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USE OF ADVANCED MODELING AND SIMULATION TECHNIQUES TO IMPROVE PERFORMANCE AND ACCELERATE ACQUISITION OF ARMY VEHICLE SYSTEMS

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ABSTRACT

An increasing pace of technology advancements and recent heavy investment by potential adversaries has eroded the Army's overmatch and spurred significant changes to the modernization enterprise. Commercial ground vehicle industry solutions are not directly applicable to Army acquisitions because of volume, usage and life cycle requirement differences. In order to meet increasingly aggressive schedule goals while ensuring high quality materiel, the Army acquisition and test and evaluation communities need to retain flexibility and continue to pursue novel analytic methods. Fully utilizing test and field data and incorporating advanced techniques, such as, big data analytics and machine learning can lead to smarter, more rapid acquisition and a better overall product for the Soldier. Logistics data collections during operationally relevant events that were originally intended for the development of condition based maintenance procedures in particular have been shown to provide substantial opportunities to apply advanced data analytics.

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1. INTRODUCTION

For much of the commercial auto industry, an evolutionary approach to design characterized by improvements regularly introduced between model years, and major redesigns on a multi-year, reoccurring basis is standard. This approach is not directly applicable to Army vehicle systems due to the Army's relative low volume of vehicles produced, long life cycles required, and imprecise knowledge of environmental and usage conditions. Historically, some of the risks associated with developing, producing and maintaining a fleet of quality Army ground vehicle systems were mitigated by long acquisition cycles with copious resources devoted to requirements development, methodical analyses of alternatives, extensive developmental and operational testing with opportunities for design improvements to be introduced, and structured, independent evaluations.

Changes are being made to the Army acquisition process in order to deliver novel capabilities to the

Soldier more rapidly that may disrupt these risk mitigating strategies. While some gains are expected to be achieved by reducing administrative burden via restructuring the organizations responsible for acquisition within the Army, fundamental changes on what tests are performed, what data is collected, how that data is converted into information and what questions are evaluated will be required. Updates to the Army acquisition process include higher tolerance of risk but with an overall goal of improving the return on investment. As Secretary of the Army Ryan D. McCarthy stated, "if you fail, we'd like you to fail early and fail cheap." [1]

As part of the Army Futures Command, the Combat Capabilities Development Command – Data and Analysis Center (CCDC DAC) is working with the acquisition and test and evaluation communities to ensure that the goal of improved return on investments is met. One of the most promising approaches is to develop tools and techniques that maximize usefulness of the data collected across the lifecycle of ground vehicle systems. Significant data are available to be collected with minimal effort and cost during testing and training. This data could be used to evaluate, improve or characterize current and future ground vehicles. Similarly, a vast array of built-in sensor data from systems such as the Engine Control Unit, Transmission Control Unit, Anti-lock Braking System and Body Control Modules is accessible from the data bus of many Army vehicles. Capturing this data in conjunction with some relatively inexpensive metadata can lead to substantial gains in system knowledge that can be leveraged for current vehicle improvements or development of future ground vehicle systems. Focused efforts to collect, analyze and utilize these data sets will help the Army to ensure delivery of better solutions, faster to the warfighter.

2. OPERATIONALLY RELEVANT ELECTRICAL POWER

One area where significant opportunity exists for leveraging data and is of significant interest to the Army is in the area of ground vehicle electrical power. The demand for ground vehicle electrical power on the Battlefield continues to grow as Soldiers are equipped with newer technologies and capabilities. [2-4] In order to support acquisition decisions related to increased need for electrical power (alternators, generators, Auxiliary Power Units (APUs), batteries), Army analyses must capture realistic estimates for ground vehicle power demands (current and future growth). Attempts to address electrical power in major Army studies have been limited. Typically power demand studies include a cumulative summation of electrical loads which omits power profiles and any real chance to address operational relevance. Historically, this audit-style approach leads to unrealistically high estimates and typically conflict with measurements from deployed units. Figure 1 compares the legacy power audit approach with the proposed less conservative, but more realistic approach.

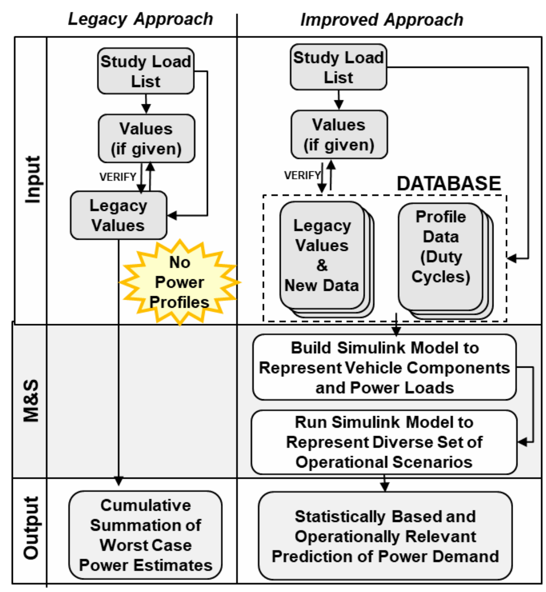

Figure 1: Electrical Power Prediction Modeling

In 2016 as part of an Army Study Proposal, the CCDC DAC led an effort to collect operationally relevant electrical power loads during Soldier training exercises. In order to capture sub-system level data, data acquisition devices were installed on vehicles to collect electrical power data related to individual equipment utilization during operationally relevant events, see Figure 2. In addition, metadata including the types of mission and role that the vehicle system was playing were captured during the events.

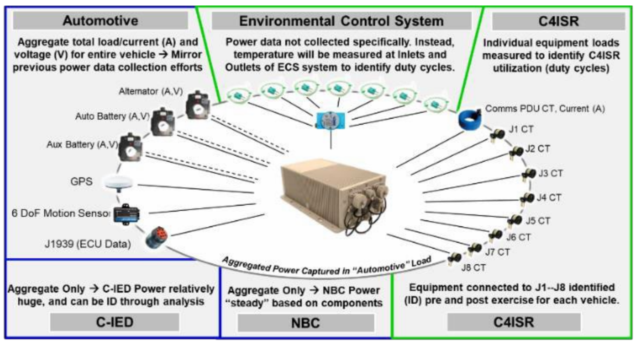

Figure 2: Item and System Level Data Collection

In order to process the measured data, checks were performed for common instrumentation and quality issues. Fundamental parameters characterizing the usage were identified and calculated for each item level measurement. These included average current, current variance, average time interval for each state, and utilization factor. Additionally, legacy developmental test data were leveraged to create system level usage profiles and extend the data to a wider variety of ground platforms and mission combinations.

While the collected data was useful in achieving the primary goal of capturing realistic usage profiles of various equipment on the system, the full utility of the data was achieved with the creation of a simulation tool to analyze a wide range of vehicles/configurations, see Figure 3. When combined with the data collected, this simulation tool is widely applicable to multiple platforms and phases of the acquisition cycle. This simulation tool could be readily applied during requirements development, prior to developmental testing to assist with defining test profiles and even in sustainment as the basis for testing engineering change proposals.

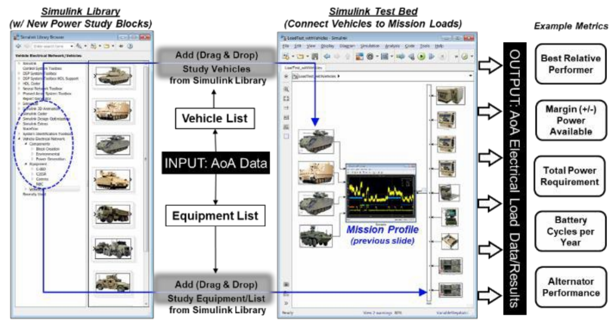

Figure 3: Electrical Power Simulation Test Bed

3. LOGISTICS TEST DATA ANALYTICS

A second area that has shown significant promise in maximizing the use of available data is applying analytics to logistics data collections. In addition to sensors applied for specific measurements during a test focused on the supportability of the system or a similar field collection, significant data has been collected from the vast array of built in sensors through the data bus of many vehicles. Collection of instrumented data during thousands of miles of Reliability, Availability and Maintainability (RAM) testing or even a small number of data bus channels on the hundreds of fielded vehicles in the fleet can result in terabytes and even petabytes of data. The primary purpose of these data collections is to provide information required for the independent evaluation of the system or to support a specific logistics analysis such as the development of condition based maintenance procedures. Figure 4. shows an example of a simple algorithm that CCDC DAC developed to support RAM evaluations. The Global Positioning System data of the vehicle is compared to known test course locations and layouts to determine the time and mileage on each course. This data proved useful to program and test managers for tracking performance and durability trends and ensuring proper test distribution.

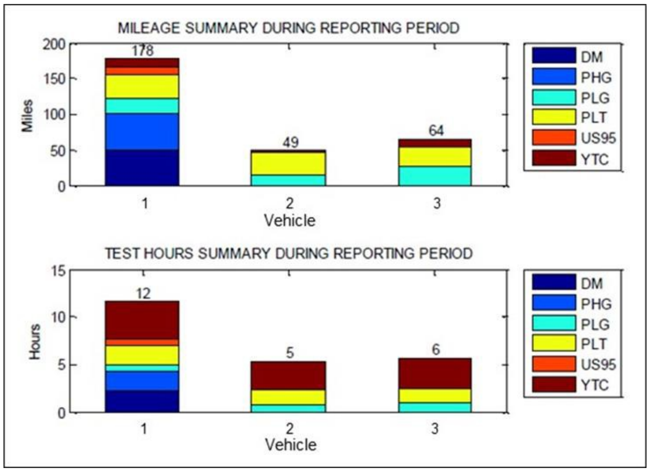

Figure 4: Mileage Summary

Through the use of machine learning algorithms and big data analytics, the CCDC DAC has developed tools that can provide a wide variety of additional information. One of the most well defined capabilities of big data analytics is to identify trends. [5] Figure 5 shows the results of a field data collection that clearly shows the frequency of operation at various speeds in particular gear ratios. This information is useful for establishing expected usage during requirements development, as a check on realism during developmental and operational tests, and even in establishing thresholds for accelerated life testing.

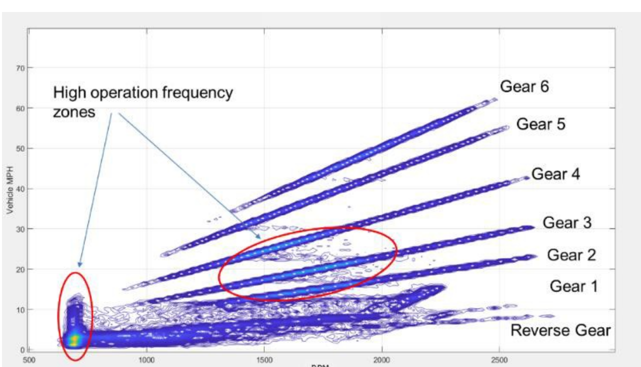

Figure 5: Moving Density

Figure 6 is an example of developing vehicle performance characteristics from the same field collection that would support system-level dynamics models. As an organization, CCDC DAC primarily performs modeling and simulation for the acquisition and sustainment communities. Gathering the requisite subsystem performance data is a significant barrier in developing system-level models and often the published information is idealized performance. Leveraging logistics test and field collections to supplement vendor supplied information has provided significant benefit.

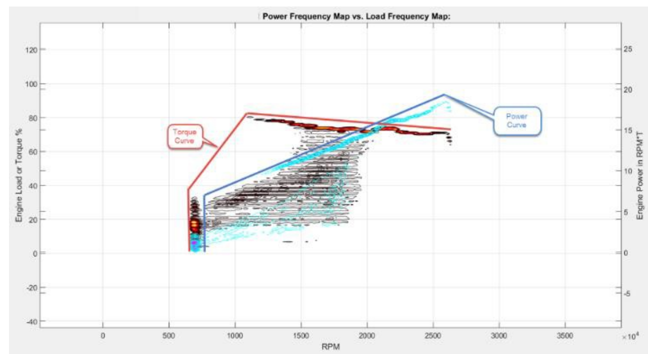

Figure 6: Engine Operating Characteristics

Figure 7 shows another example where a trend identified from field data gave insight and led to additional modeling capability. Fuel consumption estimates are typically derived from expected mission parameters as defined by an operation mode summary/mission profile and steady state trends of fuel consumption defined through testing. The relatively linear relationship between fuel consumption and vehicle power produced enabled the development of a fleet-level fuel modeling capability focused on mission roles and patterns associated with the region of operation. Additionally, this characteristic curve has been useful in identifying outliers as candidates for condition based maintenance.

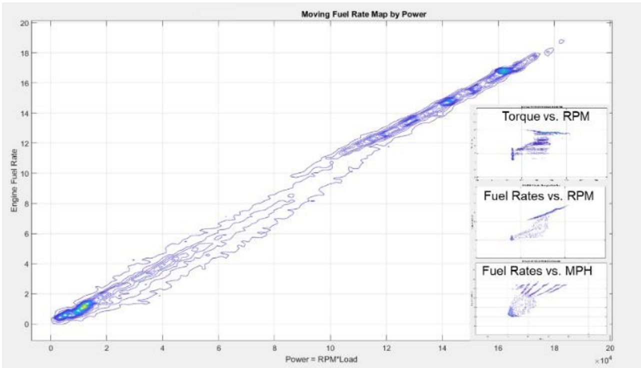

Figure 7: Fuel Consumption for Engine Power

Logistics data collections provide substantial opportunities to apply data analytics. CCDC has demonstrated a variety of system and component level information to classify usage, identify threshold limits and gain insight into technical specifications. This information can be applied across the acquisition lifecycle for purposes including requirements development, developmental and operational test planning, accelerated life testing, health and usage monitoring algorithm development and safety confirmations.

4. CONCLUSIONS

An increasing pace of technology advancements and recent heavy investment by potential adversaries has eroded the Army's overmatch and spurred significant changes to the modernization enterprise. Commercial ground vehicle industry solutions are not directly applicable to Army acquisitions because of volume, usage and life cycle requirement differences. In order to meet increasingly aggressive schedule goals while ensuring high quality materiel, the Army acquisition and test and evaluation communities need to retain flexibility and continue to pursue novel analytic methods. Fully utilizing test and field data and incorporating advanced techniques, such as, big data analytics and machine learning can lead to smarter, more rapid acquisition and a better overall product for the Soldier.

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