Health and Usage Monitoring Proof of Concept Study Using Army Land Vehicles

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Abstract

Defence is undertaking major reforms in an effort to deliver *through life support* savings in materiel sustainment. The integration of Health and Usage Monitoring Systems (HUMS) into land platforms is an area that promises wide ranging benefits including increased platform availability and efficiencies in fleet management. Land Engineering Agency (LEA) has embarked on a program of work designed to prove that employing HUMS on land platforms will deliver improvements in the management of land materiel.

To validate that HUMS is a viable concept, the platform Original Equipment Manufacturers (OEMs) were contracted to each design and fit HUMS to four of their in service platforms. These vehicles were operated routinely and the HUMS data integrated with Defence's Military Integrated Logistics Information System (MILIS), before being analysed for its ability to support fleet management. The trial outcomes demonstrated the capability for HUMS to deliver enhancements in fleet management through Condition Based Maintenance (CBM), automated data entry, enhanced operational statistics, and increased understanding of the platform's mission profile.

Keywords: Health and Usage Monitoring Systems, HUMS, Land Vehicle, Fleet Management, Condition Based Maintenance, Sensors, Data Logging.

Introduction

In order to reduce the cost of sustaining military fleets, Land Systems Division (LSD) is driving reforms in the areas of fleet management and maintenance engineering. The integration of a HUMS into legacy and future land platforms promises wide ranging benefits in terms of fleet management efficiencies, informing platform Life of Type studies, as well as options for pursuing a CBM regime. For these reasons, LEA has undertaken a study to prove the benefits of fitting HUMS to the M113AS4, Bushmaster Protected Mobility Vehicle (PMV) and Australian Light Armoured Vehicle (ASLAV).

Background

A generic vehicle HUMS in the context of the LEA solution is illustrated in figure 1. Sensors measure vehicle parameters at a relatively high sample rate, for example, 10 samples per second (Hz). The sensor data is initially stored in the Vehicle Data Logger which is also capable of conducting a significant amount of on-board data processing. The current LEA strategy transfers the stored data to two data bases:

[1] The opinions expressed in this paper are those of the authors and do not necessarily reflect the position of the Australian Department of Defence.

- The Forensic Data Base contains the raw, unprocessed detailed data used to investigate accidents, incident or significant failures; and
- The MILIS Data Base contains daily Operating Statistics and Condition Based Monitoring Data which has been heavily reduced compared to the raw data.

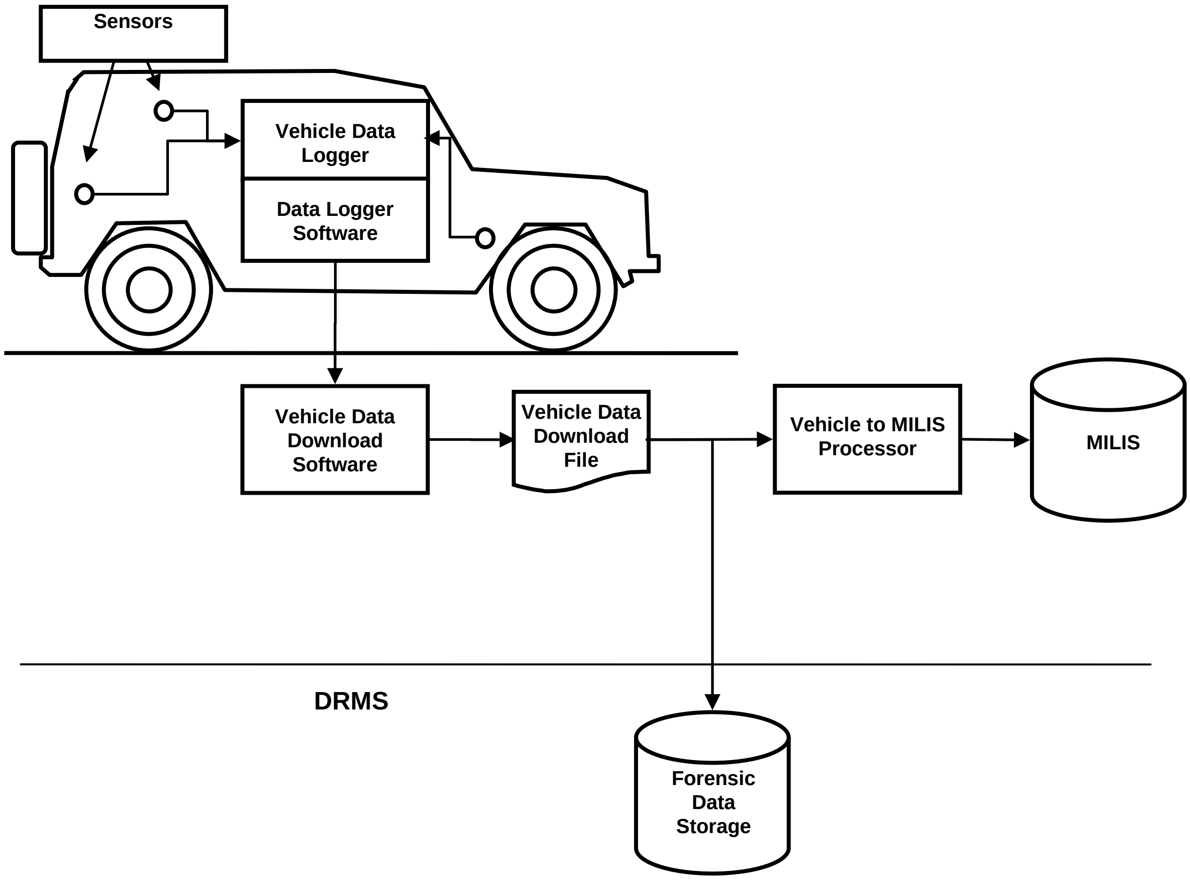

Fig 1: Generic HUMS illustration

A Vehicle to MILIS Processor is required to provide the interface between the raw vehicle data and the MILIS database.

The HUMS Proof of Concept has established the ability to reduce the reliance on equipment operators and draw data direct from the vehicle that will provide opportunities to enhance fleet and maintenance management through:

- enabling a transition from reactive and fixed interval maintenance to CBM;
- reduced effort and improved accuracy in recording usage data;
- the provision of a wider range and detail of operating statistics;
- visibility of component wear rates to support Life of Type (LOT) analysis;
- an increased understanding of the impacts of environmental effects;
- the development of a prognostics capability; and
- enhanced parts/consumables planning.

Data collected on duty cycles and the environment also provides an improved understanding of actual mission profiles leading to enhanced support to current force development and more accurate use scenarios and requirements for new capabilities.

Aim

The aim of this HUMS Proof of Concept study was to:

- demonstrate that it is feasible to retrofit HUMS to in-service vehicles;
- demonstrate that commercial HUMS can operate reliably in a military vehicle environment;
- identify issues with interfacing HUMS with MILIS;
- quantify the benefits HUMS will provide in terms of enhanced Fleet Management;
- investigate the use of HUMS to provide increased understanding of LOT of Land Platforms, and to improve LOT predictions;
- demonstrate the ability to support force development management through a better understanding of duty cycles and actual mission profiles; and
- demonstrate the ability for HUMS to enable the objective investigation of accidents and incidents leading to reduced operator misuse and increased safety.

Methodology

Commencing in Sep 2011, the Proof of Concept study consisted of the following activities:

- requirements elicitation with users, maintainers, capability managers, OEM representatives and Fleet Managers;
- preparation of statement of requirement for HUMS design;
- contract OEM to undertake design, development and demonstration of HUMS;
- install and commission the HUMS on each vehicle type;
- operate the vehicles in a controlled training environment and log sensor data;
- weekly download and analysis of the data;
- process, transfer and storage of relevant data in MILIS; and
- extract data from MILIS using the MILIS reporting function.

The following testing occurred:

- four M113AS4 were fitted with MoTeC HUMS and operated as per routine training at School of Armour from 16 Jun 12 to 28 Sep 12;
- four PMV were fitted with MoTeC and Dytecna HUMS and operated as per routine training at the School of Artillery from 10 Jul 2 to 21 Sep 12; and
- one ASLAV was fitted with MoTeC HUMS and operated at Accredited Test Services at Monegeetta while undergoing various other test activities (17 Aug 12 to 21 Sep 12).

Results/Discussion

Physical Description of HUMS Systems

Stakeholder elicitation resulted in a number of sensor measurements being identified as the basis for the Proof of Concept trial. This list was used to prepare the Statements of Work against which the vehicle OEMs prepared their HUMS designs. Sensors utilised to support the requirements included:

- Engine Torque;
- Air Temperature – Manifold;
- Ambient Air Temperature;
- Battery Monitoring System :
  - Battery Time Remaining;
  - Battery Current;
  - Battery State of Charge;
  - Battery State of Health;
  - Battery Temperature; and
  - Battery Voltage.
- Odometer;
- Speed;
- Drivers Seat Acceleration (Lateral, Longitudinal, and Vertical); and
- Engine Oil Condition Sensor:
  - Density;
  - Dielectric Constant;
  - Temperature; and
  - Viscosity.
- Engine Oil Pressure;
- Engine Turbo Boost Pressure;
- Engine Coolant Temperature;
- Engine RPM;
- Fuel Used;
- GPS Altitude, Date, Heading, Latitude, Longitude, Satellites Used, Speed;
- Final Drive Temperatures;
- Throttle Position;
- Engine Hours;
- Transmission Hours; and
- Transmission Oil Temperature.

A brief description of the physical installations for each vehicle type follows:

- M113AS4 – BAE Systems interfaced a MoTeC Vehicle Data Management System (VDMS) to the vehicles' engine CANBUS and installed thermocouples to the final drive and transmission, fitted an oil condition sensor, GPS, and Battery Condition Monitor (BCM).
- PMV – Thales interfaced a MoTeC and a Dytecna data logger into the vehicles CANBUS to access data from the engine, transmission, and sensors including brake switch and accelerator position. They also added a GPS sensor.
- ASLAV – Without a CANBUS, General Dynamics installed sensors onto various subsystems and interfaced these directly with a MoTeC Data Logger.

Installation Effort

The HUMS systems were installed and commissioned without any major issues. The time taken to install the HUMS systems were as follows:

- M113AS4: BAE Systems took 24 hours over 2 days with three personnel to install and commission the HUMS into 4 vehicles.
- PMV: Thales provided one tradesman and an engineer for 2 days and followed up with an engineer and the MoTeC technician for 1 day to install 4 vehicles.
- ASLAV: GDLS-A allocated 2 days for an engineer and a tradesman to install an ASLAV.

The existence of a CANBUS on the vehicle was found to simplify installation considerably.

Data Logging Strategy

Two data logging strategies were applied during this study: high resolution and low resolution. The M113, PMV and ASLAV data logging systems were programmed with high resolution strategies, logging data at relatively high sample rates (0.1 to 10Hz) and storing the data with negligible processing. This logging strategy resulted in weekly download files in binary *.ld* format of approximately 65Mb (or 0.5Gb in the text based *.csv* –comma separated variable - format).

As the PMV was fitted with two loggers, a low resolution strategy was also tried on the Dytecna data logging system in which data was logged at relatively high sample rates but only stored data for each 30 second period. For each period, sensor data was processed to determine the minimum, mean and maximum values and only these values were stored. This strategy requires very little storage memory and may need to be exploited to reduce bandwidth requirements if wireless data transmission is utilised. This strategy creates *.csv* download files of approximately 160Kb per 6 hour period.

The high resolution logging strategy has a number of advantages: complete time history data in its raw format is available for forensic analysis; new derived sensors can be introduced and applied to historical data; more complex processing can be undertaken since processing power is not limited to the on board computer; and, the relatively complex Vehicle to MILIS Data Processing software can be centralised and managed in one location, rather than being distributed onto each vehicle in each fleet.

Both the Dytecna and MoTeC systems are capable of logging using either strategy.

Data Storage Strategy

Logged data is accessed via a laptop installed with proprietary software and connected to the data logger with an Ethernet or USB cable. In this study, data was downloaded from vehicles weekly and transferred for storage on the Defence Restricted Network (DRN) using a USB memory stick. The subsequent data processing was affected by copying the raw data files from the DRN to standalone computers using a USB Memory Stick.

Using the high resolution data download strategy, the weekly manual download period was dictated by the size of the download files and chosen so as not to exceed the storage capacity of the loggers. Another reason to not delay manual download by more than a week, is to avoid failures occurring which should have been predicted during a timely subsequent trend analysis.

Measurement and Logging Issues

For various reasons sensor faults can cause data "drop outs" or periods during which sensor voltage drops cause a loss of accuracy. Some examples discovered during the trial are shown in figure 2.

Certain channels were found to have "spiky" data comprising discrete high frequency errors which in some cases correlate with ignition-on and ignition-off events. Sensors can also feature "noisy" output, or high frequency random error superimposed on the measurement signal. It is often necessary to filter this noise out using a low pass filter before the data is used for calculating derived parameters or other important measures.

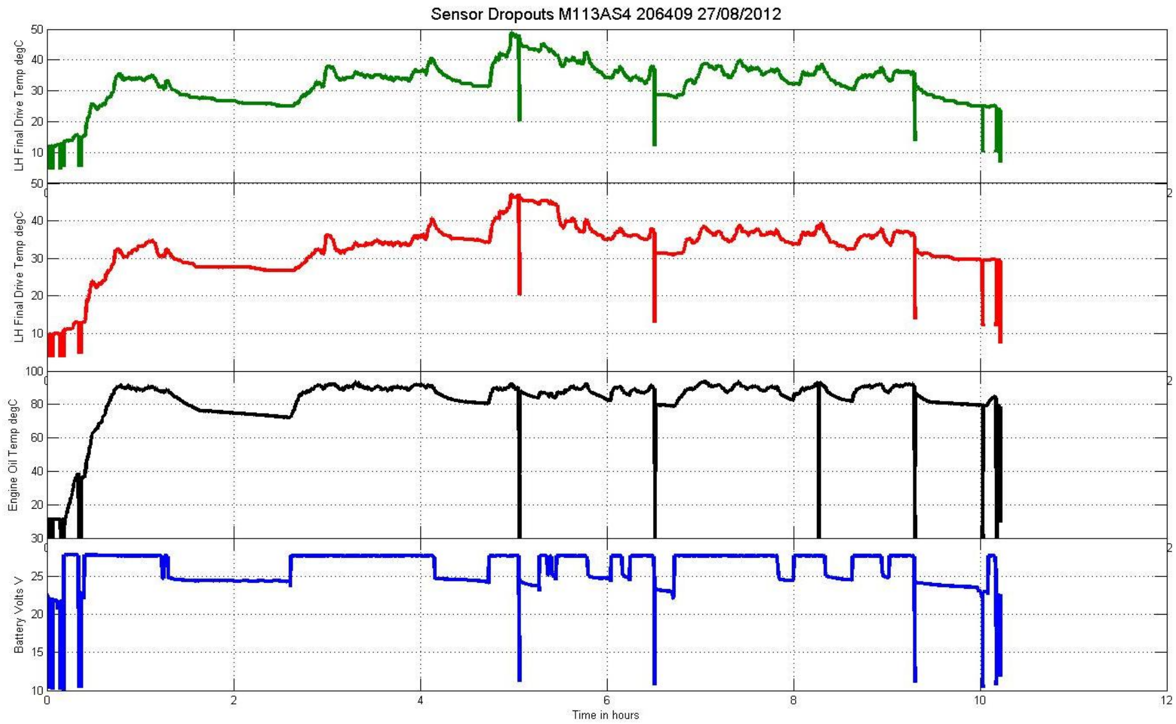

Fig. 2: Voltage dropouts in sensors

In the case of the example in figure 3, spiking has the potential to invalidate the data it will render important parameters such as maximum temperatures useless unless they are removed.

If spiking or drop-outs occur, either the hardware needs to be fixed, or a means implemented of correcting the errors through subsequent software processing. For this trial, there was no time to investigate a hardware fix so a software filter solution was sought. It was found that a Chebyshev digital filter effectively reduced spiking without detrimentally affecting the underlying data.

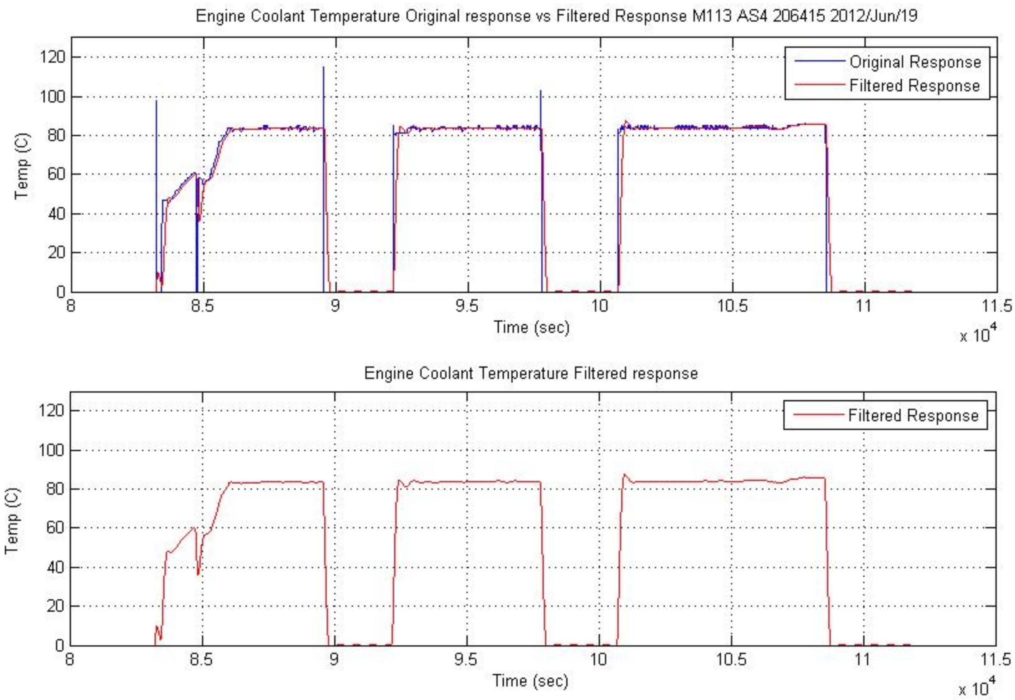

Fig. 3: Error Spikes in Engine Coolant Temperature (M113AS4)

When introducing or commissioning a HUMS, it will be essential that all data channels are checked for the occurrence of such anomalies and to verify sensor accuracy.

A complete HUMS solution would include self-diagnostic features to reduce the likelihood of erroneous data being produced. For example, after an extended period of non use, such as a vehicle being left overnight, all temperature sensors should be recording temperatures close to the ambient temperature. Significant deviations are an indicator of a sensor fault and the maintenance system could use this information to raise an inspection. This type of sensor cross checking should be exploited where possible.

Derived Sensors

A number of derived sensors were developed and demonstrated during the trial:

- Terrain Type – The terrain types correlate to the way Defence classifies vehicle mission profiles. This derived sensor determines the class of terrain on which the vehicle is operating by using vehicle speed and vertical acceleration inputs. The algorithm splits the day's data into 100m segments calculating the segment's mean speed and Root Mean Square (RMS) of the vertical acceleration. Terrain classification is determined using the following logic:
    - First Class Road segments are those that exhibit RMS vertical acceleration below a certain threshold.

- Second Class Road segments are those that exhibit RMS vertical acceleration above a certain threshold and mean speed above a certain threshold.
- Cross Country Terrain segments exhibit RMS vertical acceleration above a certain threshold and mean speed below a certain threshold.

Fig. 4: Determination of Terrain Type

(Figure 4 illustrates how the algorithm works, each point on the plot representing a 100m segment. The thresholds were arbitrarily selected for the demonstration in this trial. Any such algorithm introduced into service would need to have its thresholds determined experimentally.)

- **Vibration Dose Value (VDV)** is a measure of the amount of damaging whole-body vibration experienced by a human subject. Extended exposure to whole body vibration can lead to abdominal and chest pain, and spine problems. VDV is a function of the vertical acceleration to which the subject is exposed. Its calculation involves mathematical operations including the use of special filters [1]. The ISO Standard [1] recommends a VDV health limit of $21ms^{-1.75}$ per day.
- **Engine Coolant Temperature Delta** is the difference between ambient temperature and engine coolant temperature. It is only relevant when the engine is at or above the normal operating temperature. If the Delta is trending down, it is an indicator that the engine cooling system is losing performance and should be checked.
- **Battery Power.** Battery power in kW is a function of the voltage (V) and current (A) entering and leaving the batteries.
- **Alternator Power.** In this trial, alternator power was estimated using a relationship based on Engine RPM. The ideal HUMS would include a current and voltage sensors for the alternator, so that Alternator energy could be determined accurately.

- **Total Electrical Power.** The total power demand of the vehicle at any point in time can be determined by summing the power output of the alternator and battery.
- **Engine Power and Torque.** Engine power and torque are able to be calculated as long as the mass of the vehicle is reasonably well known. They are calculated from the tractive effort estimated from the longitudinal vehicle acceleration and knowledge of the slope on which the vehicle is operating. Slope can be derived from the change in altitude provided by the GPS, and the distance travelled. Maximum torque and power for each day could provide a way of monitoring engine performance. More work is required to ascertain the level of accuracy that can be obtained for estimating engine power and torque using these parameters.

Issues with Interfacing HUMS Systems with MILIS

The trial successfully demonstrated an interface between the Vehicle Data Download and MILIS however; the process involved an undesirable number of manual steps. Assuming a weekly download strategy, the Vehicle to MILIS processor will be required to automatically:

- receive the weekly time history download for each vehicle;
- convert the weekly time history data (Greenwich Mean Time - GMT) into daily data (local time);
- clean data by removing corrupting, noise, spikes, dropouts and other errors automatically through filtering and other means;
- perform sensor range checks, and appropriate diagnostics;
- calculate derived sensor channels;
- calculate daily Op Stats and CM Stats; and
- send the Op Stats and CM Stats for automatic upload to MILIS.

Enhanced Fleet Management

The trial identified a number of examples where HUMS data highlighted areas for potential through life savings. One example illustrated a situation where batteries were replaced, even though the previous weeks HUMS data indicated that the batteries were healthy. Following battery replacement the HUMS was powered up, the data was downloaded and the files analysed to determine the reason for battery replacement. The analysis revealed that the batteries were replaced because they had been completely discharged over a 6 day period through failure to switch the vehicle off. In this case it was the forensic level data shown at figure 5 that provided information as to the root cause of the failure.

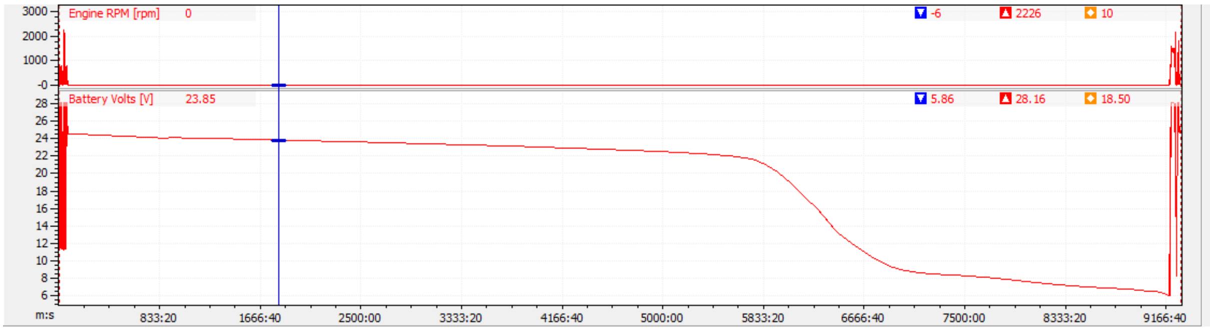

Fig. 5: MoTeC I2 showing Engine RPM and Battery Voltage over a 6 day period.

The study demonstrated how HUMS enables detailed analysis of fuel usage of fleets. Data revealed that M113AS4 used for training, typically spend up to 50% of their time idling which accounted for approximately 20% of daily fuel usage (figure 6). This information is vital to the development of strategies to save fuel.

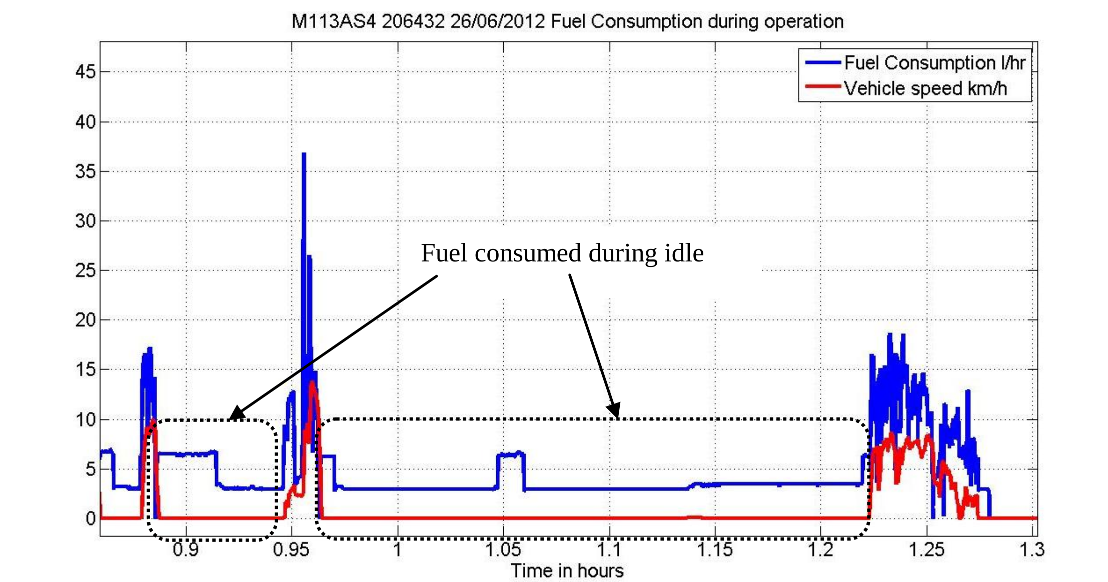

Fig. 6: Fuel consumed during idle when the vehicle is not moving

Condition Based Maintenance

The trial demonstrated the ability to monitor parameters that allow condition based maintenance activities to be scheduled. The following parameters can all be used to trigger alarms which can initiate a maintenance activity.

- **Oil Condition:** Sensors can ascertain oil condition through measurement of a number of parameters. Initial oil condition monitoring may not result in an oil change, but may initiate oil sampling and a detailed laboratory oils test.
- **Turbo Pressure:** Turbo pressure trends are monitored and activate maintenance alarms when consistent pressure drops are recorded, averting catastrophic failures.
- **Engine Coolant Temperature:** Monitoring the delta between coolant temperature and ambient temperature allows the cooling system performance to be managed.

- **Engine Oil Pressure:** Engine oil pressure is an indicator of the performance of the critical engine lubricating function. HUMS can monitor the pressure and a trend alarm can indicate the probable time of failure triggering preventative action.
- **Engine Power:** A derived sensor was tested to demonstrate that reductions in engine power are indicative of issues and can help diagnose engine problems.
- **Battery Condition:** The battery monitoring system reports battery State of Charge to alert the operator when batteries need charging, and battery State of Health to notify maintainers in advance of when the batteries should be replaced.
- **Final Drive Temperature:** Excessive oil temperature can cause oil to break down losing its lubricating properties, and accelerated wear and damage of bearing surfaces will ultimately lead to failure. Monitoring the temperature of susceptible and expensive sub-systems such as the final drives can avoid such critical failures.
- **Vibration Dose Value (VDV):** VDV is a measure of the vibration that can be absorbed by the human body and according to Ref. 1 should not exceed a value of $21ms^{-1.75}$ over the course of a day. A consistent rise in VDV may be an indicator that the suspension is developing a fault and not isolating vibration as it should.

These parameters have the potential to provide diagnosis, prognosis, extend the time between maintenance, and if monitoring to detect trends, they could reduce the number of breakdowns. In order to fully exploit HUMS, RAM analysis needs to be conducted on logged parameters over a period of time to assess optimal settings for alarms and trend rates.

Normal operator alarm conditions for parameters such as temperature and pressure are set at extreme levels so as to reduce the occurrence alarm activation. This means that the values are close to the point that failure will occur, requiring that the vehicle has to be stopped to avoid damage. By monitoring trends, it is possible to estimate the amount of time left prior to the alarm condition. In this way maintenance can be scheduled optimally with the avoidance of unexpected alarm conditions and or failures. It is envisaged that the Condition Monitoring data will be uploaded to MILIS on a daily basis, and that MILIS will provide trend analysis functionality, predicting the time to failure and scheduling maintenance activities prior to that.

Vehicles in storage can remain monitored by HUMS and maintenance actions be raised automatically when conditions require it. For example MTU, the M113 engine OEM, requires engines installed in the M113AS4 to be started every month if stored between 1 to 3 months. Non-use for greater than three months requires preservation action [2].

Operating Statistics

Op Stats or Operating Statistics can be used by fleet managers and maintainers to plan the efficient use of the vehicles. The Op Stats obtained during the Proof of Concept study were:

- **Distance Travelled (km):** Basic vehicle odometer reading.
- **Road Class Traversed:** Proportion of distance covered on first class, second class or cross-country terrain. This provides basic verification of the mission profile which is used as a basis for informing spares holdings.
- **Fuel Consumption:** This can feed the cost of fuel back to fleet managers enabling strategies to be developed to reduce fuel usage.
- **Engine Hours:** Basic engine usage statistic.

- **Engine RPM Histogram:** Provides detailed information on engine usage. This statistic provided insight into any engine over-speed or excessive idling and their effect on fuel usage and potential for engine problems.
- **Vehicle Current Demand:** This verifies the amount of electrical power required to operate the vehicle and is valuable for determining whether electrical power systems are up to the task of providing power for mission critical systems.
- **Ambient Temperature:** Temperature has a bearing on the failure rates of certain components. Monitoring ambient temperature enables RAM analysis to determine those components affected by temperature and allow fleet managers to adjust spares holdings according to the climatic region in which vehicles are operating.
- **Vehicle Location (Latitude/Longitude):** This enables fleet managers to prepare reports on where vehicles are operating and determine location based statistics. It also enables RAM analysis to determine failures that are influenced by location.
- **Vehicle Speed profile:** This verifies the mission profile of the vehicle and helps fleet managers and maintainers understand vehicle operating scenarios.
- **Master Switch on/off time:** this gives the times of day during which the vehicle is being operated. For example it can indicate the percentage of night operations.

HUMS have the potential to reduce the effort required by operators to log Op Stats and greatly enhance Op Stat accuracy, regularity, and detail. A small number of sensors can provide a significant number of beneficial Op Stats that can improve fleet managers' and maintainers' understanding of environmental effects. Increased understandings of mission profiles can enhance spares forecasting and assist Force Development to specify future capability.

Op Stats and CBM data can be stored in MILIS at irregular periods (as is current practice) or in regular intervals such as weeks, days, or shifts. The choice of a daily period used in this study was convenient and proved an appropriate basis on which to base subsequent processing. Periodic data records lend themselves more readily to analysis than irregular ones and it makes sense to base the period on an administrative cycle such as a day.

An on-board clock and calendar function is required by the HUMS data logger to register logged data to specific calendar dates and times. GPS units provide convenient time and date information suitable for storage by a data logger. The default condition is for the GPS to provide time and date data in GMT. Ideally the off-board Vehicle to MILIS processor would convert time and date to local time, with location being determined through reference to HUMS GPS coordinates.

Additional Sensors

A wider range of Condition Monitoring parameters and Op Stats are available with additional sensors. The following list of potentially beneficial sensors (or derived sensors) could be fitted to vehicles.

- External and Internal Environmental Conditions (e.g. Humidity, Temperature);
- Alternator Current and Voltage;
- Fluid Levels;
- Exhaust Oxygen;
- Air filter Differential Pressure;

- Brake System Parameters;
- Structural Stresses;
- Tyre Pressures/Central Tyre Inflation System Status/Tyre Wear;
- Weapon System Usage e.g. Rounds Fired, Drive Status; and
- Vehicle Mass, Available Payload, Centre of Gravity.

Ideally the selection of additional HUMS sensors would be based upon cost and benefit informed by a Failure Modes, Effects and Criticality Analysis (FMECA) of the vehicle system and subsystems.

Life of Type

Tracking component usage to determine the amount of life in a component is only useful if the amount of life is accurately known. This is sometimes the case with major driveline components such as differentials, gearboxes and engines, but is often not the case with structural components such as the chassis and suspension components. Furthermore, the life of structural components is highly dependant on the loading to which the components are subjected to throughout their life. For this reason, LEA is undertaking a related task to help determine the life of type of land platforms. This task is the development of a fatigue life prediction capability, which is being developed through the following steps:

- Determination of road loads through instrumentation and test;
- Finite Element Analysis of Structures; and
- Determination of fatigue related material properties through testing.

This data is then being used to determine how the life of land platform structures reduces, based on whether they are operating on First Class Road, Second Class Road, or on Cross-Country terrain. Interim results are confirming that Cross-Country operation is most damaging to platform structures, followed by second class and first class operation.

Combining the knowledge obtained on the life of components with respect to terrain types with accurate usage data obtained by HUMS, accurate monitoring of the life of structural components can be achieved, enabling more accurate Life of Type determinations to be made.

Accidents/ Incidents Investigation

HUMS data can be used to investigate accidents or incidents in order to understand their underlying causes. HUMS provides objective evidence to answer questions as to the root causes of accidents and underlying reasons for vehicle behaviour.

The study demonstrated how detailed HUMS data could be used to analyse incidents. GPS data from the M113AS4 HUMS was displayed in Google Earth as a track, defining in detail where the vehicle has travelled. MoTeC I2 HUMS data analysis software was used to present HUMS sensor values referenced to the instantaneous position of the vehicle on the GPS track. In this way questions relating to what the vehicle and driver were doing just prior to the accident can be answered.

Conclusions

It is feasible and relatively simple to install HUMS into in-service military vehicle fleets. The simplest installations are those which interface directly with the CANBUS and complexity increases as additional new sensors are included.

There are two primary data logging strategies: Onboard Processing and Off-board Processing. Off-board processing is preferred at present because it:

- allows the storage of detailed forensic data extracted from the logger in its raw format;
- enables the possibility of retrospectively processing data if and when a new MILIS fields are introduced;
- means that complex data processing software is centralised resulting in simplified configuration management; and
- potentially allows more complex derived sensors and data processing to occur (noting that the processing ability of the loggers was not tested in this study).

On board processing may need to be considered if wireless data transfer is utilised and if the available bandwidth imposes limitations on the amount of data that can be transferred.

For manual download of HUMS data from the vehicle, a download period of one week was found to be suitable under the conditions presented in this study.

The logging of Op Stats and Condition Monitoring data into MILIS on a daily basis is judged to be appropriate in terms of technical practicality and usefulness of stored data.

A clock is required so that time and date data is logged enabling Op Stats to be registered on a daily basis. A GPS is ideal for this purpose.

A Vehicle to MILIS data processor is required to significantly reduce the vehicle HUMS data from approx 0.5Gb per week of high sample rate sensor data to a few kilobytes of Op Stats and CM data for input to MILIS.

The Proof of Concept Trial successfully demonstrated the capture, transfer and processing of HUMS vehicle data into MILIS. This process required a number of manual steps to be accomplished. It is feasible for these steps to be automated and this would be required for the practical introduction of HUMS into service

HUMS, including their sensors, should undergo a commissioning phase prior to entering service to ensure that accurate data is being recorded.

The Proof of Concept trial demonstrated how HUMS can be used to determine the type of terrain on which the vehicle is operating. This, in conjunction with fatigue analysis of the vehicle structure, enables the life of structural components to be monitored accurately and will allow objective life of type assessments to be made for vehicle fleets. This methodology requires further work, particularly with regard to developing methods to calibrate vehicles to ensure accurate determination of terrain type.

A range of derived sensors were demonstrated. A culture embracing condition based maintenance could feasibly exploit the development of derived sensors to significant advantage. Derived sensors can be introduced at very low cost as they do not require hardware to be installed.

Op Stats were demonstrated to provide verification of mission profiles and usage data.
The trial demonstrated how Condition Monitoring data from HUMS could be uploaded to MILIS to automatically trigger maintenance actions based on actual vehicle health rather than on a pre-set schedule.

The use of HUMS to investigate accidents or incidents was demonstrated

Recommendations

The conclusions from the proof of concept study lead to the recommendation to transition the HUMS Study from Proof of Concept to Pilot Program by monitoring a fleet, or a significant portion of a fleet with the following outcomes:

- Development of a database within MILIS to enable a transition to Condition Based Maintenance by providing a historical record on which to set maintenance thresholds and alarms and to gain an understanding of the types of trend analysis required to support CBM;
- A thorough understanding of the issues in physically transferring data from a large number of vehicles to the department's Information Technology systems, including the investigation of automated wireless data communications;
- Development of a means to automatically process vehicle HUMS data and upload it to MILIS.

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