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THESIS

A HUMAN SYSTEMS INTEGRATION APPROACH TO ENERGY EFFICIENCY IN GROUND TRANSPORTATION

by

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December 2015

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A HUMAN SYSTEMS INTEGRATION APPROACH TO ENERGY EFFICIENCY IN GROUND TRANSPORTATION

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ABSTRACT

This effort establishes the feasibility of implementing telematics systems into the United States Marine Corps' decision-making process in order to increase its operational reach and overall effectiveness. It is based around a qualitative case study evaluation of commercially implemented telematics. Telematics, as defined by Fleetmatics, is the integrated use of telecommunications combined with information and technology communication systems used to achieve improved operational capabilities while creating a more effective and efficient workforce. This research was done through numerous interviews with a variety of personnel who use telematics. The information is then partitioned and analyzed using a systems engineering framework utilizing a human systems integration methodology. This analysis acts as a framework to outline best practices in metering and monitoring. Once established, it is applied to the Marine Corps to determine a feasible way to implement similar technologies on its ground vehicles. This study prescribes policies for the successful use of telematics systems in the Marine Corps that will make it a more fuel-efficient fighting force. As a result, the Marine Corps extends its operational reach, improves its warfighting capability, and reduces the risk to the warfighter.

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LIST OF ACRONYMS AND ABBREVIATIONS

CBA	capabilities based assessment
CMC	Commandant of the Marine Corps
COACH	cognitive adaptive computer help
CPI	continuous process improvement
C2	command and control
DOD	Department of Defense
E2O	Expeditionary Energy Office
E2W2	expeditionary energy, water, and waste
FFBD	functional flow block diagram
HFE	Human Factors Engineering
HSI	Human Systems Integration
ICD	Initial Capabilities Document
INCOSE	International Council on Systems Engineering
OTA	operator task analysis
ROMO	range of military operations
SE	Systems Engineering
T/E	Tables of Equipment
T/O	Tables of Organization
USAF	United States Air Force
USMC	United States Marine Corps

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EXECUTIVE SUMMARY

In 2011, the United States Marine Corps (USMC) released the *USMC Expeditionary Energy, Water, and Waste Initial Capabilities Document* (E2W2 ICD). The E2W2 ICD, produced by the Marine Requirements Oversight Council, was an extensive requirements document outlining, "152 capability gaps across 29 tasks in six E2W2 capability areas: planning, production, storage, distribution, disposal, and management" (Marine Requirements Oversight Council 2011, 5). These gaps affect every producer and user of energy across all USMC operational areas. The E2W2 ICD outlined specific needs of the USMC and acted as a starting point from which both materiel and non-materiel solutions could be developed with the intended purpose of bridging existing capability gaps.

This research focuses specifically on four tasks contained in the E2W2 ICD, centered on the management or planning of operational energy. The first is focused on managing the supply, demand, and use of energy through the use of sensors and management systems to track energy efficiency. The second is the idea that the USMC should employ the right people in the right locations to reduce energy consumption while maintaining mission effectiveness. The third task states that energy sensors or other metering devices employed should be capable of measuring data real-time and have a way of analyzing and reporting the findings. Finally, the fourth task directs that there be operational energy management, to allow for optimal decision making while in an expeditionary environment.

This research will approach these tasks through the use of a systems engineering (SE) method based on human systems integration (HSI) principles. The SE method will provide a holistic means of analyzing data to determine the most beneficial measurable metrics, in a telematics system. An SE approach will also provide a way of taking lessons learned from industry practices and applying them to the USMC, where the use of such a system is largely undeveloped with no quantifiable measures in place to implement such a system. Finally, using HSI as a focus within a SE method will enable research to determine benefits of the telematics system itself as well as providing possible benefits

and the best methods related to the human factors of users interacting with and utilizing such a system.

Specifically, this study determined the benefits of telematics for use in USMC ground-based vehicles. It includes suggestions on how to incorporate and better utilize currently deployed systems in a fully integrated telematics system. Because telematics range in their level of complexity, this study identified what level of telematics implementation and data collection would be useful to the USMC within the constraints of the overall mission. Since there is a nearly limitless amount of data that can be collected when employing these types of systems, a determination was made in the areas of data collection that are the most beneficial and how to both interpret and disseminate the information collected. Finally, since most of the current telematics systems are being used in civilian arenas, their application into military environments was considered throughout all aspects of the study ensuring a continual effort is being made to increase overall system performance without detracting from mission effectiveness.

Telematics were found to be an essential system for the USMC to implement into their vehicles in the near future. Telematics being the integrated use of telecommunications combined with information and technology communication systems used to achieve improved operational capabilities while creating a more effective and efficient workforce (Fleetmatics 2015). Telematics incorporate various hardware and software components to send, receive and log data. These components are used in an array of functions from simple data logging to fully autonomous vehicle operations, depending on the level of complexity deemed feasible and necessary by the user.

Telematics were shown to be a key tool in order to increase fuel efficiency. This increase in fuel efficiency would lead directly to a USMC fighting force with increased operational reach and overall mission capabilities. Telematics were shown to have the ability to increase productivity and in doing so created a leaner more dynamic workforce. The telematics systems also created vehicles with higher levels of survivability and reliability and provided higher levels of safety for operators employing them in the field. Finally, telematics were able to provide large increases in situational awareness allowing better overall decision making and increased operational effectiveness. Implementing telematics would be a key tool in ensuring the USMC stays the world's premier fighting force by allowing for higher levels of situational awareness, improvements in driver performance and safety, and superior methods of management. This would also result in large reductions in fuel consumption that would extend the USMC's operational reach.

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I. INTRODUCTION

A. BACKGROUND

By 2009, the United States Marine Corps (USMC) had been engaged in the war on terror for more than eight years. During that time frame, the Marine Corps had simultaneously conducted various humanitarian and peacekeeping missions throughout the world. This period of prolonged engagement, in forward-deployed arenas with varying and complex missions, revealed a number of capability gaps within the USMC due to inefficient and overuse of energy resources. The Commandant of the Marine Corps (CMC) voiced concern on 13 August 2009 at the USMC Energy Summit when he declared energy to be a top priority for the USMC (Commandant of the Marine Corps 2009). Subsequently, on 1 October 2009, the CMC announced the creation of the USMC Expeditionary Energy Office (E2O) and tasked them with the mission to, "analyze, develop, and direct the Marine Corps' energy strategy in order to optimize expeditionary capabilities across all warfighting functions" (Assistant Commandant of the Marine Corps 2009, 5). In March of 2011, the CMC released the "USMC Expeditionary Energy Strategy" to act as a framework for USMC operational energy goals and mission objectives. In it, the CMC outlined his vision for the change by describing how the USMC would treat operational energy.

> The current and future operating environment requires an expeditionary mindset geared toward increased efficiency and reduced consumption, which will make our forces lighter and faster. We will aggressively pursue innovative solutions to reduce energy demand in our platforms and systems, to increase our self-sufficiency in our sustainment, and reduce our expeditionary footprint on the battlefield. Transforming the way we use energy is essential to rebalance our Corps and prepare it for the future (Commandant of the Marine Corps 2011, 3).

In 2011, the USMC released the "USMC Expeditionary Energy, Water, and Wasted Initial Capabilities Document" (E2W2 ICD). The E2W2 ICD was an extensive requirements document outlining, "152 capability gaps across 29 tasks in six E2W2 capability areas: planning, production, storage, distribution, disposal, and management" (Marine Requirements Oversight Council 2011, 5). These gaps affect every producer and user of energy across all USMC operational areas. The E2W2 ICD outlined specific needs of the USMC and acted as a starting point from which both materiel and non-materiel solutions could be developed with the intended purpose of bridging existing capability gaps. Through various avenues, including the USMC E2O, the USMC has since used this guidance directing its effort toward achieving the overall vision "to be the premier self-sufficient expeditionary force, instilled with a warrior ethos that equates the efficient use of vital resources with increased combat effectiveness" (Commandant of the Marine Corps 2011, 7).

One such effort, conducted by the USMC E2O in conjunction with the Naval Postgraduate School (NPS), was focused on reducing energy use in the Marine Corps expeditionary forces in order to extend reach, save lives and more effectively expend their budget (Salem and Gallenson 2014, 2). Researchers applied grounded theory in observing and interviewing over 60 Marines in four different operational environments. The results of this research revealed five areas where the USMC could improve energy efficiency: "revise operational procedures; initiate policies that improve overall efficiency; build individual energy awareness and knowledge; incorporate energy efficient technologies; and nurture a culture of energy awareness" (Salem and Gallenson 2014, 2). The study found that there was a significant opportunity for the USMC to make changes to reduce energy use while simultaneously increasing their operational reach (42). The research also gave next steps to modify behaviors within the USMC concerning energy use. Of note for this thesis was the need to examine industry best practices in metering and monitoring as well as a way of implementing new behaviors and technologies in the USMC (Salem and Gallenson 2014, 42). This analysis will use these past findings as a foundation from which to analyze the use of telematics within the Marine Corps.

B. PURPOSE

This research will develop and prescribe specific methods and techniques to implement telematics within the USMC toward achieving the goals set forth in the USMC Expeditionary Energy Strategy. Telematics is the integrated use of telecommunications combined with information and technology communication systems used to achieve improved operational capabilities while creating a more effective and efficient workforce (Fleetmatics 2015). Telematics incorporates various hardware and software components to send, receive and log data. These components are used in an array of functions from simple data logging to fully autonomous vehicle operations, depending on the level of complexity deemed feasible and necessary by the user.

This study will determine the benefits of telematics for use in USMC ground-based vehicles. It will include suggestions on how to incorporate and better utilize currently deployed systems in a fully integrated telematics system. Because telematics range in their level of complexity, this study will identify what level of telematics implementation and data collection would be useful to the USMC within the constraints of the overall mission. Since there is a nearly limitless amount of data that can be collected, when employing these types of systems, a determination will be made in the areas of data collection that are the most beneficial and how to both interpret and disseminate the information collected. Finally, since most of the current telematics systems are being used in civilian arenas, their application into military environments will be considered throughout all aspects of the study ensuring a continual effort is being made to increase overall system performance without detracting from mission effectiveness.

C. BENEFITS OF STUDY

The recommendations are centered on achieving higher levels of fuel efficiency in USMC ground vehicles. This effort will seek to attain this efficiency by recommending an approach to USMC leadership for deploying appropriate telematics systems into USMC ground vehicles as well as a method and strategy for the implementation of a telematics system into operational processes. Once deployed, telematics would ideally increase efficiency allowing USMC ground forces to extend their operational reach and overall mission capabilities. This research seeks to push for a USMC force that can increase their ability to remain lean, agile and adaptable, making them a more dynamic fighting force in an ever-evolving battlespace environment. Furthermore, the implementation of these telematics devices will also allow for higher levels of system survivability and reliability increasing the safety of the Marines employing these technologies in the field. At the same time, telematics will provide useful feedback to both the Marines operating in the field as well as to leadership significantly increasing situational awareness. An increased level of situational awareness will allow for better overall decision making and operational effectiveness. Finally, in the current fiscally constrained Department of Defense (DOD), this effort will allow for significant cost savings through reduced fuel consumption. These cost savings could then be shifted to other essential mission areas ensuring the USMC truly remains, as the CMC states in his Vision and Strategy 2025, “the world’s premier expeditionary fighting force” (Commandant of the Marine Corps 2008, 3).

II. LITERATURE REVIEW

A. INTRODUCTION

This chapter will explain the principles used in the analysis of both the benefits and possible implementation of telematics systems into Marine ground vehicles. It will outline the use of fundamental systems engineering (SE) techniques to analyze the requirements set forth by the USMC. Next, the SE processes will be broken down into a logical framework needed to isolate individual operator tasks necessary to develop a system architecture. The next section will describe human systems integration (HSI) principles and how they will be used to analyze specific operator tasks found using SE techniques. Finally, the last part of this chapter explains qualitative research methods and their benefits in analyzing tasks in an HSI framework.

Telematics have previously been analyzed through a myriad of methods. One of the most comprehensive studies was performed by Fleetmatics, a developer and manufacturer of telematics systems. The company conducted a data pull from hundreds of thousands of vehicles utilizing their telematics systems over a five-year period (Fleetmatics 2014). The company used the data to determine the benefit of telematics noting improvements such as a 13% increase in productivity, a 20% decrease in labor, and over 100,000 dollars saved in monthly fuel costs (Fleetmatics 2014). Another telematics case study involved a commercial trucking company, which used a scorecard method with weighted rankings to determine profitability in the areas of operations, safety and fuel consumption (Nussbaum 2015). The scorecard would draw data from the telematics and automatically generate scores in the three specific areas that would then be totaled to rank the drivers and act as a basis to provide each driver’s quarterly bonus level. Another case study conducted by Verizon, a communication technology company, looked at a fleet of 600 public vehicles utilizing their telematics in the city of Ventura, California (Verizon 2015). In this study, the company implemented telematics using a set of predetermined objectives, including lowered maintenance costs, reduced idling times, and reduced fuel usage. The company then collected specific data to determine how telematics were improving these different areas with one of the findings being a 10% decrease in fuel usage saving the company 15,000 dollars annually.

These studies as well as many others provided data related to the implementation and benefits of using telematics systems. However, there were some inherent shortfalls with the investigations. All the studies looked at data either based on predetermined metrics or simply used a large amount of collected data to determine benefits in previously implemented telematics. The studies also relied, almost entirely, on quantitative data with little information coming from qualitative sources. The effect of collecting data in this manner resulted in focused findings that did not show how the use of telematics might be improved upon, but only how current implementation was performing. Additionally, since the data collected was isolated to specific areas of implemented telematics and not a deep study into the overall interactions of the systems, it would not be useful for determining best practices or the way that system might be adopted and integrated into another organization.

To address some of these limitations, this research will use a SE method based on HSI principles. The SE method will provide a holistic means of analyzing data to determine the most beneficial measurable metrics in a telematics system. As discussed below, an SE approach will also provide a way of taking lessons learned from industry practices and applying them to the USMC, where the use of such a system is largely undeveloped with no quantifiable measures in place to implement such a system. Finally, using HSI as a focus within a SE method will enable research to determine benefits of the telematics system itself as well as providing possible benefits and the best methods related to the human factors of users interacting with and utilizing such a system.

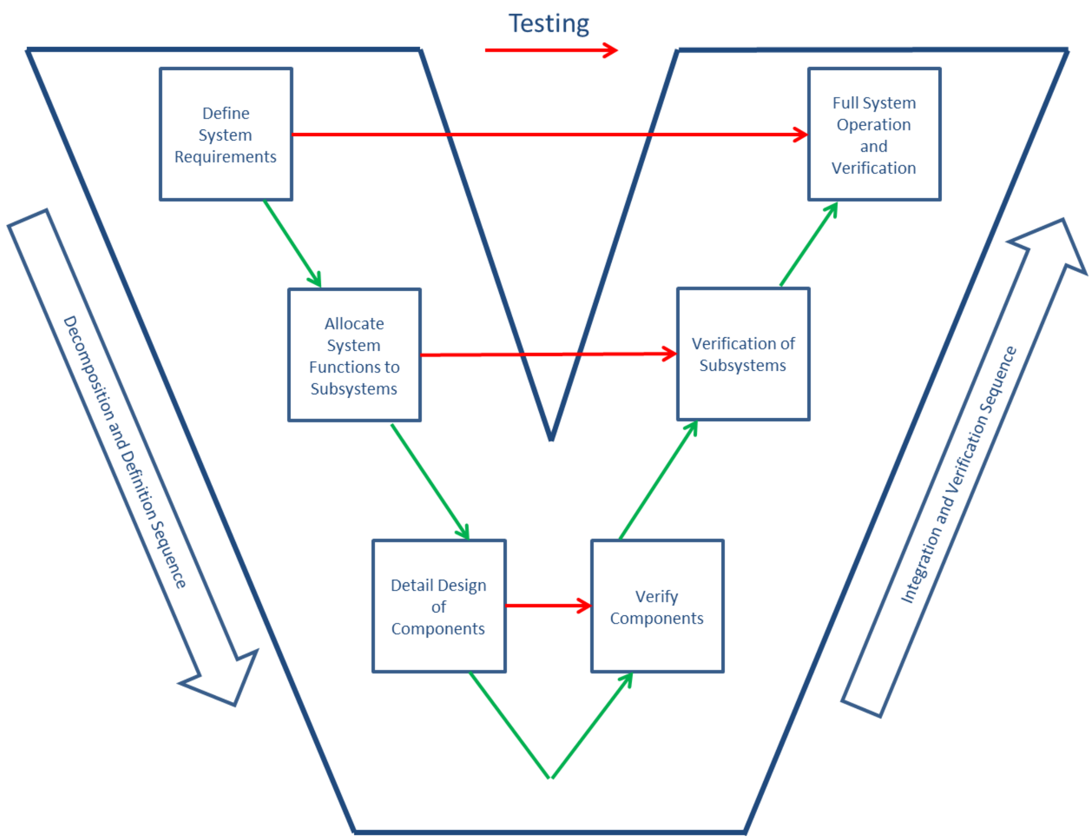
B. SYSTEMS ENGINEERING APPROACH

The International Council on Systems Engineering (INCOSE) defines SE as

> an interdisciplinary approach and means to enable the realization of successful systems. It focuses on customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem (Haskins 2011, 7).

A system, in the context of SE, is, "an integrated set of elements, subsystems, or assemblies that accomplish a defined objective" (Haskins, SE Handbook Working Group, and International Council on Systems Engineering 2011, 364) as defined by stakeholders and the users of a system. The primary user in question for this research is the USMC and the system being analyzed will be telematics employed in their ground vehicles. The definition of SE shows there are multiple considerations and steps necessary to provide a quality product in line with the needs set forth by the end user. As such, SE can be implemented using a variety of different models. We will use a "Vee" Process Model for our research purpose (Figure 1).

Figure 1. Systems Engineering "Vee"



Source Blanchard, Benjamin S. and Wolter J. Fabrycky. 2011. *Systems Engineering and Analysis*. 5th ed. Boston: Prentice Hall, 37.

The "Vee" process model is effective at taking a preexisting complex system or set of user needs and breaking them into basic components to allow for an effective design solution. However, each step within the model can require a great deal of examination depending on the complexity of the system being analyzed. The left side of the "Vee" focuses on system decomposition and definition, and will be the primary point of focus. Since this effort concentrates solely on identifying useful telematics for possible implementation into USMC vehicles, the decomposition and definition process starts by defining high-level system requirements. In this case, the requirements of the USMC have been provided by the E2W2 ICD and by direction of the E2O. The next step is to use these established operational requirements to allocate different system functions to different subsystems starting with a functional analysis.

The functional analysis consists of converting the system requirements into detailed design specifications that will then determine the resources required for system operation (Blanchard and Fabrycky 2011, 37). A functional analysis makes it possible to create a top-level system architecture that ties requirements together with the system structure. Once this system architecture is established, the process of functional allocation can then take place.

Functional allocation is the process of breaking down a top-level system into its elements through partitioning. Partitioning determines what types of things (such as hardware and software) can be used so that a minimal number of subcomponents are required to perform necessary functions while maintaining sufficiently high levels of reliability and effectiveness (Blanchard and Fabrycky 2011, 91). Usually, both the functional analysis and allocation can be completed using things like functional flow block diagrams (FFBD) to hierarchically breakdown different system functions. However, in a telematics system where the functions are so closely tied to the user, a different type of analysis is required. Therefore, this research will focus on functional analysis and functional allocation using a combination of task analysis methods.

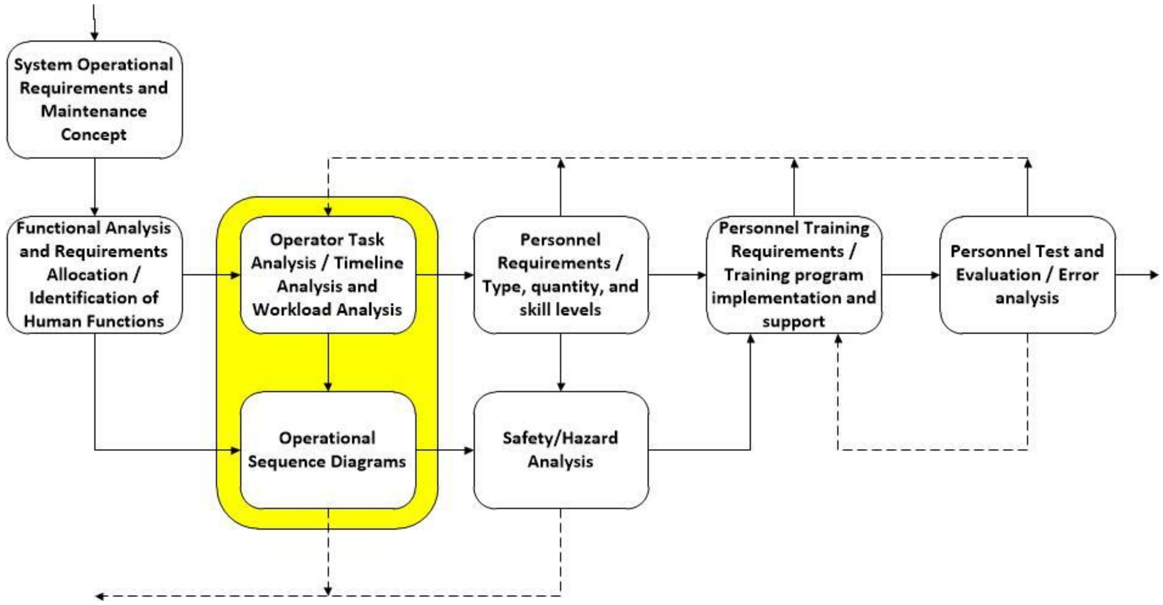
Task analysis, in a general sense, is the determination of the tasks that need to be performed to accomplish a system's functions (Boehm-Davis, Durso, and Lee 2015, 66). Task analysis will be used even further to determine specific tasks required to complete high-level functions and to identify who or what should be carrying out those tasks (Boehm-Davis, Durso, and Lee 2015, 67). There are multiple ways to carry out a task analysis. This study seeks to analyze both the system and how the user interacts with the system. Based on this, this research will use operator task analysis and cognitive task analysis since they both focus specifically on the interaction between the user and the system, and are directly aligned with an HSI framework.

Operator task analysis (OTA) is a method in which the specific functions completed by an operator in the system are determined. These functions are then broken down into sub-categories such as duties, tasks, subtasks and task elements to establish a hierarchy of different operator functions (Blanchard and Fabrycky 2011, 486). Once the functions are categorized, a determination will be made as to what information is necessary for task completion, the amount of informational feedback needed for the user, time requirements to complete the task, environmental impacts on both the user and the system and the necessary skill and training requirements to complete the task (Blanchard and Fabrycky 2011, 487).

Cognitive task analysis augments OTA. Telematics systems can become quite complex, thus creating, highly cerebral task loaded environments. Cognitive task analysis methods examine very cognitive and complex systems to identify the types and amount of mental activities being completed. The level of mental activities required to operate the system are then used to develop top-level system requirements to support and minimize the different mental tasks (Boehm-Davis, Durso, and Lee 2015, 67). This type of analysis will be essential to ensure tasks required by the USMC operators are not so extensive that they lead to mission degradation.

Once the task information is determined, using OTA and cognitive task analysis, it will be used to isolate the specific tasks required for successful system operation as well as determining who or what should be carrying out those tasks. Then, as seen in Figure 2, this information can be paired with the functional analysis and allocation information to develop a top-level system architecture and, more importantly for this research, a functional architecture. The functional architecture is a "description of the system in functional terms" (Blanchard and Fabrycky 2011, 93) and will act as the basis for telematics system capabilities recommendations to the USMC.

Figure 2. The Application and Relationship Between Functional Analysis and Task Analysis in System Design



Adapted from Blanchard, Benjamin S. and Wolter J. Fabrycky. 2011. *Systems Engineering and Analysis*. 5th ed. Boston: Prentice Hall, 487.

C. HUMAN SYSTEMS INTEGRATION

HSI serves as a framework to analyze human interactions within a system, making it an ideal way to accomplish an in depth task analysis. HSI is, "a set of systems engineering processes that ensure all human-related technical issues are properly identified and addressed during system planning, design, development, and evaluation" (Boehm-Davis, Durso, and Lee 2015, 21). In order to be successful, telematics systems require an intricate interaction between the user and the system (BNOTIONS 2014). This interaction often requires the use of multiple sensory systems and a continual input and output between the user and the system (Pompei et al. 2002, 411–416). Since the implementation and use of telematics systems is dependent not only on the system, but also on how the user interacts with the system, using HSI is a logical means to analyze and eventually design such a system for operational use. HSI has varying domains depending on what source is being considered. This research will use the United States Air Force (USAF) HSI domains because, among all the services, they provide the most detailed framework for in-depth analysis (Boehm-Davis, Durso, and Lee 2015, 39).

USAF HSI domains consist of the following: manpower, personnel, training, human factors engineering (HFE), survivability, habitability, system safety and occupational health hazards, and the environment (Air Force HSI Handbook, 11). The following domain definitions will be based on definitions laid forth by DOD Instruction 5000.02 with slight variations and modifications made to best suit this specific area of study.

1. Manpower

Manpower is "the number of people needed to operate, maintain, train, and support a system" (Boehm-Davis, Durso, and Lee 2015, 40). This can include but is not limited to all civilians, contractors and military personnel required for successful system operation.

2. Personnel

Personnel is defined as the human performance characteristics of the people needed to operate, maintain, and support the system. These characteristics can include physical or mental capabilities required to train for, operate, maintain, and sustain the system (Boehm-Davis, Durso, and Lee 2015, 40).

3. Training

Training involves both the instruction and resources necessary to deliver a sufficient level of knowledge to enhance user capabilities and maintain system proficiency while reducing overall training costs.

4. Human Factors Engineering

HFE is, the integration of human abilities and limitations, "into system definition, design, development, and evaluation to provide for effective human-machine interaction" (Boehm-Davis, Durso, and Lee 2015, 40). HFE also seeks to develop designs that minimize; cognitive and physical task loading, required extensive training, critical errors, or cause safety hazards.

5. Survivability

Survivability is the consideration of the risks to personnel operating a system so as to design accordingly to provide protection from threats and accidents that might occur. Furthermore, this includes any inherent threats that might affect ingress or egress if components within a system were to be damaged or destroyed.

6. Habitability

Habitability considers the physical environment, personnel services, and living conditions that impact system operation, related to overall quality of life and morale for users of a system.

7. System Safety and Occupational Health Hazards

System safety and occupational health ensure system design minimizes the risks of acute of chronic illness, disability, death, or injury to any person involved in maintaining or operating a system (Boehm-Davis, Durso, and Lee 2015, 40).

8. Environment

Environment is the consideration of design characteristics that both minimize the impact to the external environment, as well as allowing the system to perform optimally in the environment it is anticipated to operate in (Boehm-Davis, Durso, and Lee 2015, 40). Environment includes the naturalistic interpretation (air, water, land) of the environment, as well any organizational environments including; socioeconomic, educational, political, cultural or legal that directly influence how a system operates (Hendrick and Kleiner 2002, 55).

D. QUALITATIVE RESEARCH ANALYSIS

Due to the unique nature of the problem posed by implementing telematics, this effort will use qualitative research techniques. Qualitative research is done in an attempt to find general themes, patterns or insights into a particular problem, whereas quantitative research uses set measures to allow for quantified and statistically significant information about those particular measures (Patton 2002, 5–14). The use of a telematics system to achieve higher levels of fuel efficiency in the USMC, is largely undeveloped with no known quantifiable measures available to implement such a system. Based on this, it was determined that the use of qualitative research techniques would be the most appropriate method of analysis. The use of a qualitative method is also supported because telematics systems include complex sets of interactions between hardware, software and system users. This was shown to be true in the previous research done for E2O in which a qualitative ethnographic approach using situational observations was used to reveal existing patterns and practices and, "capture the 'social meanings and ordinary activities' of people in 'naturally occurring settings' " (Salem and Gallenson 2014, 7). Therefore, the focus of this research is directed at how the users of the system experience it and how they interpret what they experience (Morse and Richards 2002, 28).

Qualitative data usually comes in three forms: interviews, observations, and documents. Interviews consist of open-ended questions that allow for in-depth responses revealing the user's experiences, perceptions, opinions, feelings, and knowledge of a system (Patton 2002, 4). Observations involve going into the field where a system is being used and taking note of different activities, behaviors, actions, interactions, organizational processes, or any other human system experiences taking place (Patton 2002, 4). Finally, documents are any written materials to include things like system documentation, official publications, reports, or even personal correspondence that shed light into how the system is used as well as the user's experience and perception of the system (Patton 2002, 4). Since this research is largely systemic in nature where the fundamental question is "how and why does this system as a whole function as it does?" (Patton 2002, 119), emphasis will be placed on conducting interviews and will use observations and documents as supplemental sources of data when necessary. The purpose of using a qualitative approach for this research is to develop a theory about how a telematics system functions. This theory will be created inductively through fieldwork and interviews, and ties together seamlessly with an HSI focused task analysis (Patton 2002, 11). This framework, based on commercial industry practices, will then be used as a guide for the future implementation of telematics systems into USMC ground-based vehicles.

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III. METHODOLOGY

A. INTRODUCTION

This chapter will explain how qualitative methods will be applied to determine the best implementation of telematics into the USMC. It will start by outlining the overall scope of the research to include specific requirements that were used in developing the approach. The chapter includes details on data collection. It explains collection methods, types of information collected, as well as the specific roles of individuals that were interviewed. Finally, it describes how the collected data was analyzed to provide pertinent results for the intended area of study.

B. SCOPE OF THE STUDY

In order to begin the case study research, it was first necessary to begin the decomposition and definition process by defining high-level system requirements to understand the scope of the problem to be analyzed. As discussed previously, the Marine Corps released the E2W2 ICD in 2011, which laid out 29 tasks for the Marine Corps to try and strive to achieve (Marine Requirements Oversight Council 2011, 5). Specifically for this research effort, four of the 29 tasks in Table 1 were applicable and served as requirements for this effort.

Table 1. Requirement Set Forth by the USMC E2W2 ICD

Task Number	Thrust Area	E2W2 Capability Area	Task	Task Description
2	Energy, Water, & Waste	Management	Provide the capability to Manage Energy, Water, and Waste Resources in an Expeditionary Environment	Manage the supply, demand, and usage of energy and water in the operating environment. Assess usage data to determine energy efficiency. Employ sensors, software data management systems to process, analyze, and report E2W2 demand and consumption information at the unit and enterprise level.
4	Energy	Planning	Plan for reductions in energy demands of current and future capability sets without reducing combat/mission effectiveness	Employ tailored T/O and T/E to achieve mission objectives, and optimize T/E using an energy system of systems approach. Provide the right personnel with the right equipment to optimize energy employment across the ROMO.
7	Energy, Water, & Waste	Management	Provide the capability to Measure Energy, Water, and Waste Resources in an Expeditionary Environment	Employ sensors, meters, and other monitoring technology to gather real time or near real time data on energy, fuel, and water demand and consumption, and waste management processes. Include software data management systems to process, analyze, and report E2W2 demand/consumption information at the unit and enterprise level.
14	Energy, Water, & Waste	Management	Provide the capability to Analyze data on Energy, Water, and Waste Resources in an expeditionary environment	Employ operational energy management data and analyses at the unit level to optimize logistic support and operational decision making.

Adapted from Marine Requirements Oversight Council. 2011. *Initial Capabilities Document for United States Marine Corps Expeditionary Energy, Water, and Waste*. CDTM Document Number: 11110808578-v2. Washington, DC: Marine Requirements Oversight Council.

These four tasks are either centered around the management or planning of operational energy. Task number two is focused on managing the supply, demand, and use of energy through the use of sensors and management systems to track energy efficiency. Task number four is the idea that the USMC should employ the right people in the right locations to reduce energy consumption while maintaining mission effectiveness. Task number seven states that energy sensors or other metering devices should be employed that can measure data real time and then have a way of analyzing and reporting the findings. Finally, task 14 directs that leaders make critical decisions based on operational energy factors while in an expeditionary environment.

Additional requirements were set at a USMC Operational Reach Wargame in June 2015. The Assistant Commandant of the Marine Corps published a report based on the wargame where he pointed to three areas of particular concern: improving energy command and control (C2), rebalancing combat and logistic forces, and an overall transformation of the USMC logistic force (Assistant Commandant of the Marine Corps 2015, 2). With regard to improving C2, it was found that a more robust logistic system was needed to provide real-time feedback on energy consumption. This feedback would provide, "more actionable, relevant, and reliable information on current operating forces' energy requirements and thus improve energy planning" (2). The rebalancing and transformation of logistic forces centered on the operational need to extend forces far beyond the 50-mile requirement set by the 1980s Field Logistics System and amphibious concept.

Applying the requirements from the E2W2 ICD and the 2015 Operational Reach Wargame, it is possible to determine areas of concern for the Marines Corps. The four concept areas will serve as the primary focus when collecting and analyzing data. As previously discussed, this research will be attempting to achieve these requirements by making recommendations on the implementation of telematics within into USMC ground-based vehicles. This focus solely on ground-based vehicles will allow for a more focused research effort and will make it possible to better align a commercial case study with the USMC. Because of the alignment with Marine Corps goals and a specific focus on vehicle telematics, this author hopes to provide relevant and accurate measures to implement telematics into the USMC successfully.

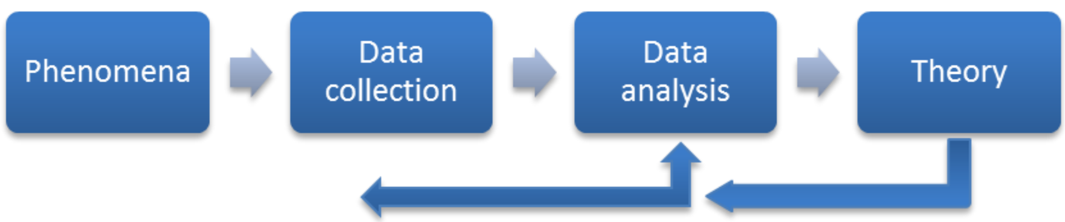
C. APPROACH

This section will describe the different approaches used to analyze telematics. It will start by talking about grounded theory. Specifically, it will focus on applications and methods for conducting grounded theory research. The next section will focus on how to conduct a case study and the associated benefits with using a case study for qualitative analysis.

1. Grounded Theory

Grounded theory is a qualitative analysis technique used to develop theories pertaining to social occurrences. In other words, it is used, "to develop higher level understanding that is 'grounded' in, or derived from, a systematic analysis of data" (Lingard, Albert, and Levinson 2008, 459). Grounded theory is an appropriate method of analysis when the aim of the study is to explain a complicated process instead of validating a pre-existing theory (Lingard, Albert, and Levinson 2008, 459). This also means researchers approach the problem with knowledge of the subject material but with no theories to direct their study. The primary design of a grounded theory analysis is rooted in an iterative approach as depicted by Figure 3. The iterative study "entails cycles of simultaneous data collection and analysis, where analysis informs the next cycle of data collection" (Lingard, Albert, and Levinson 2008, 459). Since the process of data collection, data analysis, and theory building is iterative, it also means there is not a set sample of participants to use for interviews when the research begins. Instead, as analysis is conducted, a wide array of participants is chosen in an effort to confirm or refute the theory emerging from the research (Lingard, Albert, and Levinson 2008, 459). The data analysis is all based on a continual comparison of incoming data. Areas of interest are noted within the data and compared with the other data sources to note any similarities or differences (Lingard, Albert, and Levinson 2008, 459). This constant data comparison leads to a continual refinement of the emerging theory, "which produces the richness that is typical of a grounded theory analysis" (Lingard, Albert, and Levinson 2008, 460).

Figure 3. Basic Steps in Grounded Theory Research



2. Case Study

Qualitative analysis can be done through various approaches, to include storytelling, analytical frameworks and case studies (Patton 2002, 439). This effort will use a case study approach in order to best analyze the data and reach the most beneficial results. A case study approach was chosen based on the benefits it offers, which are specifically appropriate for this research. A case study is "the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (Patton 2002, 297). It, however, can be further composed of multiple smaller cases that consist of things like stories of certain individuals, business units, or smaller groups (Patton 2002, 297). Concentrating on one organization or group, makes it possible to collect comprehensive, organized, and detailed information about the specific group of interest (Patton 2002, 447). The collected data allows for the development of creative insights due to the, "juxtaposition of contradictory or paradoxical evidence" (Eisenhardt 1989, 546). These types of insights are critical for applying telematics, a completely new system, into the Marines Corps. The results of the study are valuable for identifying phenomena of interest and how they "are situated and embedded in local contexts" (Johnson and Onwuegbuzie 2004, 20). Therefore, the results will be readily usable and allow for a more expeditious application of the system into the USMC while creating conditions for the greatest chance of success.

D. DATA COLLECTION AND ANALYSIS

Grounded theory follows an iterative approach to data collection and analysis as depicted in Figure 3. As Figure 3 shows, data collection, data analysis, and theory building were developed and refined as new data and meaning surfaced. As part of the requirements analysis, the grounded theory process starts by selecting the central phenomena of interest, in this case metering and monitoring systems. The next step is to begin data collection. Data collection can be a combination of literature reviews, interviews, field studies, or surveys. The findings from the data collection are then used to develop significant categories that describe the phenomena. These thematic categories are used to develop a theory of factors, which are turned into coding schemes. Coding is a process of categorizing information so that it is easier to analyze the data. Once initial coding is complete, the process revisits data collection and enriches the data set by expanding the types of data that are collected. This data is coded based on the previously established codes from the literature review and new codes are added as dictated by the incoming data. Through this process of data collection and analysis, foundations for the theory begin to be established. Finally, based on this iterative process a unified conceptual model is constructed allowing for the development of a rich theory pertaining to the phenomena.

This grounded theory approach was used to determine the process necessary to conduct the case study for this research. Figure 4 shows how this research followed the iterative grounded theory process.

Figure 4. Detailed Grounded Theory Process

Phenomena	Data Collection	Data analysis	Theory
• Issue to be Studied	• 1a. Literature Review • 2a. Interviews and Observations • 3a. Theoretical Foundations	• 1b. Create Meaningful Categories • 2b. Code Interviews • 3b. Integrate Data and Theory	• 1c. Conceptualize Codes • 2c. Expand Codes • 3c. Create a Unified Conceptual Model

The research started by identifying the central phenomena of interest, in this case metering and monitoring systems. A literature review on telematics (Step 1a) was conducted pertaining to key performance indicators, past case studies, implementation guides, and human factors. This literature review uncovered three themes (Step 1b) related to the implementation of a telematics system. From these themes, an initial conceptual model was established to identify potential factors impacting metering and monitoring systems (Step 1c).

The next step was expanding data collection (Step 2a). This author developed an interview plan based on the initial model by developing interview questions and selecting participants. Participants were chosen, in accordance with grounded theory, at various levels within the company in order to provide a wide array of different perspectives (Lingard, Albert, and Levinson 2008, 459). The interview questions developed were:

1. **Structure**

   How is your fleet structured and why?

   - What divisions in the company are concerned with fuel use?
   - What roles in the company are concerned with fuel use?
   - How do the different roles address fuel reduction?
   - What is your role in the company when it comes to looking at fuel use?

2. **Metering**

   How does your company meter vehicle fuel usage? Does your company collect the data that is metered? Explain how and why.

- Are the metering systems easy to use? How?
- Do the users value the system? Why or why not?
- What works well? What is a challenge? Why? Provide an example.
- Have the tools you been using provided any new capability?

3. **Monitoring**

How does your company use the data that is collected?

- What type of display systems do you use for the data? How is it viewed?
- Who uses the data?
- What works well? What is a challenge? Why? Provide an example.
- Do the users value the system? Why (not)?
- How does your company make decisions using the data?
- Have the tools you been using provided any new capability?

4. **Communication**

How does your company communicate the data that is collected?

- What groups use the information that is collected?
- How is the information shared?
- What works well? What is a challenge? Why?
- Have the tools you been using provided any new capability?

5. **Impact**

How important is fuel use to your businesses success?

- What factors are important to your business? How is fuel use related?
- How do your metering and information tools impact your business success?
- Has fuel tracking changed how your company does business? How?

- In the future, will energy conservation be more effective by using technology controls or by changing human behavior?

6. Incentives

- Why did your company first start metering or monitoring fuel use? What was the trigger?
- How is fuel efficiency rewarded?

7. Lessons Learned

- What would your company change?
- What would your company recommend to the Marine Corps?

To select participants it was first necessary to determine the most appropriate commercial business to analyze. In considering different companies, it was necessary to find an organization that mirrored the Marine Corps in both the types of vehicles being used and the type of work being conducted. This led to the selection of the Caterpillar Corporation and the implementation and use of their telematics systems within a company called Granite Construction. Granite Construction was selected based on their similar operations to the USMC. They are a large-scale construction company with regional offices nationwide and a gross profit over 250 million dollars annually. In addition, similar to the USMC, Granite Construction handles both large and small scale projects in a wide variety of environments, ranging from the forests of the Pacific Northwest to the deserts in the Southwest. They concentrate in complex infrastructure projects including things like dam and bridge construction, tunnel boring, airfield construction, community developments, and highway construction. Finally, Granite Construction was chosen because they have a fleet of vehicles similar to the USMC, including over 2,500 pieces of heavy construction equipment and nearly 3,900 pieces of on-road vehicles.

After choosing Granite Construction, it was important to select the appropriate individuals to interview, as well as the types of data that might be helpful for analysis. The previous work done at NPS for E2O revealed four stakeholders involved in energy use: People having influence on the system, people using the system, enforcers who control the users, and the policy setter that establishes the rules for system use (Salem and Gallenson 2014, 10). Based on this finding, it was decided to analyze their system best, it was necessary to talk to a wide array of both Caterpillar and Granite Construction employees to incorporate all four types of stakeholders. This included numerous Caterpillar executives with some solely focused on telematics and others in more general managerial positions. Within Granite Construction, a similar approach was taken by interviewing employees from top level management to the superintendents who work on-site on the different projects.

In total, 14 different Caterpillar and Granite Construction employees were interviewed through a series of 10 different individual or group interviews. Multiple corporate documents including things like monitoring spreadsheets, data Excel files, and corporate policies were collected as well. The last source of data came from observations made by this author through on-site interviews. This began our second round of data collection (Step 2b).

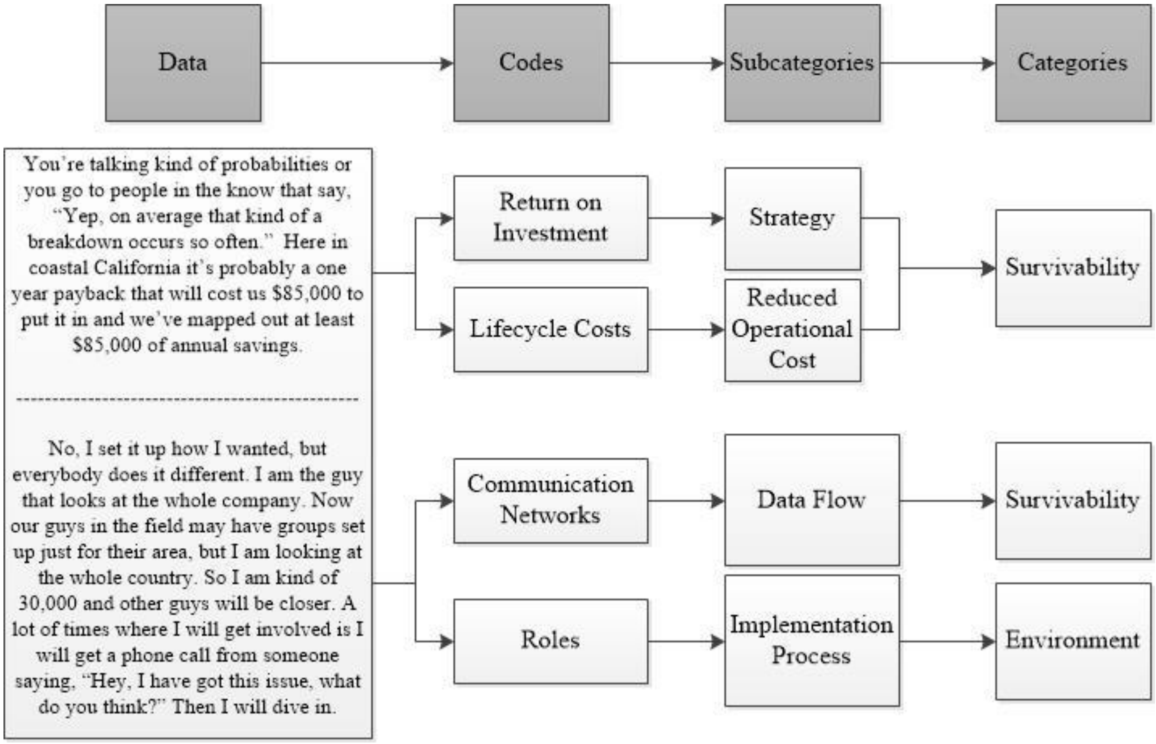
The collected data was then coded to our original coding scheme with the additional factors added as necessary (Step 2c). We then used the expanded coding scheme to enrich our understanding. Finally, we reviewed existing SE theories for appropriateness (Step 3a). Selecting the HSI approach, we then overlaid our previous themes into an HSI framework based around the different HSI categories of human factors, environment, survivability, training, manpower, personnel, habitability, and safety and occupational health. (See Table 2.)

Table 2. Categories and Subcategories

Manpower	Personnel	Training	HFE	Survivability	Habitability	Safety	Environment
Change Management	Management Roles	Driving Behaviors	Attention	Vehicle Maintenance	Comfort	Employee Safety	Organizational Environment
Routing	Vendor Selection	Other	Cognitive Load	Data Flow	Employee Rewards	Reduced Risk	Display Design
Employee Accountability			Error Prevention	Data Measurements	Employee Satisfaction		Vehicle Design
Workforce Management			Feedback	Data Analysis	Employee Engagement		Sensor Design
			Input/ Output Modality	Reduced Operational Cost	Community		Physical Environment
			Physical Access	Strategy	Environmental Protection		Implementation Process
			User Control				

An example of how data is turned into codes, subcategories, and categories is demonstrated in Figure 5. It shows two separate pieces of data taken from interviews with employees. The first piece of data applied to two separate codes and those codes applied to two separate subcategories. However, both subcategories fell under the category of survivability. The second piece of data also had two codes and subcategories. The difference being the second piece of data ended up falling into two categories of survivability and environment. This was used to illustrate how a piece of data may contain multiple codes and subcategories as well as one or multiple categories.

Figure 5. Example of the Grounded Theory Analysis



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IV. FINDINGS AND INTERPRETATION

A. INTRODUCTION

This chapter will summarize the analysis of the data collected from both Caterpillar and Granite Construction employees. It will seek to determine any benefits and best practices involved with telematics systems, as well as any possible negative issues that arise if telematics are implemented or used in a detrimental way. This analysis will also be done specifically to see how greater fuel efficiency can be accomplished allowing for extended operational reach and mission capability for the USMC. The actual analysis will be done by inspecting the data pertaining to each of the individual HSI concepts. Separating the data in this fashion will allow for an in depth investigation that will then lend itself to more realistic and useful suggestions as to how the USMC might implement and utilize a telematics system.

B. MANPOWER

Manpower is the number of people needed to operate, maintain, train, and support a system. This includes all civilians, contractors and military personnel required for successful system operation. Optimizing the number or personnel and utilizing them in an appropriate manner through the use of things like route optimization and shift scheduling allows for improvements in effectiveness and efficiency. This is because the correct number of personnel can be employed in areas where they are needed with no down time or redundancy in work efforts. Considering this, the data revealed two major themes pertaining to this category: improvements in routing and scheduling, and employee monitoring and accountability.

1. Improved Routing and Scheduling Decreases Fuel Consumption and Manning Requirements

It was found that telematics provided status updates, identified inefficiencies, and provided insights into how to maximize vehicle use. They were cable of providing Granite Construction with essential information allowing them to improve how they routed and scheduled their equipment. This was possible through the different types of information that telematics is capable of providing. One of the areas was in monitoring feedback data at the end of each day to understand the status of the different jobs. For example, telematics could show, as one Granite Construction employee stated, that "I have moved 5,000 yards of dirt and I have done this today on this particular job and worked this number of hours" (interview with a Granite Construction employee, June 2015). This information could be compared against the digitized plan. A determination could then be made on whether enough of the quadrant had been graded or cut, as well as the location of the worksite sat so any required equipment could be dispatched accordingly the following day.

Similar to measuring the progress on the worksite, telematics were also used to determine areas of inefficiencies on different work sites. The telematics could identify equipment with excessive idle times or equipment that was not being utilized for extended periods of time. There were cases of excessive idling where drivers were under the impression if they finished their work and "they shut the machine off, they were going to send them home" (interview with a Granite Construction employee, August 2015). Another instance of excessive idling was solved by adjusting the speed loader trucks traveled around a job site to assure trucks were arriving just as another truck was finishing. Management was able to identify the excessive idling and underutilized equipment and adjust or redistribute the workforce to ensure all equipment was operating at maximum capacity. These adjustments and redistributions of the workforce allowed Granite Construction to save significant fuel and become a more effective, leaner workforce.

The USMC could use telematics to improve routing and eliminate inefficiencies. The Marines could actively monitor work sites or convoys to determine how to best deploy troops into the field. They could determine things like when and where fuel would be needed based on the workload. This would allow them to potentially reduce the number of fuel convoys required if they could coordinate multiple drops, in turn, reducing fuel consumption. The Marines could also use telematics to determine inefficiencies in the field. Similar to Granite Construction, they could find equipment being underutilized and adjust assets to maximize efficiency. Additionally, there would be potential to identify areas were a reduced workforce could accomplish the same amount of work due to the increased effectiveness. For example, the USMC could implement a preventative maintenance plan centered on telematics. They would be able to plan and schedule maintenance well in advance, allowing for a reduction in the time required to complete maintenance utilizing a smaller workforce. Overall, telematics would allow for a smaller workforce with higher levels of effectiveness and reduced fuel consumption.

These monitoring systems also included automated systems, better coordinated maintenance, and reduced personnel requirements. Granite Construction achieved this by using telematics to improve vehicle routing and scheduling by actively monitoring vehicle maintenance requirements. They had automated systems within the vehicles monitoring different key elements on a scale from 0 to 100%. At 100%, it meant the part had reached full use and needed to be replaced. Automatic alerts were sent out at 70% to tell essential personnel the equipment was approaching the need for replacement or repair (interview with a Granite Construction employee, September 2015). Management, having this information in advance, could coordinate assets to accomplish maintenance when necessary and in times of reduced workload. This also meant in some situations, they could have a smaller workforce by ensuring the greatest number of vehicles were available to accomplish work and eliminating the need for spare vehicles and personnel.

The USMC could use telematics in a similar manner to allow for proactive maintenance procedures ensuring vehicles were available, overall workforce was reduced and fuel consumption was minimized. Currently, USMC experience failures and require maintenance to fix problems, taking vehicles out of operational use. Telematics would provide leadership a way to identify issues within a vehicle before a part or system actually fails. This would allow them to schedule maintenance in a more time appropriate manner. The vehicle, for example, could be repaired during a period of reduced operations or during a time when other vehicles were operational and could handle the workload of the vehicle in for repair. This would mean assets would be optimized allowing for a smaller number of required vehicles. Furthermore, having fewer vehicles would require fewer personnel and would lower fuel consumption.

2. Identifying Workforce Issues and Monitoring Employees Improves Efficiency

The other major area Granite Construction found beneficial, with regard to manpower, was using telematics to actively monitor their workforce. Workforce monitoring helps improve driver performance, decreasing vehicle accidents and mechanical failures. Telematics were able to show drivers with poor driving performance. These drivers were notified of their poor performance through supervisors or automated reports comparing them to other drivers. One system called Cognitive Adaptive Computer Help (COACH) ranked the drivers from 0 to 100 allowing the drivers to realize, "Oh the best guy is at 94 and I am at a 20" (interview with a Granite Construction employee, September 2015). The drivers could then improve their performance or if the performance persisted alternate personnel could then be hired to fill their position. This allowed employees to operate at higher levels of productivity increasing the overall workforce efficiency. Additionally, the improved performance leads to a decrease in vehicle accidents and mechanical failures. The systems, for example, were capable of training drivers to avoid speeding or negative behaviors like excessive breaking. Maintaining safe speeds reduced the number of accidents within the company and better breaking reduced the overall wear and tear on vehicles (interview with a Granite Construction employee, September 2015). This allowed Granite Construction to have more vehicles available for use at any given time reducing the required number of vehicles and saving fuel.

Implementing telematics to monitor driver performance and workforce issues would be an excellent tool for the Marine Corps. It might also be more easily applied in the USMC based on the control over the operators. Granite Construction admitted to having problems when it came to reprimanding certain individuals since ultimately the superintendents and foreman were in charge of disciplining their workforce (interview with a Granite Construction employee, August 2015). However, the USMC would have less of an issue by utilizing the chain of command to ensure the necessary changes in driver behaviors were being made to improve areas of poor performance. This would allow the Marines Corps to actively manage their workforce and maximize the performance of their operators. In addition, it would provide insight into the true number of vehicles and personnel required to complete the mission. For example, a particular squad might have been taking excessive amounts of time to deliver fuel resulting in additional support from other squads to deliver the required amount of fuel. Telematics would be able to identify these performance gaps and improve performance so only one squad was used to complete the required fuel drops. Likely there would be areas where a reduction in the number of vehicles or personnel would provide for fuel savings and allow the force to be just as effective (interview with a Granite Construction employee, August 2015).

C. PERSONNEL

Personnel deals with the people needed to operate, maintain, and support a system (Boehm-Davis, Durso, and Lee 2015, 40). The data revealed one prevalent theme relating to personnel, which was that the selection and interaction with a vendor are crucial elements for telematics.

1. Selection and Interaction with the Correct Vendor Ensures Telematics are Implemented Successfully

Granite Construction decided to implement telematics and started by trying to decide what company and version of telematics would work best for them. The factors that impacted their decision included preinstalled telematics, reliability, functionality, and vendor responsiveness. There were a multitude of vendors on the market with many of the smaller companies charging less money than larger companies like Caterpillar, Ford, and John Deer. In considering the telematics to choose, Granite Construction looked at the vehicles they currently used. Primarily the bulk of the existing vehicles were either Ford or Caterpillar. Additionally, Ford and Caterpillar also offered new vehicles with telematics already installed, and for the old vehicles, both companies had developed retrofits to seamlessly install telematics (interview with a Granite Construction employee, August, 2015). Granite Construction also researched some of the smaller less expensive options and found most were all startup type companies lacking a strong foundation or the ability to support telematics for the life of the vehicles. These combinations of reasons lead to them choosing to use the more expensive larger companies to supply telematics.

Once Granite Construction purchased telematics, there was a large variety of functionality and potential data analysis within the new systems. In an effort to determine what to use, Granite Construction turned to the dealers who were able to provide assistance through examples of the other companies they currently supported. For example, one Granite Construction employee described the learning process saying, “So the vendors who sell it are like okay, here are all the things you can do with [telematics]. Here is what other people do, here is what UPS uses it for and here is what FedEx might use it for (interview with a Granite Construction employee, September 2015).” This type of information from the dealer showed Granite Construction the types of data useful for implementing telematics and what types of things to monitor to get the most out of the systems. The other piece Granite Construction found helpful was dealer adaptability. If Granite Construction found a particular task or metric in need of monitoring, the large companies were readily available and capable of creating new hardware or adjusting the existing software to accommodate their need.

Selection and interaction with the vendor would be a key element if the USMC hopes to implement telematics successfully. The USMC should choose a dealer robust enough to handle the large capacity of work involved in the Marines Corps instead of going with the lowest cost option. Another key element would be to consider the bulk of current USMC vehicles and determine if the majority of the manufacturers have telematics available or if there is a maker of telematics capable of creating a universal system to fit all USMC vehicles. A unified system would allow for a seamless integration and provide for easier use and maintenance since it would be one common operating system. The other benefit to the Marine Corps of using a large dealer would be the support and flexibility it could provide. The larger dealer would have a host of different customers and could help the USMC find the best way to utilize telematics based on companies operating similarly with similar equipment just as Caterpillar was able to show Granite Construction similar companies like FedEx and other major construction clients (interview with a Granite Construction employee, August 2015). Finally, using a large company would provide an increased level of supportability and flexibility. The company would be well established and capable of supporting the systems through their entire life cycle while at the same time having the resources and infrastructure to make any modifications the USMC deemed necessary. For example, if the USMC decided they wanted to collect a new piece of data requiring a new hardware for a vehicle, a large company, more likely, would have the infrastructure to engineer, manufacture, and install the hardware in an expeditious and cost effective manner.

D. TRAINING

Training involves both the instruction and resources necessary to deliver a sufficient level of knowledge to enhance user capabilities and maintain system proficiency while reducing overall training costs. Increased levels of training can improve operator performance, as well as ensuring the workforce is operating at maximum efficiency and maintaining the highest levels of operational capabilities. The data revealed two main training themes: increased driver training and the ability for management to properly utilize telematics.

1. Increased Driver Training Saves Fuel and Increases Safety

Telematics have become a very useful tool for Granite Construction to identify and facilitate driver training. Telematics were able to identify drivers with negative driver behaviors, facilitate the training of those drivers and also reduce the amount of idle time they were incurring. The systems were able to provide visibility into the machines diagnostics (interview with a Granite Construction employee, June 2015). These insights were used to determine areas where drivers can improve behaviors. In some cases, telematics were also able to identify drivers with very poor driving performance. It was found that the operation of newer vehicles was not always clear to some drivers so the supervisors started from scratch, using the manuals to show drivers what gears they should be using and what specifically they were supposed to be doing (interview with a Granite Construction employee, August 2015). After training, the performance of all drivers increased significantly.

Overall, telematics were used in three main areas for driver training: harsh driving, excessive idling, and automatic overrides. Telematics was first deployed to modify harsh driving behaviors. This included things like reducing speeding events, limiting aggressive breaking and harsh accelerations, and not using jackrabbit starts (interview with a Granite Construction employee, September 2015). Identifying the drivers exhibiting these behaviors allowed supervisors either to correct the behavior through one-on-one counseling or to provide necessary training to improve driver's performance. This reduced wear on the vehicles extending their service life while at the same time allowing for better fuel efficiency and higher levels of driver safety. For example, Granite Construction found improved driver performance increased the life of essential components like the vehicle's transmissions while at the same time greatly increasing the overall reliability of the vehicle (interview with a Granite Construction employee, August 2015).

The second area telematics were used for training was in reducing the amount of idle time each vehicle was experiencing. It was found reducing idle time to zero is not a realistic goal since some amount of idle time will always be present (interview with a Granite Construction employee, August 2015). However, when drivers were trained on reducing idle time and procedures for doing so, there was a drastic decrease in the total amount of idle time throughout the fleet. Implementing this training allowed Granite Construction to reduce their total amount of driver induced idle time by eight percent leading to a significant fuel savings (interview with a Granite Construction employee, August 2015).

Finally, telematics were sometimes installed to cut the engine after a designated amount of idle time. The systems were also setup to have automatic re-starts, immediately starting back up when the driver applied the gas pedal. Reducing idle time, even more than driver behavior, proved to be one of the key metrics for saving fuel and extending vehicle life. Using these methods throughout 2014, Granite Construction was able to cut their overall idle time by 10% yielding a fuel savings of over 1.4 billion dollars (interview with a Granite Construction employee, May 2015).

The Marine Corps could use telematics as a training tool as well. Training opportunities include using disincentives, explaining the benefits of reduced idling, and removing user control. If the USMC identified areas of poor driver performance they could reprimand the individual or facilitate the necessary training to improve Marine performance. It could also be simply a means of determining if Marines using certain equipment have the necessary basic training to operate the equipment. In both cases, this training would lead to safer drivers operating with higher levels of fuel efficiency and extended vehicle service life. The Marines could also use reduced idle time as way of achieving greater levels of fuel efficiency and extending the life of vehicles. The USMC could teach drivers to minimize idle time explaining the benefit of lower fuel consumption and extending operational range. Telematics systems could also be installed to facilitate automatic stops and starts after a certain amount of idle time. Through modification of driver behavior and reduced idle time, there is a chance for the Marines Corps to realize significant fuel cost savings annually, extend the life of their equipment, and greatly increase their operational reach.

2. Management Properly Utilizing Telematics Saves Fuel and Increases Productivity

The supervisors at Granite Construction required a fair amount of training to utilize telematics efficiently and effectively. Training issues include simplicity, data interpretation, and utilizing the supplier to facilitate training. Some training was minimized because Granite Construction focused on purchasing proven technology saying, “We take more of a position of being second or third versus first at times. You know, let somebody else bang their head against the wall and figure out the technology” (interview with a Granite Construction employee, August 2015). The supervisor’s two main areas of training involved using and interpreting the correct data and determining how the data could be used to reduce fuel consumption and improve driver performance. The idea of using and interpreting the correct data was largely focused on selecting the correct data based on how the equipment was being utilized. Telematics have the capability to measure virtually anything, so supervisors had to identify key metrics associated with the goals they were trying to achieve. This meant there was a learning curve while supervisors became familiar with the software before they could start to identify the key areas to focus on. For example, Granite Construction eventually found reduced idle time to be a key component for minimizing fuel consumption, since it reduced periods of unnecessary vehicle operation and allowed for more efficient operations (interview with a Granite Construction employee, September 2015).

Next, the supervisors had to learn how they could actively use the data they were receiving to establish a more efficient workforce. This process was aided primarily through the telematics supplier showing Granite Construction areas to focus on like excessive idling times or prolonged periods of time when vehicles were not in operation. This increased situational awareness and gave the supervisors the ability to correct behaviors or shift equipment from a site with limited work to another with a heavy work load. This also allowed the supervisors to save fuel and become and more effective workforce. For example, there were situations were supervisors were able to identify worksites with heavy workloads and equipment requiring maintenance. They were able to recognize this early and take equipment from other sites where there was a low volume of work and re-deploy the equipment to the site with the heavy workload (interview with a Granite Construction employee, August 2015).

Telematics would allow Marine Corps leadership to have increased levels of situational awareness. Situational awareness can be increased through reliable software, process re-engineering, and utilizing data in a connected fashion. It would likely be best to use a reliable and tested system to ensure the hardware and software had minimal bugs. Furthermore, the supplier would have enough experience to teach the USMC the necessary processes and procedures in using telematics specifically, for the Marine Corps particular application. It would still likely take the USMC leadership a period to drill down to the essential information they would need to track since the Marine Corps operates uniquely in comparison to civilian operations. However, the supplier could also be used for assistance in this process. Once complete, the USMC could use the information they were receiving to learn how to do things such as establish practices to reduce fuel consumption. They could also learn how to use the connected elements and information to increase overall situational awareness. The leadership could move assets to areas they were needed at the time they were needed. This savings in fuel, increased situational awareness, and improved battlespace management would allow them to extend their operational reach and become a more effective fighting force.

E. HUMAN FACTORS ENGINEERING

HFE deals with designing a system to ensure effective human-machine integration. It seeks to minimize task loading, extensive system training, mission-critical errors, and potential safety or health hazards. In analyzing the data, there were three major themes that emerged: the types of inputs and outputs selected, the nature of the feedback provided, and the amount of cognitive load required to use the system.

1. Provide Minimal Feedback to Reduce Distractions

It was found that the drivers of the vehicles operated best when minimal real-time feedback was provided. This approach was taken in an effort to keep from distracting the driver from his actual work possibly leading to degradation in their performance. Instead, the real-time feedback to the driver was only provided for situations where there was potential to have severe impact to the driver or the equipment. The vehicles, for example, would display feedback to the driver if they were over speeding the engine or had high engine temperatures (interview with a Granite Construction employee, August 2015). Furthermore, this feedback was provided incrementally to allow the driver adequate time to make adjustments to prevent any potential negative situation from occurring. This incremental feedback was presented through an emergency monitoring system in either a two- or three-stage approach (interview with a Granite Construction employee, August 2015). First, the driver would receive some kind of a warning light notifying him of a potential issue. If no corrective action was taken, the warning light would then be paired with an audible tone. Finally, depending on the type of equipment, if the driver still persisted, the equipment would implement a third stage and de-rate itself. An example of a piece of equipment de-rating itself, as described by a Granite Construction employee, would be if, “the maximum RPM is 3,000 RPM on the machine, it will cut it down to 1,500 RPM” (interview with a Granite Construction employee, August 2015). This is done in an effort to minimize the negative actions and limit any further damage to the equipment. De-rating the equipment also provides a clear warning to the driver if he had previously not noticed the first two alarms.

In applying this to the USMC, the design of a system for the actual operators of the vehicles should have minimal inputs and outputs. This would allow the Marines utilizing the equipment to have minimal distractions interrupting them from an already task loaded environment. Furthermore, the incorporation of a multi-stage warning system utilizing multiple senses would ensure potential threats to the equipment and the operator would be recognized in a timely fashion with adequate time to take corrective actions. The idea of de-rating a piece of equipment would likely depend on the type of USMC vehicles. If the piece of equipment was something such as heavy construction equipment operating in relatively safe environments de-rating the equipment would be a feasible idea. However, if implemented in things like convoy vehicles, frequently operating in hostile environments, de-rating the equipment could have negative effects by not allowing the operator full performance from the vehicle. In these situations, the potential damage to the vehicle would be acceptable to ensure the highest level of safety for the driver. Therefore, vehicles frequently operating in non-hostile or protected environments should implement a three-stage system and the vehicles operating in and around hostile environments should implement a two-stage system.

2. Customize Reports for Appropriate Level of Situational Awareness

The operators of the vehicles received minimal feedback; the bulk of the outputs and feedback from the telematics were sent to the on-site foreman and supervisors. However, the data the foreman and supervisors received were not necessarily always the same and were sent out at different intervals. The foreman, in charge of directing all on-site work efforts, would have a wireless device connected to the equipment through cellular or GPS channels. The data sent to the foreman was comprised of two major types of data. The first was concerned with equipment and operator safety. The foreman would receive alerts, either by text or email, notifying them real-time of diagnostic issues or negative operator behaviors (interview with a Granite Construction employee, August 2015). They could use this information to stop any potential problems that might be arising. The second type of data was for the foreman's situational awareness to allow him to better coordinate the worksite, plan for future work and increase overall productivity. An example of this was explained by one Granite Construction employee as, "So I have the alerts set up to where if [the equipment] has 25% of fuel left, it pings and sends an email to myself and the oiler saying; hey this thing needs fuel. We either know that it needs fuel, or we plan on fueling it later so we aware of it" (interview with a Granite Construction employee, August 2015). The foremen also had the ability to track all of their equipment real-time allowing them to actively manage their worksite.

The foreman in this situation would correlate directly to a squad leader or small unit commander within the USMC. The squad leaders would be provided with real-time data to monitor and manage their squads. They would know where their different vehicles were at any point in time as well as the current status of all the vehicles. They could also use the data to correct any negative operator behaviors. They would be able to use the increased situational awareness to better plan operationally. Asquad leader could better coordinate things like fuel fill ups possibly re-fueling a vehicle before entering a hostile area or having fuel pre-staged for vehicles at a location appropriate based on the vehicles current fuel supply.

Similar to the foreman, the supervisors receive information pertaining to situational awareness. However, they receive the information on a daily basis instead of receiving it real-time. The supervisors receive alerts, but they receive them from all of the worksites they are overseeing. This information allows the supervisor to coordinate among all of their projects. One Granite Construction employee explained a situation where they are able to see where certain machines might be down or in need of maintenance on one site that has extremely time sensitive work (interview with a Granite Construction employee, August 2015). The supervisor coordinated with his foreman to send another piece of equipment from a less critical site to support the critical site the following day. This coordination led to a more effective workforce with a much higher level of job performance (interview with a Granite Construction employee, August 2015). The supervisors also had the ability to use the data they received and input it into a system known as the Cognitive Adaptive Computer Help (COACH) (interview with a Granite Construction employee, September 2015).

COACH uses an algorithm to assign a score to each driver. It is based on a 100-point scale and the drivers receive deductions from their score for any negative driving behaviors such as speeding or harsh accelerations. All of the driver's scores are then compiled into a scorecard to rank them among one another. This scorecard was used either as a way to rate the employees or solely to encourage competition among drivers to achieve the highest score. In one area, as described by a Granite Construction employee, the supervisor set a minimum score for all of his workers to achieve (interview with a Granite Construction employee, August, 2015). The operators' driving was so poor before implementing telematics that they all essentially started with a score of zero. Within, thirty days of implementing COACH all of the drivers had improved to at least a score of 46 with some of the drivers scoring all the way into the 1990s (interview with a Granite Construction employee, August 2015).

The USMC could use the data sent to the supervisor and send it to leadership possibly at the platoon or battalion level. Similarly to the supervisors in Granite Construction, the platoon leader could use the information to increase his situational awareness allowing for more efficient and effective operations. Determining the factors critical for operational effectiveness is essential to implementing telematics and would be a possible area for further research. This increased efficiency would also lead to decreases in fuel consumption through things like re-routing and asset management. Additionally, implementing a COACH type system could prove to be an invaluable asset. It would allow leadership to track operators' performance as well as allowing the operators to have insight into how they were performing among their peers. Leadership could use it as a way to objectively rank the different drivers amongst each other on evaluations or solely as a way to motivate drivers to improve their performance.

3. Use Automation to Reduce Cognitive Load and Increase Safety and Fuel Savings

The benefit and requirements of telematics concerning cognitive load was approached from two different areas concerning the drivers of the vehicles: vehicle automation and performance limiters. This first area was from the standpoint of automating vehicles. Automating vehicles was done to reduce the amount of cognitive load required by the drivers by reducing the number of tasks they were required to complete. Cognitive load is the amount of mental effort required to complete a task. An example of automation was Granite Construction's use of imbedded GPS sensors to automatically adjust the blade of a piece of construction equipment to put a two% fall into a hill (interview with a Granite Construction employee, September 2015). This type of automation allowed drivers to focus on other tasks and ultimately lead to Granite Construction becoming more efficient and faster. Overall, they found it led to a 25% to 30% reduction in errors when automated telematics were implemented to assist drivers (interview with a Granite Construction employee, September 2015). Another area of cognitive load dealt with restricting behaviors by implementing telematics to limit the performance of vehicles. For example, Granite Construction had installed restrictors limiting their on-road truck to 70 miles per hour and also had idle cut-offs installed (interview with a Granite Construction employee, August 2015). Limiting the speed increased the driver's safety and also increased fuel efficiency as it was found that speeds above 55 exponentially increased the amount of fuel consumption (interview with a Granite Construction employee, August 2015). The idle cut-off ensured trucks and equipment were not run unnecessarily leading to great reductions in fuel consumption. These restrictions ensured the best practices concerning fuel usage were maintained without requiring the driver to take any actions.

As before, this automation and restriction of driver behavior would likely have to be viewed in two different ways when applying it to the USMC. On things like construction equipment operating in non-hostile environments automation and limited vehicle performance could easily be implemented to ensure the highest level of safety, work efficiency and minimize fuel consumption. However, when applied to vehicles in hostile environments it would likely take a smaller role or have to be modified. Automation could be applied, but it would need to have some kind of override should the driver deem it necessary to takeover manually as dictated by safety or other operational requirements. Similarly, restrictions to speed and acceleration could be implemented but would also likely need to have overrides or safety measures in place to ensure that if the operators did need the full performance of the vehicle, it was available to them.

F. SURVIVABILITY

Survivability is the consideration of risks to personnel operating a system and to design accordingly to provide protection from possible threats and accidents. Furthermore, this includes any inherent threats that might affect ingress or egress if components within a system were to be damaged or destroyed. Considering this, the data showed telematics had one primary theme in this area concerned with data collection and usage leading to higher levels of system survivability.

1. Proper Data Measurements and Analysis Leads to Increased Situational Awareness and Reduced Operational Cost

The collection and analysis of the appropriate data lead directly to increased situational awareness as well as lower overall operating costs. Granite Construction, when implementing telematics, had to decide exactly what type of data would be most appropriate to collect in order to reach their company objectives. Their goals, as described in their strategic planning document, consisted of things like improved fleet efficiency, lower fuel consumption, and reduced maintenance costs (interview with a Granite Construction employee, June 2015). Telematics had the ability to measure virtually any aspect within the vehicle, so it was necessary to limit the data collection to only the essential areas necessary for achieving their goals. Additionally, reducing the amount of data collected prevented data overload and simplified the use of telematics (interview with a Granite Construction employee, May 2015).

Granite Construction started the process of identifying key data collection areas by consulting with Caterpillar who identified 25 common areas of data collection based on customers with similar applications (interview with a Granite Construction employee, September 2015). Granite Construction took an initial period to review the data received in these different areas and eventually conducted a series of continuous process improvement (CPI) events to isolate what they found to be the most useful for their specific work application. The result was Granite Construction focusing on four primary areas of data collection: vehicle idle time, driver behaviors, vehicle health, and vehicle usage (interview with a Granite Construction employee, September 2015). These areas, all centering around vehicle maintenance, were chosen because telematics were designed to measure direct readings from the vehicle, and the most prevalent type of readings available related directly to vehicle maintenance. Additionally, other areas relating to things like fuel consumption were limited and were rudimentary in what they provided allowing for minimal in depth or root cause analysis.

The data collected allowed for improvements in how Granite Construction was conducting their maintenance. As discussed above, telematics allowed the supervisors to monitor idle time and identify areas where it could be limited (interview with a Granite Construction employee, August 2015). This reduced the wear and tear on the vehicles allowing them to have extended service life and longer periods between routine maintenance. Driving behaviors, including things like harsh breaking, hard accelerations, and excessive speeding, were also tracked and were able to identify drivers with habits detrimental to vehicle health. Granite Construction was able to train or monitor these drivers accordingly to decrease their negative impact to the vehicles (interview with a Granite Construction employee, September 2015). The vehicle health would inform Granite Construction on the state of essential components on all of their vehicles. It could measure things like temperature, fluid state, and engine parameters. These were measured real-time and sent alerts for sudden failures or warnings for parts approaching necessary replacement. In either case, supervisors were informed of the vehicle state and could either stop the operation or proactively plan maintenance to ensure the vehicle would remain operational. Finally, vehicle usage was a simple metric to determine the amount of hours each piece of equipment had incurred in order to plan for things like routine and preventive maintenance. All of these measures ensured maintenance was being tracked real-time and completed in a timely and efficient manner to ensure the greatest number of assets were available at any given time.

This too would be helpful for the USMC maintenance program. The Marines Corps could use telematics to monitor the state of their vehicles and proactively plan maintenance. This would allow them to repair a part, possibly overlooked before telematics, before it enters a hostile environment where the vehicle might have previously broken down. They could also monitor things like run time and idle time to identify areas of unnecessary wear as well as planning in advance for routine and preventative maintenance. Marines would also be able to track the behavior of their drivers allowing them to identify drivers with harsh driving behaviors and train or remediate the drivers in proper driving habits. This would significantly decrease the wear on the vehicles and equipment. These would all be excellent tools for increasing leadership situational awareness into the current state of their vehicles and the actions necessary to make improvements. Furthermore, this increased situational awareness would allow them to route vehicles appropriately to ensure the highest levels of vehicle reliability. Vehicle reliability would ensure the Marines operating those vehicles would be assured the best chance of ingress and egress from hostile areas increasing their safety.

The improved survivability of the vehicles leading to increased situational awareness and user safety was just one benefit of using maintenance related data. Granite Construction found implementing telematics with data collection and analysis focused on maintenance also lead to secondary benefits of reduced operational cost in areas like fuel consumption, vehicle utilization, and personnel costs. These reductions in cost were attributed to similar behaviors to improve maintenance and ended up contributing to the other areas where Granite Construction was trying to save money and become more efficient. One Granite Construction employee commented on fuel usage saying, "…it ends up being almost a secondary or tertiary benefit from the telematics and what we are using them for" (interview with a Granite Construction employee, May 2015). The cost of maintenance decreased significantly by eliminating the excessive wear and tear on the vehicles. Similarly, by knowing the status of the different vehicles Granite Construction was able to improve routing effectiveness and cut down on personnel and equipment costs. For example, Granite Construction was able to identify certain workers taking excessive amounts of times to make deliveries. They could then correct the behavior to speed up the delivery time and reduce the number of trucks required to fill orders due to the increased efficiency (interview with a Granite Construction employee, August 2015). Minimizing idle time and improving driver behaviors correlated directly to an increase in miles per gallon decreasing fuel cost for the company. One Granite Construction employee commented on fuel consumption saying, "it's all about preserving the vehicle, but it also improves the fuel economy. I mean if you are not jamming on the breaks and having harsh accelerations there is a return" (interview with a Granite Construction employee, September 2015). Overall, Granite Construction found monitoring maintenance issues to be the easiest way to implement telematics and the key areas related to good maintenance practices were also linked to the other areas where they were trying to reduce cost and improve efficiency. The USMC, similar to Granite Construction, could base their telematics on maintenance. This would allow them to have all the benefits associated with maintenance while at the same time incurring all the efficiency and cost savings in areas like fuel consumption.

G. HABITABILITY

Habitability considers the physical environment, personnel services, and living conditions that impact system operation, related to overall quality of life and morale for users of a system. Habitability, after reviewing the data, had two primary themes that emerged: engagement and interaction with employees and the operating environment within the vehicle.

1. Engagement and Interaction with Employees Raises Employee Morale and Improves Performance

Granite Construction uses a variety of methods to engage and interact with their employees. These methods include competitive rankings, and cost awareness. Telematics provide a host of information allowing for them to collect data and score their employees against one another based on driving performance. These rankings are then posted daily for all employees to see. Granite Construction has found by solely posting the results it acts as a way to, “reward the good performers but at the same time you are showing the poor performers” (interview with a Caterpillar employee, May 2015). This started competition among the drivers where they were challenging each other to see who could get a better score. It also allowed a non-punitive way of showing the poor performers they needed to improve their driving behaviors. As a result, Granite construction was able to limit the number of employee reviews necessary reserving them only for sever or extreme incidents (interview with a Granite Construction employee, August 2015). This method of scoring was also taken up a level and used to compare different projects to one another. The telematics software would automatically alert supervisors with performance reports like, “Congratulations on running 4% more efficiently than similar fleets in your region” (interview with a Granite Construction employee, September 2015). This moved the motivation and competition beyond the operator level and extended it to the supervisory level as well.

The other method of engagement with the employees was to use the telematics reports on fuel efficiency and post them for their employees to see, thereby increasing cost awareness. The supervisors made it known to their employees that, “if we can lower our costs to operate equipment, then we can lower our equipment rates that we charge the jobs and that means that we can lower our price that we charge the customer which means we can get more work” (interview with a Granite Construction employee, August 2015). The employees understood more work meant they will have the opportunity to make more money. The employees, in turn, had a vested interest in helping the company to save money on operation costs.

The USMC could implement both methods of engagement and interaction to improve soldier morale while at the same time improving fuel efficiency. The first method of scoring and ranking the vehicle operators against one another would be an easy means to create natural competition among Marines and would subsequently improve their driving behaviors and reduce fuel consumption. Also, by limiting the amount of required counseling, it would increase morale and make the times when counseling was necessary carry a more significant importance. The second method of posting company fuel reports could be very useful to the Marine Corps but would likely have to be approached in a slightly different fashion. This is because Granite Construction and other civilian companies are motivated by profit, but the USMC is based on completing the mission and supporting fellow Marines. This means instead of showing increased fuel efficiency as a profit potential, instead approach fuel efficiency from a standpoint appealing to Marines. For example, it would be easy to equate a percentage of fuel savings into a number of miles that could be traveled. These miles could be translated into a number of missions possible if a certain percentage of fuel savings was achieved. Therefore, the commanders could set fuel savings for their troops to strive for and equate them to increased operational reach making the unit a more effective and respected fighting force.

2. Comfortable Vehicle Environments Improve Performance and Increase Fuel Efficiency

The other area of habitability revealed through the use of telematics was that vehicle comfort could have both positive and adverse effects on fuel consumption. Telematics were able to measure the amount of idle run time of the different vehicles within the Granite Construction fleet. They found in certain areas the idle run time was much higher than the rest of the fleet creating a much higher fuel burn. When this issue was looked into, it was found the operators of those vehicles were often in environments with extreme heat or extreme cold. As a result, operators in these extreme environments would opt to leave their vehicles running when they were out of their cabs with a Granite Construction employee describing it as, “The guy is running around and it’s, you know, 20 degrees outside he is not going to turn [the truck] off because he doesn’t want it to get freezing inside the cab” (interview with a Granite Construction employee, September 2015). This similar type of behavior was also found in areas where the temperature was not nearly as extreme. In those cases the supervisors were able to spot the behavior and take the appropriate measures to remediate the actions (interview with a Granite Construction employee, August 2015). Overall though, it was found when equipment was operating in temperate environments problems with extended idle times were not nearly as large of an issue.

This idea of driver comfort leading to increased fuel efficiency would have a direct tie to the USMC. The USMC currently operates in areas with above average temperatures. In addition, the Marines operating the vehicles are usually wearing an excessive amount of gear and are in a very confined space. Telematics would make it possible to identify operators with significant idle times and educate the troops to turn off vehicles when not occupied. Another possible solution would be to consider an alternate heating or cooling system in the vehicle when it was not occupied. Something like a solar or electric powered system would allow the cab to stay at a reasonable temperature while still providing for significant fuel savings.

H. SYSTEM SAFETY AND OCCUPATIONAL HEALTH HAZARDS

System safety and occupational health hazards is based around designing systems to minimize risk in areas like disability, death, or potential injury to any person involved in maintaining or operating a system. The data analysis revealed three major themes related to system safety and occupational health hazards: Improving operator performance, monitoring vehicle health, and implementing telematics to decrease susceptibility.

1. Improved Driver Training Reduces Negative Behaviors and Increases Safety

Granite Construction used telematics in a variety of training applications. The telematics were able to monitor simple information such as whether or not a driver was wearing a seatbelt an any given time or if they forgot to apply the parking break. Telematics also monitored more complex driver safety behaviors such as whether the driver was speeding, having hard accelerations, or using excessive breaking (interview with a Granite Construction employee, September 2015). It was found the simple readings were helpful, but most of the drivers were already adhering to the safety procedures being measured. Instead, the most beneficial aspect was to use the more complex driver behavioral readings to determine the drivers with continual safety issues. Granite Construction did this by recording data over a prolonged period of time, usually on a weekly or monthly basis, and using software to analyze the driver’s behaviors. This information was then provided to the supervisors who used it to identify drivers with consistent safety violations, so they could then counsel the drivers on safe driving practices. The interaction with the un-safe drivers was usually implemented on a three-strike basis allowing the drivers' time to improve their performance. In situations where the behavior still persisted, the supervisors then applied disciplinary actions. An international crane company consisting of hundreds of cranes and based in South America implemented this type of telematics safety program. When it started, the company was having hundreds of safety violations daily, but within months, the daily number of violations had decreased to nearly zero (interview with a Granite Construction employee, August 2015).

The Marine Corps could benefit greatly by using telematics to improve safety. Telematics could be setup to track potential safety hazards that result in the highest number of historical mishaps. This information, similar to Granite Construction, could then be provided to either the platoon or squad leaders and be used to train and remediate operators on their negative behaviors. Additionally, it could be used as an incentive. Since all the drivers are being monitored, they could be ranked either within a squad or squads could be ranked against other squads. The drivers or squads with the best safety records could then be rewarded for their continual efforts to maintain safe driving practices.

2. Monitoring Vehicle Health Identifies Potential Issues and Allows for Proactive Maintenance

Telematics also were used to monitor vehicle health. They would measure things like crucial engine component temperatures and hourly usage for different parts. The system would automatically send alerts to the supervisors and maintenance personnel if a vehicle was experiencing a potential issue such as a pump running at a higher than normal temperature. One Granite Construction employee described the alerts as, “You know, it’s like having a brain that is telling you these things are going on and us being able to say, you know, after four days of having a cough, maybe I should have the doctor take a look at it” (interview with a Granite Construction employee, August, 2015). These alerts allowed the supervisors and maintenance personnel to do two things. They could identify potential issues on different machines and plan for proactive maintenance. This allowed them to schedule their workforce more efficiently and have the parts needed to repair the vehicles readily available when the maintenance was required. This also afforded them the ability to locate machines real-time experiencing severe problems that might not be readily apparent to the driver. In those cases, the supervisor could cease operation of the equipment before any additional damage was incurred. Some of the equipment even had telematics programmed to identify severe problems and take action without any outside input. For example, certain equipment had telematics, described by a Caterpillar employee, able to, "actually shut down an engine or piece of equipment as part of its protection mode" (interview with a Caterpillar employee, May 2015).

Monitoring vehicle health could have even greater benefits to the USMC than it does for Granite Construction or other civilian companies. This is due largely to the hostile situations in which the USMC frequently operates. Telematics would allow the Marine Corps to have real-time data on all of their vehicles' health. Similar to Granite Construction, this would allow for proactive maintenance and provide a vehicle force with higher levels of availability. The additional benefit to the USMC would come from knowing which equipment was experiencing issues and deciding either not to utilize the vehicle initially or to pull the vehicle out of the field. This would decrease the number of vehicle breakdowns in hostile environments and in turn greatly increase the safety for the Marines operating those vehicles. The one part of the telematics used by Granite Construction likely not useful to the USMC would be the autonomous protection features. This is because the environment where Marines operate dictates the safety of the user takes precedence over the safety of the vehicle. If Marines were in a hostile environment and a vehicle experienced a severe issue, it is more important to continue use and risk damage to the vehicle than to put a Marine's life at risk.

3. Implementing Telematics Securely Reduces Troop Susceptibility

The last aspect involved with system safety relates to how the actual telematics system is employed and how the data signals are transmitted. Granite construction used either non-secured cellular networks or satellite communications to relay their telematics data (interview with a Caterpillar employee, May 2015). This would pose a problem for the Marine Corps. If the non-secure signals were intercepted by an enemy force, they could be exploited to provide a reverse firing solution to the enemy since all of the vehicles would contain positional information. Therefore, the USMC would likely need to look into employing telematics using some kind of secure or encrypted network to achieve an appropriate level of safety. Additionally, Marines operate in remote areas where cellular networks are not always available and even receiving a satellite link can be problematic. Based on this, another alternative would be to download the data directly from the vehicle's onboard telematics computer daily, knowing this option would not allow for real-time monitoring.

I. ENVIRONMENT

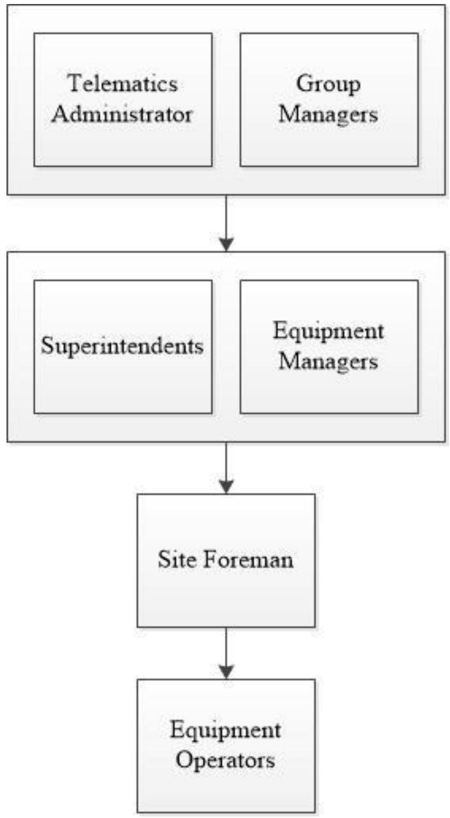
Environment is the consideration of design characteristics that both minimize the impact to the external environment, as well as allowing the system to perform optimally in the environment in which it is anticipated to operate. It includes the naturalistic interpretation of the environment, as well any organizational environments including socioeconomic, educational, political, cultural or legal that directly influence how a system operates. The main theme emerging from the data concerning environment was how the organization was structured and based on the structure how the telematics data was shared.

1. Organizational Structure Is a Key Component to Successfully Implementing Telematics

Granite Construction found that how telematics were implemented within their company and how the data was disseminated was equally as important as the systems themselves. Implementing telematics within the organization consisted of establishing a strategic plan, identifying key leadership roles, defining system alerts, and allowing for open dissemination of data. It was found once the telematics were installed, it was necessary for the organization to determine its primary areas of concern. Based on these, Granite Construction was able to work in conjunction with Caterpillar to determine what metrics needed to be monitored with telematics and the types of individuals that needed to be involved. Granite Construction had a set of goals including reduced fuel usage, better vehicle maintenance, improved usage of their assets, and extended service life of their equipment. Once established, Granite Construction started to assign personnel and responsibilities to utilize telematics and achieve its objectives.

Granite Construction started by selecting an individual who would act as the owner or administrator of the overall telematics system. This person was solely in charge of creating, maintaining and coordinating the telematics central system within the company. Working with this individual, there were four group managers. Group managers were in charge of geographic regions and consisted of: the Large Project Group dealing with the company's largest tasks, the Northwest Group consisting of Arizona, Nevada, Utah, Washington, and Alaska, the California Group working throughout all of California, and the Operations Services and Support Group that acted as support for all three of the other groups (interview with a Granite Construction employee, August 2015). The group managers had superintendents in charge of managing a host of different job sites. The superintendents also worked hand in hand with equipment managers who were in charge of monitoring the health and status of all the equipment on those different job sites. Finally, there were site foreman who were in charge of overseeing individual worksites and the equipment and operators within that worksite (interview with a Granite Construction employee, September, 2015). An organizational chart depicting this structure is shown in Figure 6.

Figure 6. Granite Construction Organizational Structure



The administrator of the telematics system was established to act as a central source for change management in the system. This is the only person with the administrative rights to setup the type of system alerts being sent, as well as responsibility for determining who would receive different alerts. For example, alerts were setup to notify the key personnel when a heavy piece of equipment had 25% of its fuel left (interview with a Granite Construction employee, August 2015). The administrator setup the system to automatically inform the supervisor, foreman, and the oiler via an email or text to their cell phones or laptops. The supervisor and foreman would know they had a piece of equipment in need of fuel and plan the work to facilitate re-fueling the vehicle, and the oiler could schedule the re-fuel so the piece of equipment would not run out of fuel. This centralized administrator allowed for the data collection and dissemination throughout the entire company to be standardized resulting in a common reporting system (interview with a Caterpillar employee, May 2015). The telematics system reports, however, were made accessible to everyone in the company from the administrator all the way down to the actual operators.

The telematics reports were openly disseminated to everyone in the company for a number of reasons. The open sharing of the reports gave insight and visibility into the system. Everyone was able to go into the system and see the type of data being collected and how it was being used. This initially worked to communicate the intent of the system and lead to buy-in throughout the company causing there to be virtually no push back to telematics when they were implemented. Additionally, the open sharing of all the information allowed the different levels of management to utilize the information in a way that worked best for the level of work with which they were dealing. After time and experience using the system, the different levels within the company also developed standardized practices for utilizing telematics. The operators of the equipment had minimal telematics within their cabs aiding them with essential job activities and could use the system reports to see how they were doing in relation to other operators and find the areas in which they needed to improve. The foreman, superintendents, and group managers used the system reports in a more managerial fashion described by a Caterpillar employee as:

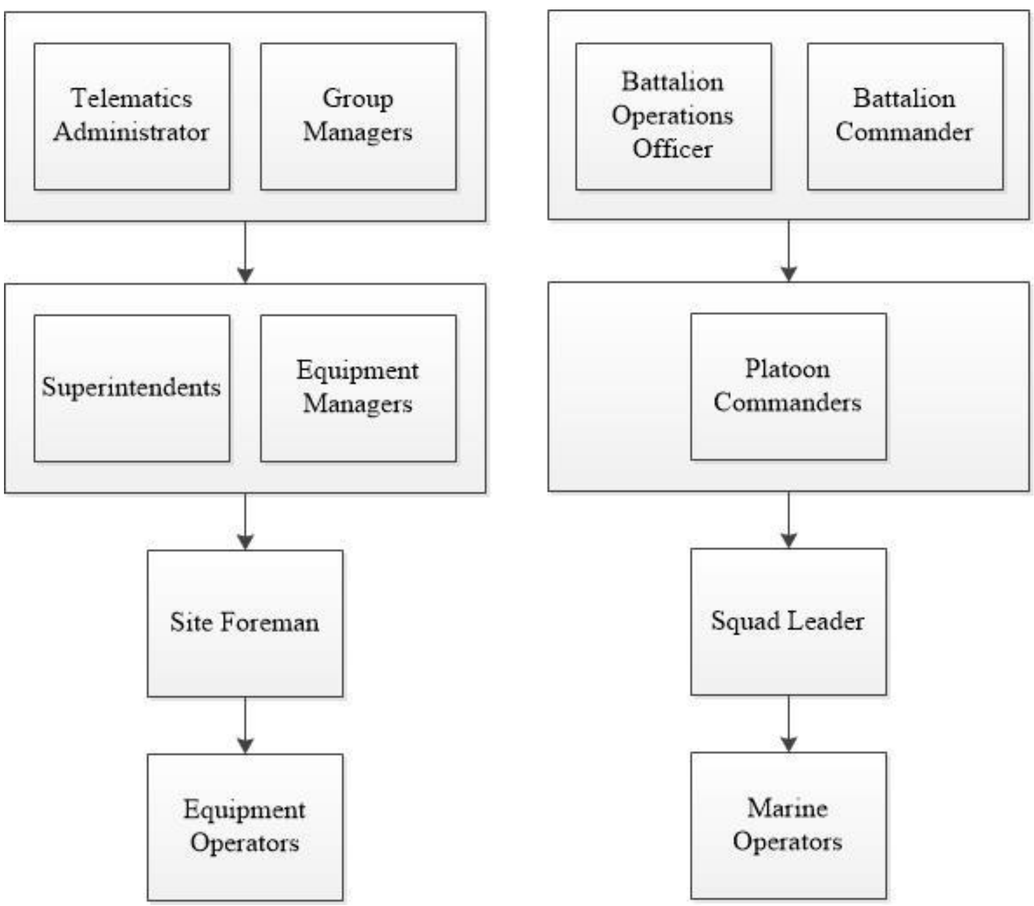
> The foreman is looking at the overall site and how is that progressing against the plan. Have I moved enough dirt, filled enough locations, dug enough this week, this day. Do I have all the equipment for me to stay on target? Am I ahead? Am I behind? The ability to visualize the entire site and just simply show that red means you still need to cut more here, blue means you need to fill, and green means you are right on grade. Make a decision on redeploying the next day where things need to go. Then you know the [superintendents and group managers] are looking at overall complete utilization and site to site comparisons and progress against the overall plan and the ability to predict to when either maintenance costs are going to increase or reduce or when a job is going to be done to be able to know what equipment or assets are going to be available for the next bit. (interview with a Caterpillar employee, May 2015)

Establishing these different roles within the company and common practices for utilizing telematics was very beneficial. It allowed for a more expeditious and simpler implementation process when telematics were originally deployed. Limiting the number of alerts sent out as well as limiting the number of people receiving the alerts ensured there was not an overwhelming amount of data being transferred. Instead, only designated key individuals for different alerts were sent information pertaining to the work they were in charge of which also reduced any redundant efforts in solving potential issues (interview with a Granite Construction employee, August 2015). Throughout the company it greatly reduced the amount of arguments with an example described by one Granite Construction employee as, "We would earlier have a guy say 'Oh it didn't happen on my job. That must have happened before it came to me.' Suddenly, everybody can see and there is no reason to tell stories to each other" (interview with a Granite Construction employee, August 2015). Overall, throughout the company, there was more support from the employees in reaching the overall goals knowing what was necessary to reach the goals, where they were currently at in reaching them, and what they could do to change or improve their behaviors to reach them in the most expeditious manner possible.

The implementation of a similar organizational structure to utilize telematics within the USMC would be a seamless process. This is because the setup and structure of Granite Construction already mirrors the Marines Corps command structure. Similarly to Granite Construction, the USMC would need to identify the key goals they would like to achieve through the use of telematics. This would drive the data collection and how the administrator would setup the system features and reports.

The administrator for the USMC would best be someone in a battalion type level already involved in battlespace logistics (Figure 7). Telematics would probably not change the job but instead provide a tool to execute the job more effectively. Group managers would be analogous to someone like a battalion commander in the USMC. The battalion commanders could use the information, similar to the group managers, to facilitate troop movements and as a global view of the battlespace to enhance their situational awareness and increase their ability to plan for upcoming operations. The superintendents might be compared to someone like a platoon or convoy commander. They could use the information to manage their different squads and identify what squads had existing or developing issues. The platoon commanders would also know where they stood against other platoons in similar areas and could make changes as necessary to improve any deficiencies in performance. The foreman could be analogous to a squad leader. The information would allow the squad leader to know exactly the state of their mission or task and what they needed to do to ensure they stayed on timeline. Finally, the operators would be the individual Marines running vehicles. They could use the information to monitor their individual performance and compare their performance to other Marines to see the areas where they could seek additional training or improve performance. Utilizing a similar structure in this way would accomplish the same benefits experienced with Granite Construction of things like the ease of implementation, increased visibility, fewer discrepancies, and reduced redundant work efforts. Primarily, similar to Granite Construction, it would improve all Marines support of the system and the subsequent drive to achieve the main goals set by leadership.

Figure 7. A Comparison of USMC Structure to Granite Construction



V. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

This chapter will focus on summarizing the findings of the data analysis portion. It will take findings from each of the different HSI concepts, summarize the analysis, and then provide an overview of recommendations for how the USMC should implement telematics into their ground-based vehicles. Specifically, the recommendations will focus on how to implement telematics to best achieve greater fuel and operational efficiency and consequently extend operational reach. Finally, based on the observations of this researcher and the data analysis, potential areas of future study will be suggested.

B. CONCLUSIONS

This research indicates that telematics systems could be a key component in helping the USMC achieve their goals related to energy management and consumption. Specifically, using telematics would directly contribute to the goals laid out in the USMC E2W2 ICD applicable to this research. These goals, previously listed in the methodology section, are all centered around the management or planning of operational energy. Most importantly, their overall intent is an improved fighting force. Telematics systems are designed to allow for increased levels of management and operational planning and may prove to be a useful tool in energy planning.

The first task listed in the E2W2 ICD focused on managing the supply, demand, and use of energy through the use of sensors and management systems to track energy efficiency. This research with industry has shown that using telematics allows for all of these things. Telematics enabled Granite Construction to become a more agile and effective workforce with increased levels of situational awareness. They were able to improve their vehicle routing, decrease the size of their workforce, and improve individual driver performance. These improvements, as well as a host of others, allowed them to more efficiently control the supply and demand of fuel as well as make large improvements in fuel efficiency and overall consumption. Additionally, telematics were setup in such a way that the management of these different aspects was simple and allowed the system to automatically generate the bulk of information with only minimal human oversight.

The next task listed in the E2W2 ICD was based around the idea that the USMC should employ the right people in the right locations to reduce energy consumption while maintaining mission effectiveness. As seen in the case study, telematics were useful on issues relating to workforce management. First, telematics allowed leadership to determine the performance of vehicle operators. This allowed leadership to train or replace drivers with patterns of poor performance. Training drivers also increased productivity so Granite Construction could both manage where the assets needed to be and also the number of people truly required for different tasks. Second, telematics used incoming data and alerts to determine exactly who the essential personnel were who needed to fix different problems. The system helped to identify who should be informed when a problem would arise and then issued limited alerts and reports to those individuals. This made the overall company much more effective and allowed for a leaner more efficient workforce.

Another task in the E2W2 ICD was the need for energy sensors capable of measuring, analyzing, and reporting data real-time. In the systems observed, telematics were shown to provide real-time data via cellular or satellite networks. Telematics were also able to take real-time data and present it in a way that was easily understood and readily usable to people using the system. The systems also allowed for customization allowing real-time data to be sent to only essential personnel. An example of this is how telematics were setup to send automatic alerts if a part on a vehicle was experiencing abnormal or dangerous conditions. The alert was sent directly to the superintendent, foreman, and equipment manager so vehicles could be re-routed and appropriate vehicle maintenance could take place.

Finally, the E2W2 task directs there be operational energy management to allow for optimal decision making while in an expeditionary environment. Telematics would provide a level of operational energy management far surpassing any past or current management techniques. This is because telematics provide a common system where all assets can be tracked and monitored. It also allows for things like proactive maintenance and optimal vehicle routing. Additionally, telematics have methods of directly monitoring the performance of drivers. This information allowed for improvements in driver behaviors and led directly to large savings in fuel consumption and reduced wear on the vehicles. Finally, telematics were found to be an excellent way of increasing leadership's situational awareness allowing them to better utilize their workforce in an effective and efficient fashion.

Telematics should be considered an essential system for the USMC to implement into their vehicles in the near future in order to increase fuel efficiency and in the end improve the organization's combat readiness to achieve its mission. First, the increase in fuel efficiency would lead directly to a USMC fighting force with increased operational reach. Increased operational reach would allow the Marines Corps to become a more versatile fighting force with increased overall mission capabilities. Second, telematics were shown to have the ability to increase productivity and in doing so, created a leaner, more dynamic workforce. Telematics systems also created vehicles with higher levels of survivability and reliability and provided higher levels of safety for operators employing them in the field. Finally, telematics were able to provide large increases in situational awareness allowing better overall decision making and increased operational effectiveness. Implementing telematics would be a key tool in ensuring the USMC stays the world's premier fighting force.

C. RECOMMENDATIONS

The USMC should implement telematics in a similar fashion to that of Granite Construction. There were key elements, discussed in the analysis, to ensure telematics are implemented successfully and used in the most effective manner. These recommendations have been compiled and are summarized in Table 3. Looking across the eight human systems integration factors, this researcher has structured a systemic set of recommendations for implementing telematics within the Marine Corps. First, is the recommendation to use telematics for improving routing inefficiencies, optimizing staffing, encouraging proactive maintenance, and improving driver performance. Second, an implementation plan should emphasize external personnel issues by ensuring strong vendor support. Third, telematics can be used to help leadership identify training gaps and unsafe driving. Fourth, human factors should be taken into account: minimize distractions, use simple warning systems, target the correct personnel, and automate tasks where appropriate. Fifth, system survivability can be strengthened by the appropriate use of telematics for proactive maintenance. Sixth, implementation of a telematics system should take into account: issues of habitability including leveraging natural competition, educating personnel about the benefits, and recognizing the impact of comfort issues. Seventh, health and safety is impacted by telematics by improving awareness, reducing the likelihood of equipment failure, and ensuring the use of a secure system. Finally, it is important to address the organizational environment by creating an agent for change, targeting information for maximum impact, and increasing data transparency.

Table 3. Recommendations for Implementing and Utilizing Telematics

HSI Categories	Recommendations
Manpower	Use Telematics to Improve Routing and Eliminate Inefficiencies
	Use Telematics to Identify Areas where a Reduction in Manning is Possible
	Use Telematics to Implement Proactive Maintenance Procedures Ensuring a More Readily Available Force
	Allow Telematics to Monitor Driver Performance and Workforce Issues
Personnel	Use a Well Established Telematics Dealer with a Robust Customer Base
	Select a Telematics Dealer with the Resources and Infrastructure Necessary to Support the USMC
Training	Utilize Telematics to Identify Drivers with Isufficent Training
	Utilize Telematics to Identify Drivers Exhibiting Unsafe Driving Behaviors
	Allow Leadership a Sufficent Time to Work in Conjunction with the Supplier to Determine the Best Way to Implement Telematics within the USMC
HFE	Design Telematics to Provide Vehicle Operators Minimal Inputs and Outputs
	Design a Multi-Stage Warning System Utilizing Mulitple Senses
	Make the Telematics System Send Reports and Alerts only to Necessary Personnel
	Implement a System Like COACH to Rank Drivers and Improve Performance
	Use Telematics to Automate Simple Tasks for the Operators
Survivability	Use Maintenance as a Primary Point of Data Collection
Habitability	Score and Rank Drivers Amongst Each Other to Create Natural Competition Among Drivers
	Post Fuel Reports and Motivate Soldiers on Benefits of Reduced Fuel Consumption
	Considering Heating and Cooling Vehicles with Systems Utilizing Alternate forms of Energy
System Safety and Occupational Health Hazards	Use Telematics to Train Drivers and Increase Driver Safety
	Use Telematics to Prevent the Deployment of Forces in Equipment Likely to Fail During the Course of the Mission
	Implement Telematics in a Secure Fashion to Avoid Enemy Infultration of the System
Environment	Create an Administrator of the Telematics System with the Sole Power to Make Changes in the System
	Create a Structure to Ensure Information is only Automatically Disseminated to People Who Require It
	Allow Telematics Information to be Transparent and Readily Available to Anyone Within the Company

D. FUTURE CONSIDERATIONS

There are several areas to consider when moving forward with telematics. The next step for the USMC, in order to implement telematics, would be to select an appropriate vendor capable of supplying and supporting the number of vehicles the systems would be installed on. Once selected, the USMC could work in conjunction with the vendor to determine the specific data the systems should monitor. This would likely be similar to companies like Granite Construction where the bulk of the data would be collected and analyzed through the perspective of maintenance. However, since the Marine Corps has such unique equipment and operational environments, some of the data might have to be modified slightly to ensure it is tailored specifically for the USMC.

Another area of interest regarding telematics would be to grow the systems toward a more automated and possibly fully autonomous force. Caterpillar already has telematics systems capable of automating entire job sites (interview with a Granite Construction employee, August 2015). If similar technology was applied into military vehicles it would allow work sites to become fully autonomous with very minimal oversight and user control. Also, a fully autonomous work unit would have the potential for large reductions in energy consumption, as the machines would always be operating at maximum efficiency. An automated work unit would also reduce the number of operators required and have the potential to lower the risk to operators by limiting the number of times they would have to enter hostile environments.

The last area to consider in moving forward and implementing telematics would be to integrate telematics throughout the USMC and not just in ground-based vehicles. Telematics would allow for a common operational picture in real-time. The operational picture would be universally accessible, allowing different forces to coordinate with one another. Having a more global view of operations, through the use of telematics, would allow Marine Corps leadership to do more modern asset management. Asset management practices would allow the Marines Corps to determine things like the type and number of vehicles needed to be purchased or identify areas where potential issues such as new maintenance requirements, might arise in the future. As this paper has shown, increased situational awareness, provided by a telematics system, would result in forces becoming more effective and efficient in terms of both energy usage and operational capabilities.

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