonomic Logistics Information System (ALIS). The ALIS links this data to the LMC headquarters in Colorado, USA and the various suppliers around the world. Based on this information, status and requirements for the fleet can be determined and acted upon. While the system obviously generates information of military value, it is essentially a commercial system designed to support a specific product. 1

When acquiring a new system a general rule that is used to estimate the life cycle costs is that the platform acquisition accounts for one third of total costs. Logistics and Operational costs make up the other two thirds. An example is the Australian Joint Strike Fighter (JSF) program.

> The true cost of owning a modern jet fighter includes 25 or 30 years of maintenance support, and pilot and ground crew training, and this is often twice or more the original purchase price. The JSF program includes a global logistics sustainment system… That doesn't include the cost of fuel and weapons.2

A 100 aircraft buy is preferred by the Australian Government. Using a per aircraft cost of US$50 million, this would amount to a US$5 billion purchase. Using the general rule above, support / operating costs would equate to US$10 billion for a program cost of US$15 billion. The supplier of the JSF (LMC) estimates a 20 per cent reduction in the logistics costs over the life cycle due to the application of AL. This equates to a US$ 2 Billion savings for the Australian JSF program.2 While the financial aspects are impressive, the theatre commander would be more impacted on by the reduced turn times and availability based on actual condition as opposed to flight time.

Australia will participate in this aspect of the JSF program only because it is a mandatory condition set out by LMC. There seems to be little Australian industry interest in AL or S&RL. When the 4th Australian JSF Advanced Technology and Innovation Conference was held on 3-5 May 2010, there were two logistics discussion streams initially proposed, Autonomous and Autonomic Logistics, both streams were dropped due to lack of discussion papers, not-withstanding this, there were some outstanding individual papers presented on the topic.

The Sense and Respond Logistics concept was created by the United States Marine Corps (USMC) using the Light Armoured Vehicle (LAV) as a prototype. It uses "bolt on" sensors to generate vehicle status and prognostic information. This includes parameters such as fuel consumption, differential temperature and other vehicle data as well as ammunition usage and balance remaining. The information is provided to the vehicle as well as consolidated at the various levels of command. In a report by the Penn State IST, the authors state, "One of the key benefits of the project to date has been the organizational learning... In our opinion, *Sense & Respond* has significantly increased the Marine Corps' institutional knowledge . . ." 3

Studies by Penn State and FTI, extrapolating existing data, indicate that when deployed to the fleet, the following benefits will be realized:

> **Cycle Time:** Reduction in customer wait time of ~50%. This reduction comes about through the ability to provide early warning of abnormal conditions. These warnings enable the logistics, operations, and maintenance planners to optimize the repair and return to service.
>
> **Cost Avoidance:** >$10M annually. This is based on an inventory of approximately 400 LAV-25 variants and an estimate of $22.35 per mile cost of operating (including personnel and depreciation costs).
>
> **Reliability:** Increase mean time between failure (MTBF) >14%. This was based on a Penn State study which stated an increase in MTBF from 64 hours to 73 hours, or 14%.
>
> **Availability:** 7% increase in operating availability (A_o) translating to availability of 34 additional vehicles across the fleet based on the data shown above.4

S&RL system was developed to support both the Logistics/Supply Chain as well as Operations. Data is gathered for current level usage and is transmitted to the next level in the chain of command for aggregation and review.

> With information technology, S&RL receives, recognizes and responds to consumption and requirement patterns through the use of equipment embedded Intelligent Agents. S&RL leverages the capabilities of network-enabled forces to share logistics information, share a common perspective of the battle space, and provide early awareness of consumption and needs, allow commitment tracking and allow for reconfiguration of the logistics system when needed. It will tell the Commander "how much fight is left" in his units. 5

As illustrated in the above quote, and shown in *Figure 1*, accummulated and aggregated data provides input to the decision making process at various stages leading ultimately, to the 'Enterprise' level, a term employed by the USMC to describe its own and other organisations.

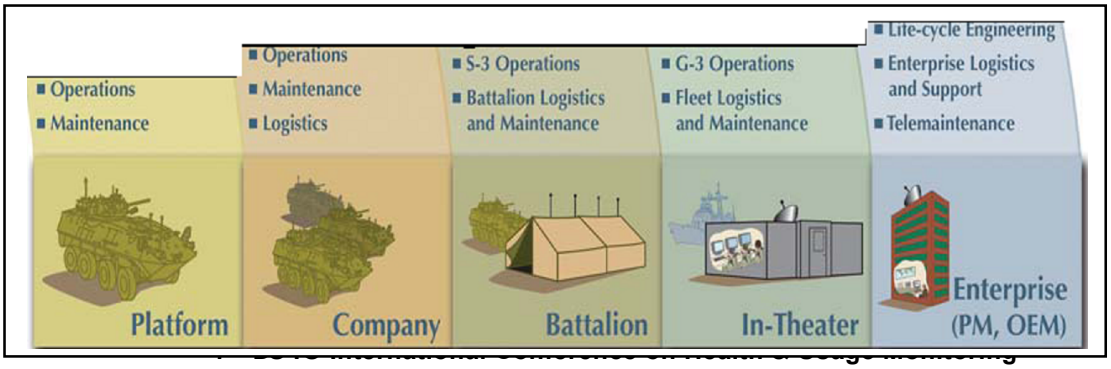


Figure 1. Overview of S&RL 4

Figure 1. Overview of S&RL 6

The Office of Naval Research (ONR) is in charge of this program and their view of the benefits was recently provided. "The Sense and Respond Logistics program will enable commanders to more accurately assess their environment, identify when a plan is executing differently than intended, and help develop alternatives ahead of real time,"7 explained Tony Seman, ONR program manager. "The technology developed for the program will combine the commander's intent with 'ahead of real time' data and use that information to develop potential courses of action and evaluate the impact of those decisions."8

As seen in the examples above, the availability of the usage, health and prognostics information in real time moves HUMS out of the realm of being solely a maintenance tool into the arena of providing the platform manager with a potent tool. The United Kingdom (UK) has also come to the same conclusion as the Americans.

The UK Ministry of Defence (MoD) initiated the Joint Asset Management and Engineering Solutions (JAMES) July 2005.

> JAMES currently manages more than 60,000 pieces of equipment for the British Army giving users and commanders the ability to identify the availability, status, condition, ownership and location of a piece of equipment in moments. 9

The UK MoD has announced Phase 2 (JAMES Land) which covers all land vehicles for the Navy and Air Force as well as the Army. It should be noted that one of the vehicles covered by this program that has the ability to be fitted with a suite of equipment to provide HUMS data, is the Bushmaster, manufactured in Australia.

The Commercial sector has moved swiftly to embed HUMS systems into their operations with the aviation industry, taking a leading role globally and, through platform acquisition, in Australia. "QANTAS Airbus AIRTRAC system provides a link between the airframe and a dedicated support facility staffed with specialist engineers available 365 days a year."10 The A380's onboard software monitors every system and instantly sends an email to AIRTRAC if

any anomaly is spotted. The instant the email is received, the required part is ordered so it's ready for the arrival of the A380. 11

The Boeing Aircraft Company offers a similiar capability.

Agriculture has adopted the concept using sensors in every aspect of planting and harvesting. Tractors have telematics and remote monitoring features. "If a service issue develops in the field, technicians at the dealership can remotely identify the problem, determine the tractor's location and proactively address the problem." 12

The discussion brings us to the question of the status of real time HUMS within the Australian Defence Force (ADF). The need has been identified within the Australian Dept. of Defence's Network Centric Warfare Roadmap, updated as of 2007.13 Logistics is included under "Collabrative Planning" and the Target State is entitled "Force Generation and Sustainment in 2020". This State is described as:

- Key logistic function networks within the National Support Area (NSA) are linked with those in theatre, and provide connectivity and a collaborative ability with industry and coalition partners.
- Commanders have an end-to-end visibility of the logistic system providing the ability to rapidly and effectively prioritise scarce resources required to generate and sustain deployed force elements.
- Automated ordering and replenishment takes place as supplies and ordnance are consumed by platforms and field units.
- The deployed force has minimised its vulnerabilites and greatly enhanced its mobility through more effective reach back, optimum force presence and the precision sustainment for the majority of logistics requirements. 14

HUMS and MILIS

When the F-35 is introduced into Australia it will bring with it the requirement to participate in the in Lockheed Martin Corporation's Autonomic Logistic Information System.15 What about the rest of the ADF? The Military Logistics Information System (MILIS, JP 2077) was identified to meet the requirements cited in the Network Centric Warfare Roadmap. This project has addressed many concerns in the ADF: the reduction of legacy systems in Defence, Improved interconnectivity between information systems and, the introduction of technology such as Radio Frequency Identification devices (RFID) for asset tracking, but it does not provide real time information to decision makers in the supply chain or related logistics areas. MILIS is conceived as a system which, at the theatre end, terminates at the unit level. There is an 'air gap' between the platform and MILIS at this point and real time data is not available as an input into MILIS. Since HUMS data is not available real time to all the stakeholders the logistic end states described in the NWC Roadmap cannot be met. Most importantly, the theatre commander does not have the information required to make the best usage of the assets. A farmer on the Darling Downs has better visibility of the remaining capabilities, connectivity and support for his

machinery than an Australian Operations Commander in Afghanistan has in real-time of the condition of ASLAVs on military tasking.

This concern impacts the ADF across the board:

-Financially, with a possible savings of all operation and maintenance costs of between 7 and 20 %;

-Increased Reliability;

-Reduction in repair cycle time;

-Increased availability;

-MOST Importantly, theatre commander's increased situational awareness 16

Conclusion

The way forward is for the HUMS data to be recognized for the important factor that it is, not only as a maintenance tool, but as a critical input into the management of assets, whether they are military or commercial.

The ADF will adopt the concept of a true end to end system eventually, if for no other reason than they need to be inter-operable with the American, and UK forces. It would obviously make sense to provide the Warfighter with the best support possible and reap the financial and efficiency benefits as soon as possible. This could be achieved relatively quickly at reasonable cost by the ADF procuring some of the bolt-on kits, proved on LAVs by the USMC, for ADF ASLAVs. The greater challenge will be modifying the system's connectivity so that it can integrate with the MILIS system. The same approach could trialed with the Bushmaster to evaluate the UK's JAMES approach. Other platforms have the capability to be retrofitted, Naval platforms, RAAF air assets, and a range of vehicles forecast to enter, and currently in, Australian Army service, but no direct interface exists between them and the MILIS/theatre level communications system. This needs to be developed within Australia for the ADF to enable the states laid out in the NCW Roadmap to be achieved.

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