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Final Report (Volume I)

Integration of Diagnostics into Ground Equipment Study

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14. ABSTRACT
The objective of this study was to investigate the viability of implementing Integrated Diagnostics incorporating Condition-Based Maintenance (CBM) for Ground Equipment used by the U. S. Marine Corps. The study reviewed the sources of Autonomic Logistics data, the data requirements, the timeliness or required "pull" of such data, its transmission means (in garrison and the field, afloat and ashore), the availability of current or planned logistic systems to receive the data, the Decision Support Tools (DSTs) to transform data into necessary information by which timely and long term support decisions can be made as part of Total Ownership Cost (TOC), and recommended standards for the Corps to apply across existing and planned end items regarding diagnostic sensor integration. The results of the study are presented in the final version of this report as a collection of templates that Program Managers for different items may use for initiating Autonomic Logistics and CBM for the platforms that they are responsible for.

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1 EXECUTIVE SUMMARY

This report represents the final deliverable of the project titled Integrated Diagnostics for Ground Equipment (IDGE).

The objectives of the study are:

- Review the sources of Autonomic Logistics data,
  - The data requirements
  - The timeliness or required "pull" of such data
  - Its transmission means (in garrison and the field, afloat and ashore)
  - The availability of current or planned logistic systems to receive the data
  - Decision Support Tools (DSTs) to transform data into necessary information by which timely and long term support decisions can be made as part of Total Ownership Cost (TOC)

- Recommend standards for the Corps to apply across existing and planned end items regarding diagnostic sensor integration

The project charged the interdisciplinary team from Penn State University to investigate the viability of implementing Integrated Diagnostics incorporating Condition-Based Maintenance (CBM) for Ground Equipment used by the U. S. Marine Corps. The interdisciplinary team was made up of participants from Department of Industrial Engineering (DoIE), School of Information Sciences and Technology (SIST) and Applied Research Lab (ARL).

The study over the past 14 months has resulted in integration of research from multiple fields, involved study of industry practices in condition-based maintenance, and has sought and obtained participation from several U. S. Marine Corps units including Maintenance and Supply divisions. A number of current systems were also studied, specifically to understand their contribution to integrated diagnostics, including Marine Corps Integrated Management System (MIMMS), Supported Activities Supply System (SASSY) and Marine Corps Equipment Readiness Information Tool (MERIT) as were current maintenance and supply practices. Prior work leveraged included the Quadrant Model as well as several studies related to research streams (e.g. data mining and data fusion) that contributed to the study.

The results of the study are presented in the final version of this report as a collection of templates that Program Managers for different items may use for initiating Autonomic Logistics and CBM for the platforms that they are responsible for. The templates that are presented range from a host of decisions that include sensor selection / placement, identification of decision nodes and support technologies including data mining and data fusion, architectural decisions such as the placement of data repositories at different locations, and current and future practices that can be uncovered as use cases and scenarios so they exhibit fidelity with current practices as well as retain informal practices.

1.1 Core Assumptions

The work contained in the report is informed by a few core assumptions that the team made in the early part of the project in collaboration with relevant personnel from the USMC, who participated in the project.

First, it was assumed that a strategy for integrated diagnostics would be *hybrid* i.e. a mix of legacy systems and new applications that would provide a migration path for the existing fleet of vehicles or major end-items as well as leverage the investments in applications and people that currently exist. In particular, this meant that the team used the U.S. Marine Corps Operational Architecture (OA) as the backdrop against which it would generate its recommendations. Two other strategies were considered and discarded. The strategy of requiring installation and use of proprietary sensor technology in vehicles that would drive the IT infrastructure for CBM was considered too risky. The strategy of only using existing applications such as MIMMS and MERIT was considered inadequate to realize the innovations that would make integrated diagnostics possible.

Second, the methodology for investigating the problem was informed by the dual, top-down (user-driven) and bottom-up (sensor-driven) approaches (see Figure 1.1) that informed each other and ensured, through an internal consistency check, that the recommendations would be feasible (bottom-up) as well as pragmatic (top-down). In particular, utilizing contemporary research in the areas of sensor technologies, data mining, data fusion, and condition-based maintenance operationalized the bottom-up approach. The top-down approach was used to envision the proposed IDGE system, operationalized by utilizing research from scenario-based analysis of systems and techniques such as use cases. The results were also informed by prior work in the areas of the Quadrant Model for supply chains and industry practices related to condition-based maintenance.

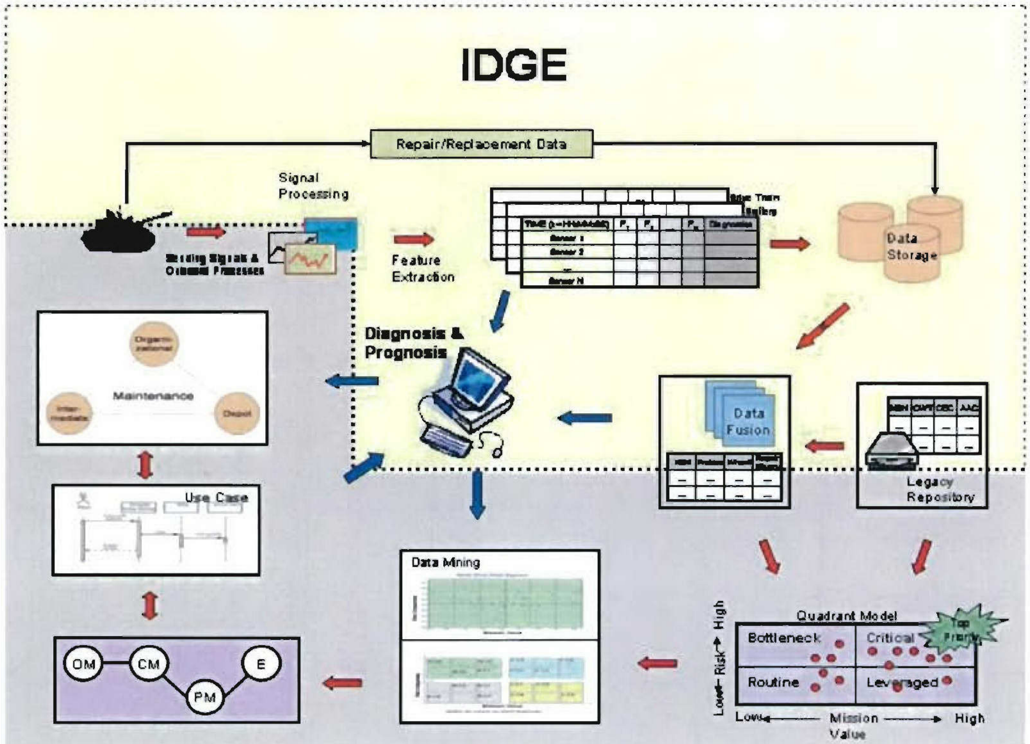

Figure 1.1 The Analysis Approach

Figure 1.1 captures the essential processes that are part of the envisioned system. This includes a CBM system on board the Light Armored Vehicle (LAV) that identifies anomalies during operations. The signals generated by the sensors are either processed on board or transmitted to an external processing unit for diagnosis/prognosis. Through diagnosis/prognosis the requirements for parts, manpower and facilities are identified. The system also allows a human-in-the-loop to do the same if required. These requirements trigger the specific maintenance processes within the OA. The information collected during these processes are stored and catalogued to maintain LAV history, and are analyzed to help in decision support at the tactical, operational and strategic levels. The study, thus, considered the full cycle of processes from identification of maintenance requirements until its fulfillment and retrograde. The pertinent issues identified during the study and the corresponding recommendations are listed against each task specified within the task description.

Third, to ensure that the study would be tied to a concrete exemplar, a specific kind of ground vehicle was chosen. This was the LAV. The LAV already has a record of deployment in the field, follows established patterns of maintenance routines and is currently under a service life extension program (SLEP). These required the team to ensure that they understand and incorporate existing systems and practices in the work carried out and the recommendations developed. Further, the LAV has been the subject of other CBM efforts (one at RIT, another at Penn State, ARL), which informed the present study.

Finally, two key considerations drove the efforts of the team. First was the mandate that the practices for integrated diagnostics for ground equipment be significantly similar for garrison and in-theatre situations instead of the current divergence between the two. To ensure this, trips were made to the Schoolhouse at the Aberdeen Proving Grounds, MD, and the Maintenance Depot at Albany, GA. Second was the desire that the study be informed by ongoing efforts in other agencies within the armed forces such as the U.S. Air Force and the U.S. Army. Expertise within the team, engaged with similar projects with these agencies, ensured that the current study was influenced by results from these agencies.

1.2 Summary of Work Performed

The report represents the work performed by the team to address the tasks it was charged with. Following the rationale discussed earlier, the approach used by the team was one of a combination of top-down and bottom-up approaches. The tasks addressed by the team were specified in the following task description (TD):

Task 1: Literature Review
- All pertinent USMC logistics information on one selected USMC end item
- Legacy logistics support systems, current operating procedures and future support concepts to include Logistics Modernization (which began under the Integrated Logistics Capability (ILC) effort) for incorporation on the selected system
- Technologies that do or could support maintenance diagnostics for the selected end item
- Data processing technologies that do or could support predictive maintenance actions and/or failure modes on the end item
- Trend analysis/decision technologies that would assist USMC logistics managers in initiating/maintaining end item reliability situational awareness

Task 2: Maintenance Data Implications
- Review what types of maintenance data that is currently being generated, the sources of this data, means of data generation, how the data is stored/catalogued/reviewed/acted upon
- Review the selected end item for the types of sensors/diagnostic tools needed to facilitate system diagnostics/failure analysis
- A recommendation on what data representation and data recognition tools are available to transform data streams into useable information

Task 3: Logistics Systems Information
- Review the suitability of current and future logistics systems to use the maintenance information generated

- Analyze the logistic support decisions for the selected USMC end item and future systems
- Determine the quantity/quality/timeliness of information to be used
- Review candidate decision tool technologies and recommend which are most suitable for implementation

Task 4: Establish Universal Data Support Requirements

- Identify data support functions for multi-sensor prognostics integration for the selected end item
- Recommend candidate web based technologies to facilitate multi-sensor prognostic integration for the selected end item

Task 5: Identify Critical Path and Risks for One the Candidate System

- Identify a critical path for implementation of a USMC Autonomic Logistics Support System by FY 2008

A significant outcome of these tasks was expected to be templates that Program Managers (PM) of different ground vehicles may use to initiate or implement efforts that can support integrated diagnostics. To address the above TD, and to specifically generate the expected outcome, the results are structured in this executive summary as the progression from the users of the envisioned system to the underlying sensors that would need to be placed on the ground equipment. Figure 1.2 below shows this progression and the templates resulting from each step in the progression.

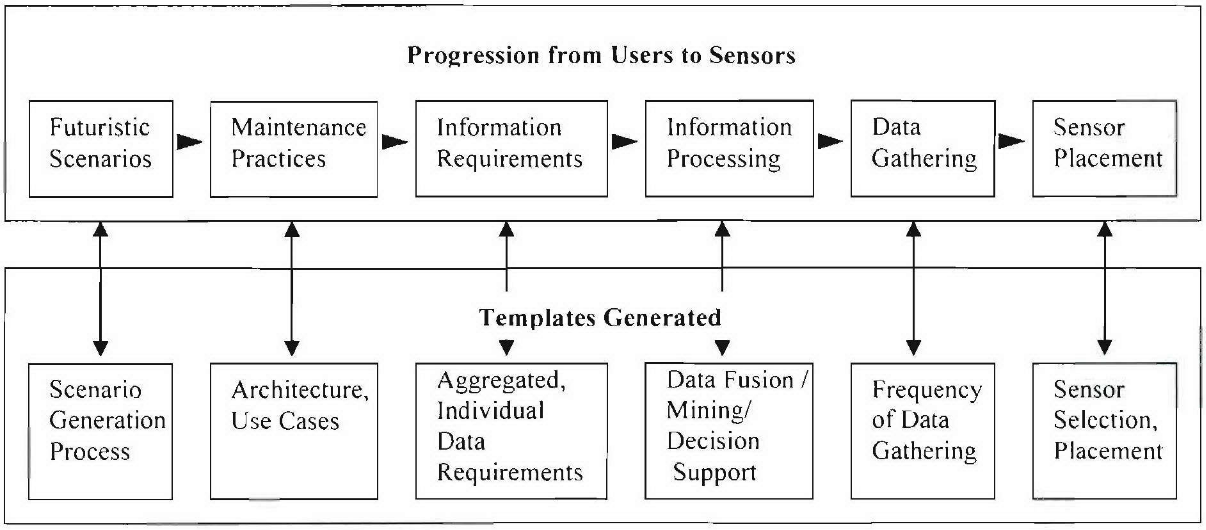

Figure 1.2 Work Performed and Templates Generated

The structure of the report reflects this bias. Figure 1.3 below shows the mapping of the work performed against tasks from the TD and their coverage in the different chapters.

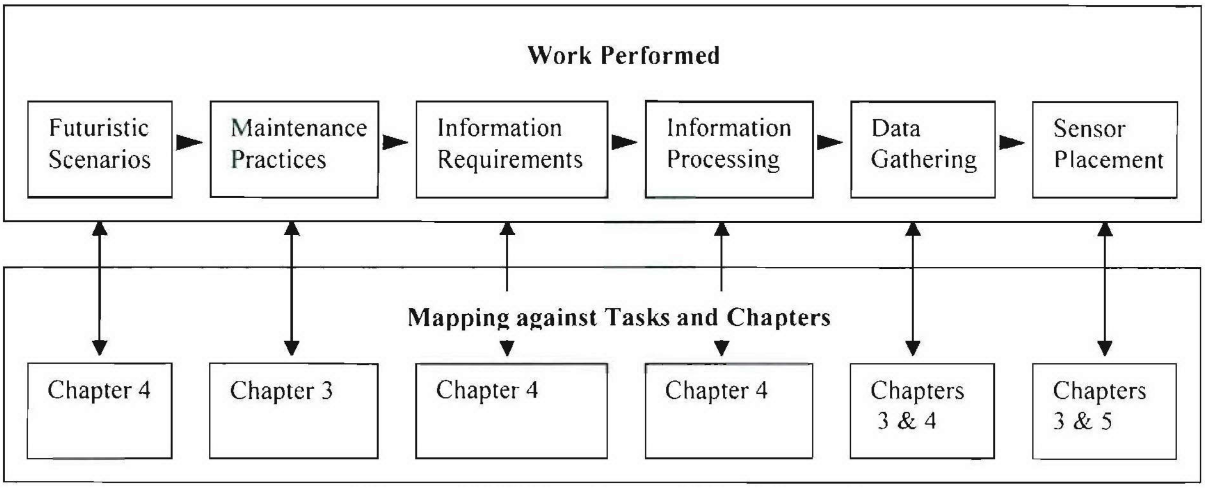

Figure 1.3 Structure of the Report

The analysis performed in this systematic manner resulted in the team's recommendation for a futuristic IDGE systems architecture.

1.3 Recommendations

The work performed so far has resulted in several templates that are illustrated in the relevant chapters and compiled in the appendices at the end of the report. The specific recommendations that we outline, therefore, are tied to the content in these templates.

Recommendation 1
The templates provided in the appendices represent the course of action on several fronts that PMs may follow for initiating Integrated Diagnostics for the ground equipment they are managing. Some of these templates provide processes that the PMs may follow (e.g. Creating Use Cases), whereas others represent an outline of decisions that they may adapt (e.g. Sensor Selection and Placement).

Recommendation 2
While the templates provide considerable guidance, they contain actionable items that are distilled from much research that has contributed to their discovery. An educated use of these templates will require tracing the elements that resulted in these templates. This information is available in the interim and final reports provided to the Marine Corps as part of this study. These templates will be made available to the Marine Corps as a single electronic, browsable source for use by the Program Managers.

Recommendation 3
The templates provided build on the exemplar, the LAV, used in this study. They will need to be adapted and tailored for each platform. Use of the templates

should, therefore, involve participation from the subject matter experts (SMEs), who are involved with the maintenance of the platform in question. To ensure a systematic evolution of these templates, a feedback mechanism and procedure should be implemented so that the adapted templates are centrally integrated across the business enterprise.

Recommendation 4
The templates provide a desirable end-state for IDGE. The vision provided by these templates for the implementation of the systems architecture will require some time and effort to realize. A transition plan to incrementally introduce integrated diagnostics should, therefore, be considered by each PM. This plan should include which systems e.g. MIMMS, MERIT will continue to play a role in the envisioned system, and how the roles of individuals and units will change upon introduction of the proposed system.

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Mr. Randy Geoghagen
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1.5 Organization of the Report

Chapter 2 deals with Task 1. Literature reviewed is identified and appropriate systems are discussed. In Chapter 3, maintenance data implications are addressed. Current maintenance practices, current data collection, the relevant sensor processing details along with decision tools such as quad model and data mining are discussed. In Chapter 4, the team's work related the current and the OA based futuristic maintenance processes, which are discussed through the help of several, use cases. Futuristic scenarios developed and discussed in detail in Chapter 4 led to the identification of the data items leading to the development of the required data bases and decision tools for tactical, operational and strategic levels. Chapter 5 covers the data support functions for multi-sensor prognostics and diagnostics and the envisioned futuristic systems architecture. Chapter 5 discusses in detail a web based proof-of-concept IDGE system with LAV as an end item. This part of the report is not exhaustive and the work is still on going through other related studies. Chapter 6 deals with critical paths and risks. This final report builds on the past Interim Reports (IRs), which are included as Appendices and summarizes the entire effort. A concise summary is given in each chapter for all those tasks reported in the past IRs. Wherever appropriate cross-references to the past IRs is given those appendices are included.

2 LITERATURE REVIEW

Task 1: Literature Review Task 1.1: Review all pertinent USMC logistics information on one (1) selected USMC end item. This will include reviewing legacy logistics support systems, current operating procedures and future support concepts to include the Logistics Modernization efforts for incorporation on the selected system.

- Task 1.2: Review of technologies that do or could support maintenance diagnostics for the selected USMC equipment.
  - Task 1.2.1: Review of data processing technologies that do or could support predictive maintenance actions and/or failure modes on the selected USMC end item.
  - Task 1.2.2: Review trend analysis/decision technologies that would assist USMC logistics managers in initiating/maintaining end item reliability situational awareness.

As a part of the literature review, we concentrated on the following:

1. Autonomic Logistics
2. Current USMC maintenance processes/systems
3. Maintenance systems in DoD
4. Maintenance systems within commercial sector
5. Sensor Processing techniques

A brief summary of our effort is reported in this chapter. Appropriate details are cross-referenced with the previous IRs and appendices.

Figure 1.1 shown in Chapter 1 represents the high-level conceptual view along with the set of processes for IDGE. The envisioned system encompasses Health Monitoring of ground equipment using sensors; A logistics system that is capable of autonomously performing the tasks of acquiring, processing and distributing data; presentation of the data in the form of usable information across the enterprise to facilitate efficient decision making. Once the team identified these goals it was necessary to scope the type of literature that would be reviewed. The team surveyed similar work done within other DoD organizations, maintenance systems used in the Industry and the best practices for maintenance. The team also reviewed the technical issues related to sensors, sensor fusion and fault diagnostics. Each of these issues was critically analyzed within the context of autonomic logistics.

The most important driving force behind the development of IDGE is the Autonomous Logistics (AL) Concept. The OA is the foundation on which AL is built. Therefore the team laid a heavy emphasis on OA. As OA covers the operations related to both the garrison and deployed environments the team religiously followed the OA architecture for futuristic IDGE system development.

The concept of AL enables automated processing and distribution of data to subsequent nodes within the system. Even though the acquisition, processing and distribution of data are automated the issue of visibility of the processes is critical to the Marine Corps environment. Therefore the human in the loop needs to be supported with sufficient information and analysis for decision-making. The idea of autonomic logistics eliminates the need for human effort in performing the non-value added activities. MC personnel will be able to utilize their time towards making decisions and execution. This reduces the cognitive burden on the personnel. The key enabler of the AL concept in the context of maintenance is information technology combined with appropriate sensors and fault diagnostics/prognostics techniques.

The team reviewed the current processes used for maintenance within the USMC and observed the following characteristics:

- *Mission critical data on weapon and support systems is communicated from the battlefield through manual methods*
- *Reporting burden on the commander is high*
- *Data is generally inaccurate and/or lacks granularity*
- *Data is not timely - up to 24 hours old*
- *Information generated, such as Inventory utilization, readiness rate etc., are not timely.*

The high level requirements for enabling AL have been identified as follows:

- Ground Equipment that encompasses both diagnostic and prognostic capability supported by Health Management system onboard
- Technical support to the operational personnel
- An advanced Information System characterized by Wireless communication technology and Integrated Data Environment (IDE) and Shared Data Environment (SDE)
- A logistic infrastructure that will be responsive to support requirements of the supported units in near real-time

The team identified similar systems and relevant maintenance practices used within the industry and within DoD. Critical analysis of these systems led to:

- Obtaining a better understanding about AL concept
- Understanding the latest technologies available for sensing and sensor processing
- Identifying the requirements of USMC maintenance personnel
- Understanding the best maintenance practices followed in the Industry today

A brief review of the systems and technologies that were studied by the team is presented in Table 2.1. The columns under reference shows the Appendix and IR documents where relevant details can be found.

Table 2.1: System Review

System Review	Issues Identified	Reference
Review of the Existing Systems and Processes		
Current practices	- Most current maintenance procedures are paper based - The information is aggregated and stored only within the supply units - Limited analysis is performed for decision support.	Appendix 8.6:Interim Report 1 (Pages 24 – 31)
MIMMS	-MIMMS is a web-based system that is used at the headquarters, depot and for field maintenance. -MIMMS is a non transactional database that is used to store request information	Appendix 8.6: Interim Report 1 (Pages 27 – 31)
MERIT	-The MERIT is a static Data repository. -The MERIT system uses a good visualization tool for viewing the equipment readiness.	Appendix 8.7: Interim Report 2/3 (Pages 50-51)
Global Combat Service Support-Marine Corps (GCSS-MC)	This is the proposed integrated system that presents enterprise wide asset visibility	Appendix 8.6: Interim Report 1 (Pages 78 – 87); (11.3 Appendix 1: Pages 78-89)
CBM in the Army	Three phase approach - Short Term immediate insertion of sensors to acquire available information - Diagnostics, deploying sensors to make automatic prediction about failures within the vehicle - Long-term goal to include prognostics module to enable anticipatory maintenance.	Appendix 8.6:Interim Report 1 (Pages 122 – 124); (11.7 Appendix 5: Pages 117-132)
Review of Maintenance Systems in the Industry		
Boeing	-Boeing uses an effective web based system myboeingfleet.com -Boeing also uses a global airline inventory network	Appendix 8.6: Interim Report 1 (Pages 134 – 136); (11.8 Appendix 6: Pages 133-141)
Penske	- Effective Oil Analysis Program - Six Sigma analysis for maintenance operations	Appendix 8.6:Interim Report 1 (Pages 143 – 147); (11.9 Appendix 7: Pages 142-148)

Automotive Telematics - GM OnStar	Automotive telematics presents the key idea of collecting health information of the vehicle and sending it to do preventive maintenance. - Currently the sensing performed on the vehicle is limited but the OnStar System gives the details of the infrastructure requirements to facilitate real-time health monitoring - Location based services - Satellite Communication to relay real-time health information	**Appendix 8.6:Interim Report 1 (Pages 150 – 170); (11.10 Appendix 8: Pages 149-170)**

From our survey we conclude that there is no single system that deals with sensor information processing to logistics integration. Each of the systems reviewed have their own merits and shortcomings. However, the relevant technologies identified have helped us in detailing the IDGE implementation architecture described in Chapter 5.

3 MAINTENANCE DATA IMPLICATIONS

Task 2: Maintenance Data Implications. Review one selected USMC end item. Selected based on span of life-cycle acquisition stages.

- Task 2.1: Review what types of maintenance data that is currently being generated. Review the sources of this data, means of data generation, how the data is stored/catalogued/reviewed/acted upon.
- Task 2.2: Review the selected end item for the types of sensors/diagnostic tools needed to facilitate system diagnostics/failure analysis.
- Task 2.3: Based on the results of tasks 2.1 and 2.2, recommend a standard maintenance data protocol for USMC end items. The recommended approach will include the following:
    - What data is required?
    - How the data will be generated/stored/used.
    - Recommendations on what data system and communication technologies are available to implement the approach.
    - A recommendation on what data representation and data recognition tools are available to transform data streams into useable information.

In this chapter the study team focused on maintenance data implications and decision-making tools. The following are addressed in detail. Appropriate cross-references are given.

1. Types of maintenance practices
2. Data related to maintenance generated
3. Systems used for maintenance and supply
4. Decision support tools: Quad Models and Data mining
5. Sensor processing and diagnostic tools

3.1 Overview on Maintenance

Maintenance is an essential part for any system/plant for sustainability of the system/plant. Monitoring plays a significant role in maintenance. Depending upon the type of maintenance requirements (scheduled, anticipatory or critical) monitoring and maintenance efforts are closely inter-related. Figure 3.1 shows the various types of maintenance practices. Specific definitions of the maintenance types are detailed in Appendix 8.6: IR 1 (pages 15-16).

3.1.1 Various Maintenance Types Related to Monitoring

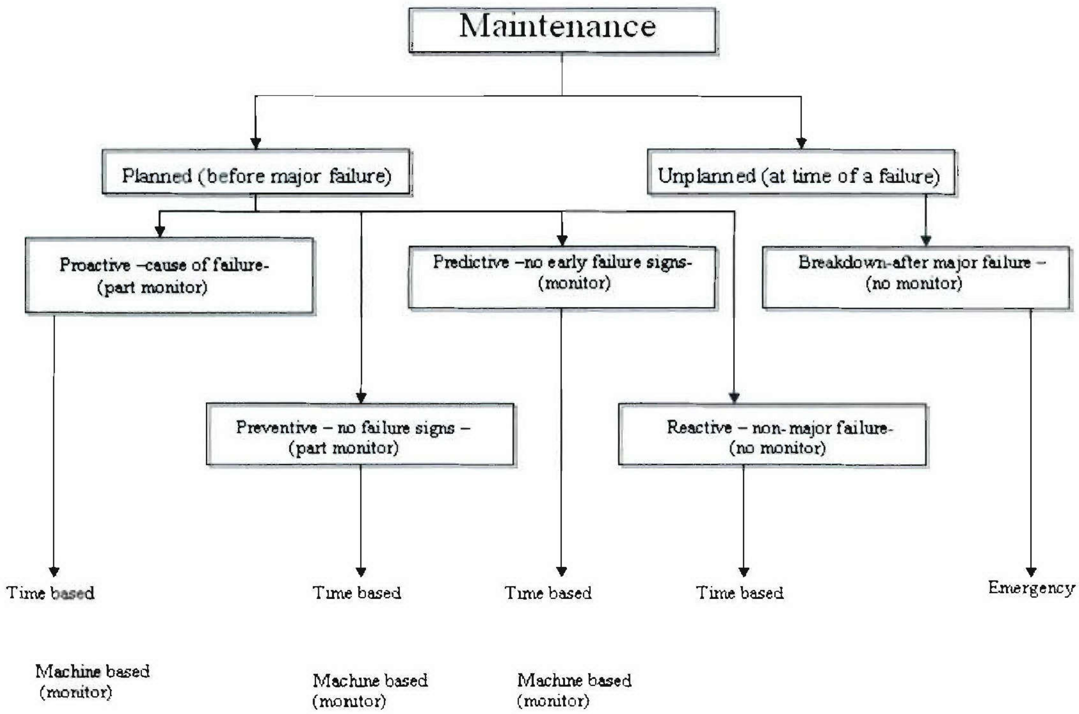


Figure 3.1 Types of Maintenance Related to Monitoring

For our study we deal with three classes of maintenance practices:

- **Scheduled:** In a system, this type of maintenance is considered to be essential and is scheduled to be performed during systems operation.

- **Anticipatory:** By taking a deteriorating current situation into consideration, this type of maintenance is performed to prevent any further deterioration. It requires a certain amount of monitoring to provide sufficient evidence to initiate appropriate action at the best time; however, it could be time based. Theoretical details related to the Anticipatory Maintenance can be found in the Appendix 8.6: IR 1 (pages 17-21).

- **Critical:** This type of maintenance comes into action after the system/component(s) have failed. It is an unplanned event (maintenance), which results in high cost and also is not appealing to the maintenance personal due to the unscheduled work.

3.2 *Current Maintenance Practice within USMC*

The current maintenance procedures use paper-based forms such as equipment repair orders (ERO), equipment repair order shopping/transaction lists (EROSL) etc. These are used for requisition purposes and are forwarded to the specific maintenance units by manual means. The data contained in these forms are later entered into the relevant maintenance systems such as MIMMS, Field Maintenance Subsystems (FMS) etc., for keeping records and maintaining visibility. These systems are stove piped and are detailed in Appendix 8.1. Table 3.1 shows the current maintenance data generated. The various forms and records that are currently used for maintenance in the Marine Corps are described in Appendix 8.1.

3.2.1 Types of Maintenance Data Currently Generated

Table 3.1: Data Attributes for ERO and EROSL

Data Attributes	Description
ERO	
ERO Number	Equipment Repair Order Number
Acceptance Information (Signature)	Signature of the person accepting the equipment
Acceptance Date (DRIS)	Date received in shop
Organization doing repairs	Name of maintenance shop performing the repairs
Echelon	Echelons of Maintenance
Serial Number	Serial Number of the Equipment
Authorization Information (Signature)	Signature of the person authorizing the work to be performed
Authorization Date	
Priority	Priority assigned to the ERO
ID Number	System ID
Nomenclature	Name and/or model number of equipment
Job Order Number (JON)	Job order number to be charged for the repair parts
Shop Section	Shop section code
Task Number (Item No.)	Serial number for task performance entered in numerical sequence
Description of Work	Brief description of each task
Labor Hours	Total labor hours to the nearest 1/10th of an hour
Mechanic Information	Signature of the mechanic performing the repair
Job Status - Code	Code indicating the job status
Status Date	Date on which the status is entered
EROSL	
ERO Number	Equipment Repair Order Number
Unit ID	Unit name and number submitting the EROSL
Date Received	Date received in shop
Date (INIT)	Date the mechanic fills in the EROSL
Material usage code	Indicates the type of part requested

	(accessories, SECREPS)
Shop Section	Shop Section Code
Supply IP	
NSN	Appropriate NSN of part to be ordered

3.3 Sensor Processing

In recent years, three major advances in information technology have enabled the development of smart systems. These developments include smart nano- and micro-scale sensors, wide-bandwidth wireless communications, and improvements in predictive diagnostics. As a result, systems are beginning to be developed to monitor their own status or health, and predict the evolution towards failure. In effect, these smart systems "feel their own pain" and can announce when they need "care and feeding". New platforms and weapon systems, such as the Expeditionary Fighting Vehicle (EFV) for example, are incorporating sensors and reporting via wireless communications to allow distribution of information about the system's health, operating status, and logistics needs. In particular, the U. S. Marine Corps has developed an OA that will accommodate platform based sensor observations, generate reports by platform operators and maintenance personnel, with communication of this information at local and global levels via wireless communications. The present study is developing this concept further including; use-cases, physical architectures, algorithms, and recommendations for improved supply chain management and logistics support. Summary of the on-going research is presented to provide a glimpse of a new capability that will exist in which commanders at multiple levels can conduct intelligent preparation of the logistics battle-space, analogous to current intelligent preparation of the battlefield.

The use of a broad spectrum of sensors and multisensor data fusion provides the opportunity to significantly improve the knowledge of the state of USMC resources (platforms, weapon systems, etc.). The expected benefits include improved system accuracy, decreased uncertainty, and increased robustness to changes in the targets and environmental conditions. A key challenge becomes how to fuse these data to achieve inferences that cannot be achieved using a single sensor or source. This section of the report describes the concept of multisensor data fusion, a summary of the state of technology and application of data fusion to condition based monitoring of systems and platforms.

A conceptual model for an intelligent monitoring system is shown in Figure 3.2. A mechanical system or military platform such as a rotorcraft (shown at the top left-hand side of the figure is to be monitored for status and mechanical health. Failure mechanisms for such a system may include corrosion, wear, lubricant contamination or degradation, thermo-mechanical fatigue, etc. These failures are typically flight or safety of flight critical. The intelligent monitoring system shown in Figure 3.2 has multiple components and functions including; (1) active and passive sensors, (2) signal processing and feature extraction, (3) pattern classification, (4) multi-sensor data fusion, (5) automated reasoning, (6) models, (7) historical data input, (8) mission constraints, and (9) human-in-the-loop decision making.

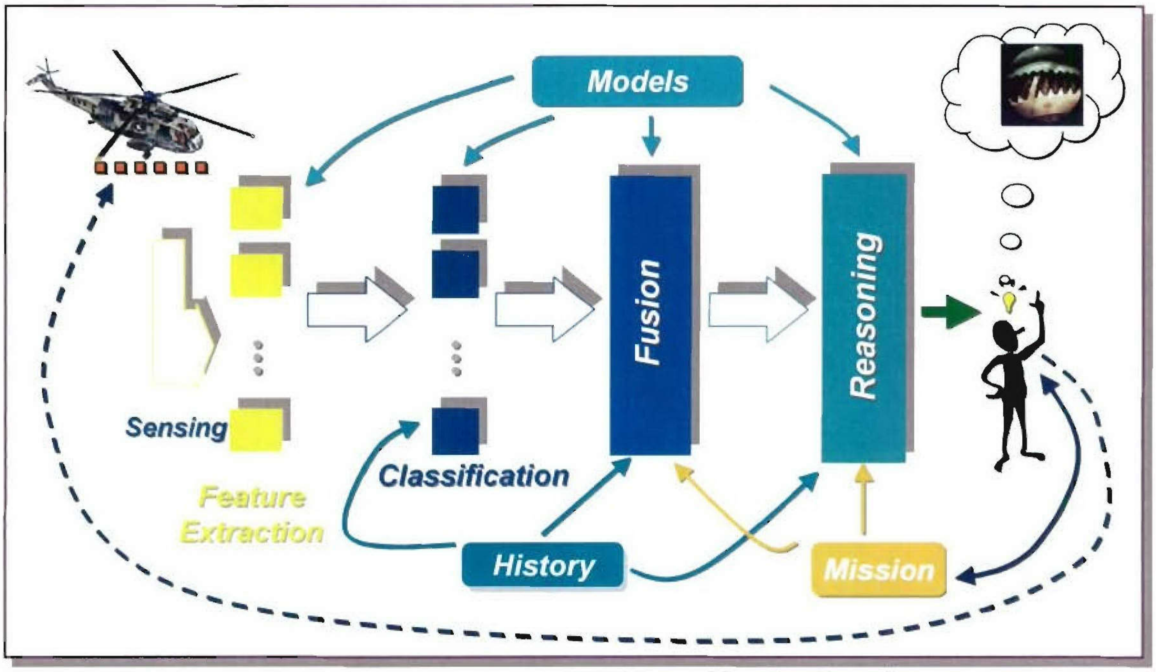


Figure 3.2 Concept of an Intelligent Monitoring System

A special aspect of this research involves developing data fusion algorithms to improve logistics support. A goal of this study is to establish templates that can apply to any piece of ground equipment with a standard means to deploy diagnostics/prognostics, track, evaluate, anticipate failure, activate the supply/maintenance system to request, order and repair the item based upon varying time constraint scenarios. Indeed, data fusion assists in this objective greatly due to its ability to abstract the data into information to be utilized at higher levels of the system hierarchy. Data fusion is applicable at all levels of the system hierarchy. At the lower levels its goal is to bring together diverse data sources and extract key information that is indicative of the equipment condition. At the intermediate levels, its goal is to integrate diverse information sources to evaluate the system behavior and assess its ability to handle its mission. In addition, at this level actions for maintenance and mission re-planning could be generated. At the higher levels, the goal is to provide contextual, actionable information to various users in the networked enterprise. Templates have been developed to help practitioners develop diagnostic processing solutions for USMC equipment. Some initial templates are presented in Chapter 5.

This section of the report describes the concept of multisensor data fusion, assessment of the state of technology and application of data fusion to condition based monitoring of systems and platforms. Examples of these applications to rotorcraft and land vehicles are provided in Appendix 8.7: IR 2/3. The examples of systems provided in this review present some demonstrations at various levels. A brief summary is also provided of application of information fusion for: (1) Monitoring the condition of individual LAVs and (2) Monitoring the location and health of several LAVs in a networked, enterprise setting. The methods and techniques described in the fault diagnosis examples are not limited to air vehicles. They can be used on a variety of mechanical equipment in military and industrial settings. In fact, systems employing such techniques are presently being tested by the US Navy and US Army for their rotorcraft applications. Also, several industrial systems for fault diagnosis are becoming available. The importance of presenting the appropriate information to the user is now being recognized in the implementation of diagnostic/prognostic systems. In Table 3.2, column 1 refers to the various sections related to Sensor Fusion and Fault Diagnosis and column 2 specifies where these details can be found in the previous IR and its corresponding page numbers.

Table 3.2: Sensor Fusion and Fault Diagnosis References

Sensor Fusion and Fault Diagnosis	
Section	**Reference**
Concept and Model for Data Fusion	Appendix 8.7:Interim Report 2/3 Pages 33-34
JDL model for Data Fusion	Appendix 8.7:Interim Report 2/3 Pages 35-36
Pit Falls in Data Fusion	Appendix 8.7:Interim Report 2/3 Pages 36-37
Application of Data Fusion to Diagnosis	Appendix 8.7:Interim Report 2/3 Pages 38-39
Fault Diagnostics Examples: Feature Level Fusion	Appendix 8.7:Interim Report 2/3 Pages 39-43
Fault Diagnostics Examples: Decision Level Fusion	Appendix 8.7:Interim Report 2/3 Pages 43 - 45
LAV Top Degrader Study	Appendix 8.7:Interim Report 2/3 Pages 45-50
Additional details related to Sensor Fusion and Fault Diagnosis were also documented in the Appendix 8.6: **Interim Report 1 (Appendix 4 Pages 98-116)** ; **Appendix 8.7: Interim Report 2/3 (Appendix 7.4 Pages 83-94).**	

3.4 Data Mining and Decision Support

3.4.1 Quadrant Model Review

The quadrant model is a classification tool used to categorize the elements along two distinctly different attributes. Relevant to this study, the attributes considered are the mission value and risk/uniqueness. The main computation performed in this model is the quantification of risk and mission value associated with the different components. In the generic quadrant model, the X-axis represents the mission value of a particular component and the Y-axis represents the risk/uniqueness associated with the components. The value from left to right on the X-axis and bottom to up on the Y-axis increases from low to high.

The quadrant model has two 'dividers' that partition the X -Y plane into four distinct quadrants. They are categorized as "Routine, Leveraged, Bottleneck and

Critical". Each of the quadrants represents components with distinct levels of risk and mission value. The dividers can be adjusted to change the fraction of components falling into the four categories. Figure 3.3 shows the quadrant model with a sample of the attributes that ascertain which components belong to the respective quadrants.

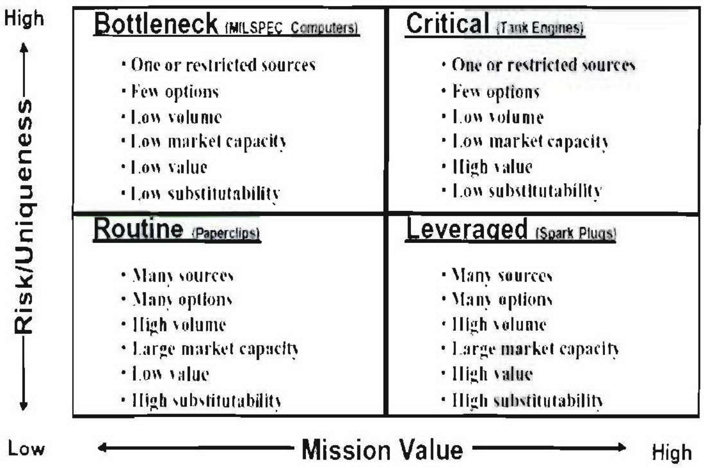


Figure 3.3 Quadrant Model Showing the Attributes & a Sample of the Various Criteria that Determine which Component Belongs to the Respective Quadrants.

With the above concept, specific business rules can be applied for each category to assist in decision making at various levels. In addition, this will help in identifying critical components in the LAV for which CBM can be enforced for diagnosis and prognosis.

The quadrant model assists in decision-making. Apart from the quadrant model, various techniques are available for analysis. One such technique considered is "Data mining". Combining data mining techniques with the quadrant model can improve the granularity of classification of SECREPS. The study team had discussions with Capt. Jake Enholm who had been working on the quad model. The work is deemed to be complementary. The study team investigated a methodology to do the transformation of attributes for plotting using tensor calculus in support of Capt. Enholm's efforts. Those initial results are promising and bear further future study.

3.4.2 Decision Support Systems with Data Mining

In this study, Data mining techniques are needed to support maintenance related decisions that are made at different levels (Strategic, Operational and Tactical) within the USMC. In the quadrant model, all the parts that are classified as critical are treated according to the same business rules. There is not much scope for prioritizing the requirements of components within each category of the quadrant model. To achieve greater granularity the use of other data mining techniques is suggested.

The primary decision considered here is that of prioritizing the procurement of components within a fixed budget. The input data considered are similar to those used for the quadrant model analysis (provided by the sponsors). Data elements used were from the FEDLOG, Logistics Data Repository (LDR), Supply chain management center, in combination with some of the simulation results.

Though the decision considered here is at the strategic level, similar techniques can be considered for the operational and tactical levels. At the strategic level, the main objective is to limit the costs incurred as part of maintenance procurement, while at the tactical level the emphasis would be on the availability of the required components. The decisions made at the strategic level would be based on historical (long term) data while the tactical level decisions would be made in near real time. It is important that the decision support system developed be aligned along the three different levels to improve operational efficiency. Figure 3.4 shows the overview of the processing element for data mining.

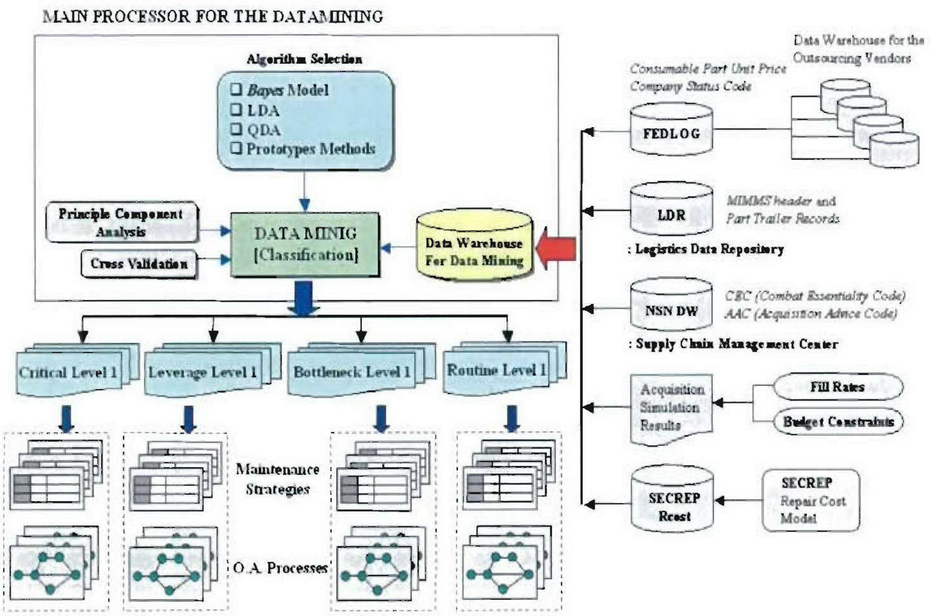


Figure 3.4 Processing Elements for Data Mining

3.4.3 Data Mining Implementation Techniques

In Table 3.3, Column 1 specifies the data mining implementation techniques for IDGE and Column 2 specifies its relevant Appendix and IR and page numbers.

Table 3.3: Data Mining Implementation Techniques References

Data Mining Implementation Techniques	
Section	**Reference**
Implementation of Data Mining Techniques	Appendix 8.7:Interim Report 2/3 Pages 26-27
Implementation of Classification Algorithm using MATLAB	Appendix 8.7:Interim Report 2/3 Pages 27-28
Validation and Evaluation of Data Mining Techniques	Appendix 8.7:Interim Report 2/3 Page 28
Misclassification Error rate of Classification Algorithms and Principal Component Analysis	Appendix 8.7:Interim Report 2/3 Pages 28-29
Sensitivity and Specificity Analysis of Classification Algorithms with Principal Component Analysis	Appendix 8.7:Interim Report 2/3 Pages 30-31
Fundamental concepts of Data Mining are presented in the Appendix 8.6: **Interim Report 1: Chapter 6 (pages 44-52)**. Theoretical details related to the various Data mining techniques are documented in the Appendix 8.7: **Interim Report 2/3 (Appendix 7.3, Pages 74-82).**	

4 LOGISTICS SYSTEM INFORMATION

Task 3: <u>Logistics Systems Information.</u> Review the suitability of current and future logistics systems to use the maintenance information generated to make logistic support decisions for the selected USMC end item and future systems.

- <u>Task 3.1:</u> Determine the quantity/quality/timeliness of information to be used at:
  - The unit/end item level
  - The Marine Expeditionary Brigade (MEB) level
  - The HQMC/SYSCOM/MCLC level
- <u>Task 3.2:</u> Review candidate decision tool technologies and recommend which are most suitable for implementation.

The OA forms the foundation to the USMC future logistics systems. In order to develop the architecture for the USMC maintenance logistics system, the team executed the following logical steps.

- Using the OA, specific cases relevant to maintenance were identified
- Details regarding the information exchange between the nodes (organizations) were captured
- The specific data attributes that is to be sent from node to node were identified
- The nodes within the maintenance cases were mapped to specific organizations within USMC
- Using this mapping, possible scenarios were generated
- Identified nodes (organizations) within these scenarios where decision making is required
- The data that needs to be captured to support each of these decisions at the nodes were identified
- Recommendations were made for the type of analysis that needs to be done and to support these decisions
- The system and technologies that would enable the exchange of the required information were identified

4.1 Use Case Analysis

4.1.1 Why Use Cases

Following the top-down perspective, that is, a user-driven analysis, we propose the use of use cases to document current and envisioned practices that users of IDGE will use. Use cases allows the documentation of scenarios using the terminology of potential users in a manner that clarifies how the proposed system will, in fact, be used by the users. These are documented to understand the decisions the actors make, the data the actors use, how they communicate with one another as well as the system, as well as to understand the limitations of constructing the system. Our efforts at creating these use cases are, therefore, informed by the following:

- We assume that the envisioned use cases will follow an anchor and adjust strategy, that is, the current practices will be respected to the extent possible.
- We assume that the envisioned use cases will provide a path to use current legacy systems in the near term with an extension to a full-blown IDGE system in the future
- We assume that the informal, social practices that make the current practices work will be retained, to the extent possible, in the proposed practices, to ensure that the benefits of these are not lost

4.1.2 Understanding Use Cases

A Use Case is a description of the interaction of a potential user with an envisioned system (Jacobson et al. 1995). The description contains sufficient information that allows progress during the analysis without final commitment. A use case is written using terminology that is familiar to the potential users. A single Use Case, thus, represents a unit of analysis that (a) potential users can relate to and confirm, (2) designers can build and deploy, (3) implementers can test, and (4) project managers can use to estimate effort. Further background information about use cases, how they are documented, their benefits, and how they can be utilized for different purposes can be found in (Appendix 8.7: IR2/3, Chapter 3).

Figure 4.1 below shows the basic use case notation. An actor (stick figure) represents the role played by a potential user. A use case (oval) is the description of interactions that an individual actor will carry out with a system (OMG 2004). In addition, functional groupings of use cases are sometimes referred to as packages (rectangle).

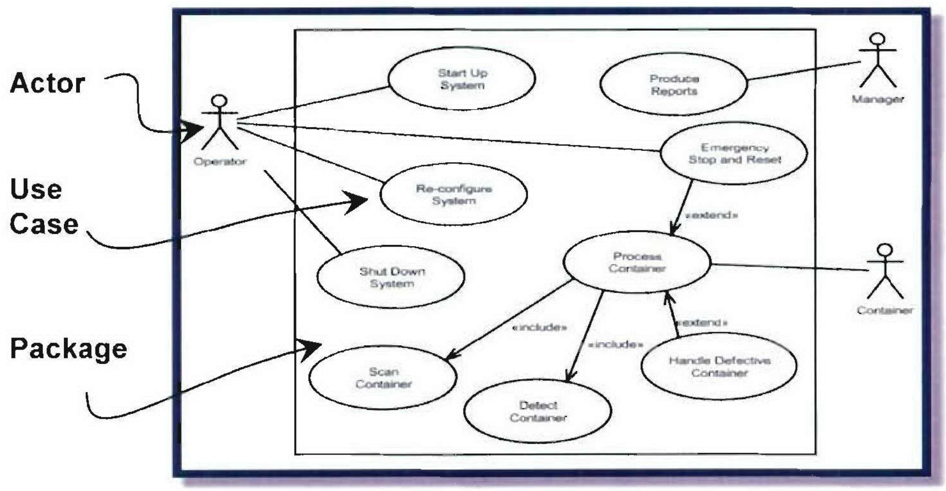


Figure 4.1 Notations for Use Cases

4.1.3 Creating Use Cases to Envision IDGE

The previous Interim Reports (Appendix 8.7: IR2/3, Chapter 3) outlined the process we had initiated for constructing the use cases. Here, we report updates to this process, including how it was adapted for the current project.

The key participants in the early phases of the process included Major Blake and Colonel Grimes, who provided valuable inputs to the early versions of the use cases. These were followed by multiple iterations of the use cases within the team, and during the months of March and April, were validated by visits to the Schoolhouse in Aberdeen, MD, and the Logistics Depot at Albany, GA.

An infrastructure – primarily containing the hardware – was created following the preliminary discussions with Col. Grimes and Maj. Blake. This is also available in the previous interim report (Figure 3.3, (Appendix 8.7: IR2/3, Chapter 3)).

Based on an investigation of how in-theatre and in-depot maintenance is done, a total of 25 use cases were initially created, which were revised following further discussions and changes following the visit to Albany, GA. At final count a total of 31 use cases have been documented and are part of this final report. Figure 4.3 shows the summary of the use cases.

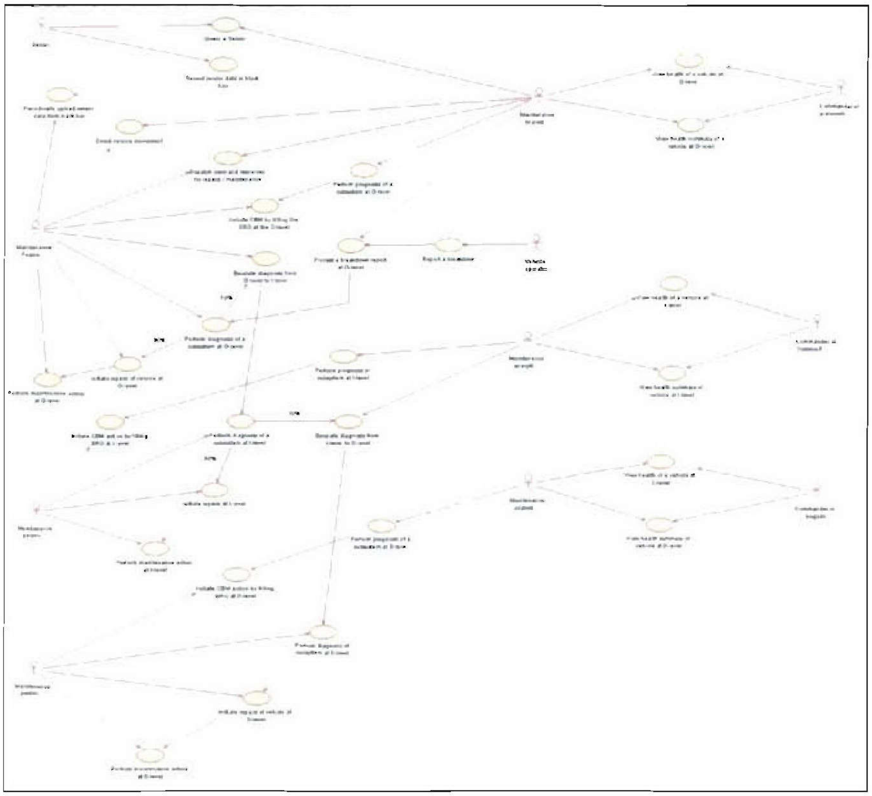


Figure 4.2 Summaries of Use Cases

We realize that the figure is difficult to read. The complete set of use cases is shown in Appendix 8.4.1 and is available for browsing in a hyperlinked format using the web browser by opening the file idge-usecase.zip (enclosed on the CD supplied with this final report). The software needed to *view* these use cases is any web browser such as Internet Explorer. Figure 4.2A shows a screen snapshot of the browsable set of use cases.

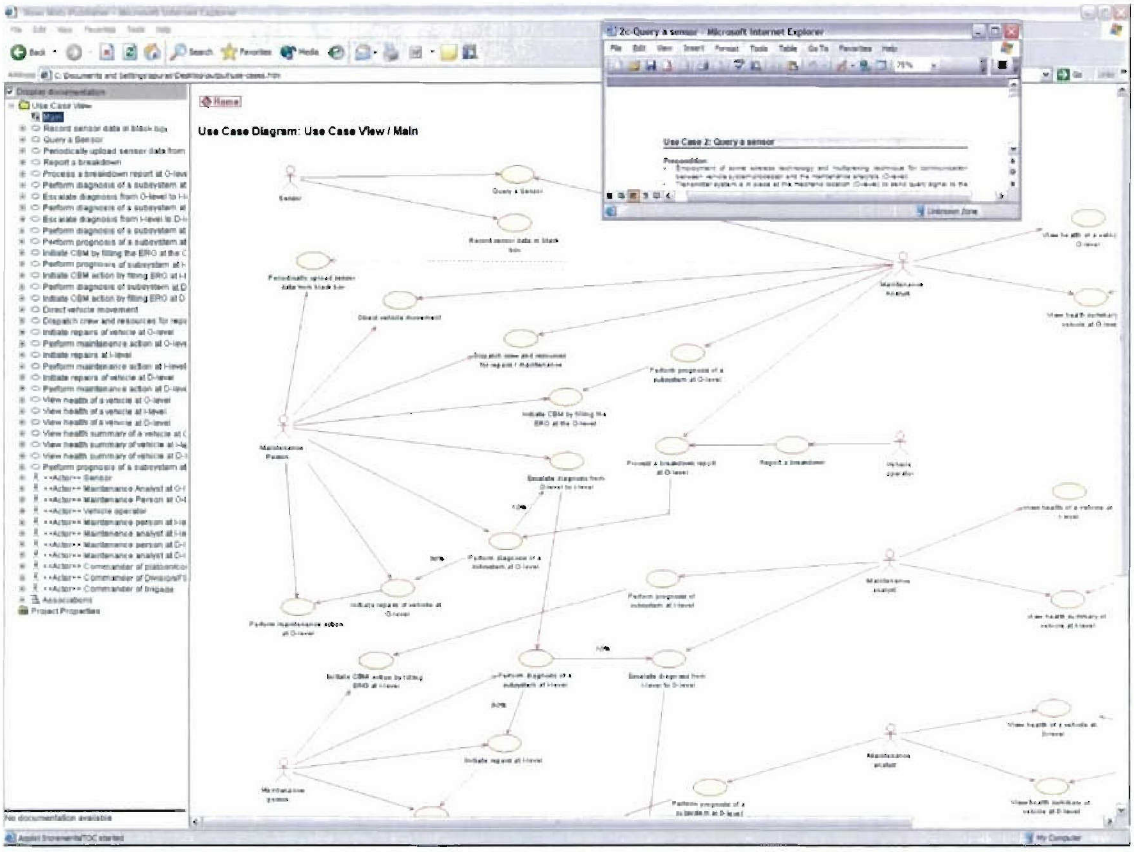


Figure 4.2A Use Cases for Browsing (enclosed on the CD)

The Figure 4.2A shows the browsable use cases. The left pane shows the list of use cases constructed. The right pane shows the use case diagram. Selecting any of the use cases will display the use case documentation for that use case. The figure above shows how selecting “Use Case 2: Query a sensor” will display the documentation in a new window.

The detail captured in the use case has improved considerably through the revisions and the information contained and can be considered valid following the visits to Aberdeen, MD, and Albany, GA. An example use case is shown in Figure 4.3.

Use Case: Periodically upload sensor data from black box in each LAV

Preamble

Preconditions:
- Existing wireless technology for communication between the field and the battalion level.
- Black box in place at the LAV to collect the data from multiple sensors in the LAV
- Transmitter system in place at the LAV to transmit the sensor signals from the black box.
- Receiver system is in place at the battalion to receive the signals and pre-process.

Actors:
- Maintenance person at battalion level
- Maintenance analyst at battalion level

Goal:
To successfully upload sensor data from each vehicle at predetermined intervals

Flow(s)

Flow of events:
1. Transmitter at the LAV uploads, at a predetermined time, sensor data collected over the last period, currently specified at 24 hours (preferred course of action when LAV is far from base).
2. Receiver at the battalion level authenticates source of data stream from field to ensure that it originates from a validated vehicle.
3. The processor at the battalion level verified/decodes the signal.
4. If successful, the battalion level analyst releases the data stream for storages and update of the database (manual check necessary to ensure integrity of the database).

Retaining human-in-the-loop

Alternative flow 1:
1. If the LAV operator notices a problem with the LAV but cannot determine the case, he may initiate an upload before the scheduled time. The remaining steps for the upload remain the same.

Retaining current practice

Alternative flow 2:
1. If an upload could not be attempted or was not successful for any reason, the black box continues to store sensor data for the most current 24 hours.
2. At the next predetermined time, the upload is again attempted. The remaining steps stay the same.

Alternative flow 3:
1. Every day, an LAV mechanic visits the front where the LAVs are deployed with a notebook (preferred course of action when LAV is not far from base – in order to present a friendly face to the crew).
2. The mechanic downloads the contents of the black box into the notebook with a hardwired connection.
3. The mechanic returns to base and uploads from the notebook to the history database.

Retaining the social and informal

Implications

Frequency and levels:
- Once a day for each LAV
- Vehicle level, Battalion level

Data implications:
Sensor stream data moved from the black box to the history database

Algorithms and Decision Support tools:

Figure 4.3 Sample Use Case

The example shows (see inset boxes) how the use cases attempt to retain use of current procedure, and maintain the social and informal practices that would provide greater acceptance of the envisioned IDGE system.

The use case also shows that a battalion level analyst may be charged with the task of ensuring that the data stream from the sensors is not spurious. This aspect of the use case demonstrates the effort during the analysis to ensure that a human actor is added to the scenarios to operationalize the notion of 'challenge and respond.' Because open system architecture will be the favored alternative for eventual implementation of an IDGE system, this step is necessary as a means of introducing security. It is indeed possible to offload this task to intelligent agents (e.g. CLC2S with intelligent agents) as the implementation and the relevant technology is more stable and mature. The human actor as described in the use case above, therefore, operationalize inserting the human in the loop that is akin to 'challenge and respond,' and will apply in both field and garrison.

It should be noted that the preconditions specified for the use cases provide considerable information about strategies that may be devised for implementing these scenarios. For example, the use case shown in Figure 4.3 indicates that it presupposes existing wireless technology in place for communication between the field and the battalion level. A modified version of the use case (e.g. the one specified in alternative flow 3 in the documentation in the figure below) may be used as an intermediate step towards attaining the scenario that requires the wireless technology in place. Issues of reliability can then be explored in the context of the precondition of existing wireless technology by comparing the existence of one or more of the alternatives such as mesh network, wireless LAN, cellular networks and satellite networks. More detailed analyses of these will require use of detailed studies about wireless technologies.

4.1.4 Creating User Interfaces as the Visible Component of IDGE

Each of the use cases created is accompanied by a detailed outline of a user interface that would provide the visible face to the use case. This technique, sometimes referred to as wireframe diagrams (Malone 2000), is useful to understand the capabilities of the proposed system. It can also provide the users a snapshot of how the system may appear, and provide future designers and implementers of the system a starting point for implementation.

Figure 4.4 below shows a snapshot of a user interface created for a *different* use case. This snapshot captures the interface that the driver of an LAV might use to report a breakdown from the field. Based on the discussions with potential users and the maintainers, the interface shows minimal data but captures the essential elements that the users indicate as key for making future decisions.

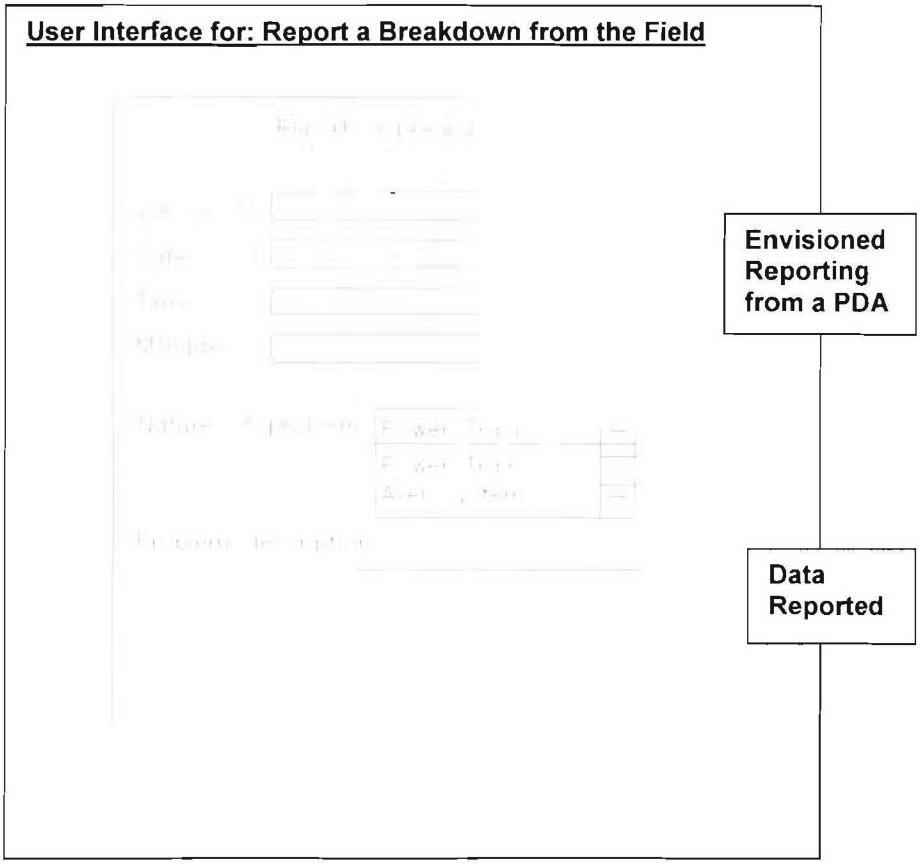


Figure 4.4 Sample User Interface

The complete set of user interfaces is interspersed with use cases shown in Appendix 8.4.1. The user interface(s) designed to capture the interface component of that use case follows each use case.

The use cases and user interfaces presented here for real-time maintenance and tracking are likely to be viable but it is difficult to tell without setting up some simulations and actual prototypes and testing. At least two further steps are necessary to ensure that a meaningful development process is implemented. The first step in this will involve simulation of the proposed system – in concert with anticipating changes to the people and procedures; and the second step will involve the actual prototyping. Efforts under way at Penn State ARL regarding viability of monitoring the health of a vehicle with sensors can be leveraged as the starting point for such prototyping. Viewed in this manner, the interfaces and on-line systems represent a possible goal, but will need to be validated and adjusted based on any system simulation and prototyping briefly described above. An initiative to fully implement the use cases and user interfaces, then, would need to follow an iterative strategy, starting with simple scenarios, and building on these to include the more demanding ones instead of attempting implementation of the entire set of scenarios in a single all-encompassing effort.

4.1.5 Understanding Data Implications

The format we have followed for documenting the use cases also provides an excellent jump-off point for understanding the aggregate data implications of the proposed use cases. This information can be captured from the use cases by examining the data implications (see Figure 4.3 above). Aggregating this information across the use cases, then, provides sufficient information about the aggregate data transferred across different levels of the infrastructure (Purao et al 1995).

The conceptualization of the *infrastructure levels* used in this report is mapped to the *organizational levels* identified in the logistics modernization efforts of the Marine Corps. Our infrastructure levels, therefore, correspond directly to the revised number of levels proposed by logistics modernization efforts that require shifting from the old five to the new three echelons of maintenance. https://mcss.quantico.usmc.mil/studysingle.asp?scn=DM980402. We have added the vehicle itself as a separate level in addition to these three because of our interest in identifying aggregate data communications across these levels. Further, to clarify whether the communication is between command and/or maintenance, we have labeled each level with a prefix of 'C' or 'M' to indicate the possible roles actors may play at each level. For example, for the O-level, we have labeled the possible roles as C1 and M1, for the I-level as C2 and M2, and for the D-level as C3 and M3. These merely act as clarifications of roles at each level and do not add any complexity to either the echelons identified by the Marine Corps nor to our analysis. For each use case, then, the data communication is specified as between these levels e.g. C1 to M1 or C1 to M2 etc. The levels are summarized below:

- The Vehicle Level (in our exemplar, the LAV) – Vehicle level
- The O-Level (connecting to the Battalion level and the vehicle level) – C1, M1
- The I-Level (connecting to the MEB and the MEF) – C2, M2
- The D-Level (connecting to the MEF and the Sea-Base) – C3, M3

As an example, consider the use case specified in Figure 4.3 above, or the user interface shown in Figure 4.4 above. Each provides the data generated and transferred across levels of the infrastructure. Figure 4.5 below shows how this information can be aggregated. The first row refers to the use case shown in Figure 4.3, and the second row refers to the user interface shown in Figure 4.3.

From	To	Frequency		Description	Type of Data	Volume of Data	
		Min	Max			Min	Max
I	II	1	1	Sensor Data transferred from Black Box to History database	Sensor Data Stream	5 MB	5 MB
I	II	1	3	Breakdown report transferred from LAV to Battalion Analyst	ID, mileage, problem code, problem description	2KB	6KB

Figure 4.5 Implications of Use Cases
(See a condensed and more efficient version in Appendix 8.4.2)

A more condensed spreadsheet showing the computation for all the use cases constructed in shown in Appendix 8.4.2. That appendix also shows the aggregate for the data transmission implications based on the data generated and used by actors carrying out these scenarios.

Template 1

Template Name:	Creating Use Cases
Purpose:	Capture envisioned practices to ensure that they are not in conflict with existing practices and can provide adequate documentation for future implementation
Process for Creating Use Cases:	1. Create an infrastructure to identify organizational levels involved (for an example, see Figure 3.3, Chapter 3, IDGE Interim Report, January 2004. 2. Interview potential users from the maintenance side as well as supply side (for the exemplar, LAV, visits were made to Aberdeen Proving Grounds, MD, and Logistics Depot, Albany, GA.) 3. Represent processes they follow using the users' terminology (for example, use terms and acronyms such as ERO) 4. Use an anchor-and-adjust strategy to retain current practices (for example, see Figure 4.2 in this report that shows how the proposed use case allowed retaining current practices) 5. Ensure that the discussions reveal informal practices, which inform the use case documentation (for example, see Figure 4.2 in this report that shows how the proposed use case allowed retaining current practices)
Expected Time Commitments:	1. Expect to spend approximately 90 minutes per use case for the first iteration 2. On subsequent iterations, expect to spend anywhere between 15 minutes to 2 hours per use case. 3. Be prepared to obtain commitments from subject matter experts (SMEs), who will participate with you in this process.
Caveats:	1. Ensure that the users are involved from the very beginning. 2. Ensure that the use cases do not delve into too much technical detail (for example, see the manner in which preconditions have been specified in Figure 4.2 in this report) 3. Be prepared to revise the use cases several times (for example, the use cases have undergone several iterations during this project. One version of the use cases can be seen in the Appendices to the IDGE Interim Report, January 2004. The most recent version is presented in Appendix 8.4 of this Final Report).

Template 2

Template Name:	Documenting Use Cases
Purpose:	Follow a standard template for documenting the use cases
Use Case Documentation:	**Use Case: Specify name that includes an active verb-subject phrase** **Preconditions:** • Specify preconditions including any technology base that is assumed **Actors:** • Specify actors engaged with performing the use case **Goal:** Specify the goal in terms of end-result to be achieved **Flow of events:** 1. Specify flow as a sequence of events 2. Specify the performer of each event i.e. write active sentences. **Alternative flow 1.** 1. If there are other possibilities in the interaction, specify these as alternative scenarios. **Frequency and levels:** • Specify in as much detail as possible, the frequency of each scenario **Data implications:** Specify, with as much detail as possible, data used and generated by the use case **Algorithms and Decision Support tools:** Identify algorithms and decision support tools and techniques, if any, necessary for each use case
Software Packages:	The de facto standard for documenting use cases is Rational Rose, which is now owned by IBM after they acquired Rational Software. This is available for 30-day evaluation at http://www.rational.com. A number of other possibilities are available, including shareware tools, which are listed at http://www.objectsbydesign.com/tools/umltools_byCompany.html. Of these, one respectable tool is Argo UML by Tigris.

Template 3

Template Name:	Creating User Interfaces (Wire-frame Diagrams)
Purpose:	Generate a user interface for the scenarios identified in the form of use cases.
Process for creating wire-frame diagrams:	1. Examine the use case statements to identify points of interaction between the users/environment and the proposed information system. 2. Create a graphical representation of the potential user interface that may support the use case statement(s). 3. Validate the graphical user interface with the potential users, when possible. 4. Identify as much of the data elements as possible and specify these using users' terminology as part of the user interface. 5. Use standard elements of the user interface such as 'drop-down box,' 'input box,' 'selection buttons,' 'radio buttons' etc.
Software Packages:	There does not appear to be a *de jure* or *de facto* standard for documenting the wire-frame diagrams. The diagrams may be created using software such as Visio (www.visio.com), since acquired by Microsoft or software such as AutoCAD (www.autocad.com). The diagrams shown in this report were constructed using AutoCAD.

Template 4

Template Name:	Using Use Cases and Wire-frame Diagrams
Purpose:	Use the use cases and wire-frame diagrams for deriving aggregate data requirements across different levels of the underlying infrastructure.
Process for deriving aggregate data requirements:	1. Identify, using the wire-frame diagrams, data elements that are transmitted (entered by the users or extracted from the database) across different levels of the infrastructure. 2. Assign sizes to the data elements. 3. Revert to the interviewees to obtain frequencies of use cases if not already identified during the process of creating use cases. 4. For use cases that are connected use probabilities to estimate frequencies e.g. one every ten vehicles cannot be diagnosed and needs to be escalated for diagnosis to the higher echelon. 5. Generate the data volume transmitted as the product of size of data elements, frequency of use case, and size of fleet.
Software Packages:	Spreadsheet management software such as Microsoft Excel is sufficient for this purpose. The spreadsheet for calculating the data transmission can be specified as the following columns: Use Case, Size of Data, Frequency, Transferred from, Transferred to If additional information is desired such as minimum and maximum frequencies and description of data, these columns may be added in the manner shown in figure 4.4.

4.2 Marine Corps Future Logistics Systems

The future Marine Corps Logistics systems will use the Operational Architecture developed by the USMC as their conceptual foundation. The five significant elements identified by the OA are:

- Request Management (RM)
- Order Management (OM)
- Capacity Management (CM)
- Production Management (PM)
- Execution (E)

These elements are common across all the nine USMC functional areas. For this study, we considered a specific functional area - maintenance. Three different maintenance processes are identified within the OA and are as follows:

- Maintenance at Supported Unit
- Maintenance at Intermediate Maintenance Activity (IMA)
- Return of MRO to Stock

The node-to-node information flows for the above three maintenance processes were generated. In addition to this, the specific data attributes that are exchanged between the nodes at each step were captured. Figure 4.5 shows the node-to-node information flow and Table 4.1 captures the data attributes exchanged between the nodes for Maintenance at Supported Unit.

Similar tables and information flows for Maintenance at the IMA and Return of MRO to stock can be found in the Appendix 8.2.

4.2.1 Information Flows Related to the Three Different Maintenance Processes

Table 4.1 and Figure 4.5 show the information flow for the Maintenance at the Supported Unit and consist of the following details:

- Speaker – Process Originating a particular communication
- Listener – The destination module, where the information is received
- Performative – The action intended to be performed for a particular communication between two nodes [Kumara et al., 2003]
- Attributes –data elements that are transferred during communication
- Medium - the required mode of communication (for example voice, text, image, form etc)

The above terms were considered from speech-act theory and the Knowledge Query Manipulation Language (KQML).

The information flow diagrams capture the sequential flow of information across the nodes for each case. The tables in combination with the information flow diagrams clearly articulate the transactions within each case.

Maintenance at the Supported Unit:

Supported unit identifies a need for a maintenance service that must be fulfilled by the logistics chain (Garrison or deployed). Maintenance Capacity Management (MCM) has capability to perform this service. Service performed at customer site. This scenario applies to both parts on hand and/or for parts not on hand.

Table 4.1: Maintenance at the Supported Unit

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Comments
1.1	Supported Unit	Supervisor	Ask	The supported unit identifies the requirement and sends it to the supervisor for validation.	Unit Identification, NSNs Quantity, Location - Text, Digital, Voice	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	The supervisor validates the identified requirement and submits it to RM	Secure signature - Encryption	Usually password encrypted
2.0	RM	OM	Inform	If unable to source internally then RM submits the request to OM on behalf of the supported unit.	Request Identification + 1.1 - Text, Digital	In addition to the request form a request ID is automatically generated by the system which would be some digital information
2.1	OM	RM	Inform			
3.1	OM	MCM	Ask	Ask the availability of resources (man power, tools and parts).		
3.2	MCM	OM	Accept	Depending on the availability of the resources MCM accepts or rejects the request.		
4.1	OM	DCM	Ask	Ask the availability of the Transportation for the pick up of products and the relevant tools to bring it to the supported unit.		
4.2	DCM	OM	Accept	Depending on the availability of the resources DCM either accepts or rejects the request.		
5.1	OM	MCM	Ask / Accept	Assess the capability of ICM to accepting the products.		
5.2	MCM	OM	Accept			

6.1	OM	DCM	Ask / Accept	Assess the capability of DCM for making the distribution resources available.		
6.2	DCM	OM	Accept			
7.0	OM	Supported Unit	Inform	Confirm with the using unit by reiterating the requirement and the terms and conditions for pick up and return.	Request ID confirmation - Text (short message) Voice	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.1	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about availability of the funds.	- Text, encryption, digital.	The total cost repair is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
8.2	FM	OM	Accept			
9.0	OM	MCM	Inform	Inform MCM to reserve and schedule the maintenance.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the maintenance.		
11.0	MCM	MPM	Inform	Inform MPM to reserve and schedule.	Order ID, NSNs - Text, Voice	The specific list of resources is sent so as to enable the IPM to reserve the resources.
12.0	MCM	DCM	Inform	Inform the relevant shipping requirements.		
13.0	MCM/ DCM	DCM/MCM	Inform / Accept	Co-ordination for pick up		
14.0	MCM	OM	Inform	Signal the delivery requirements		
15.1	MPM	ME	Inform	Assigns the resources from the execution element for this particular task.	Work order ID, Item ID - Text, Voice	Generated work order is sent to the ME so as perform the required tasks.
15.2	ME	MPM	Inform			
16.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - Text, Voice, Digital	The identified products are listed out and sent.
17 1	DPM	DE	Inform	Place a work order for the pick-up from using unit and delivery to the MCM of the products to be repaired.	Item ID, Location, Destination location - Text, Voice	The location from where to pick-up the item and product lists are sent using the e-forms.
17.2	DE	DPM	Inform			

18.0	OM	Supported Unit	Inform			
19.0	DE	Supported Unit	Inform			
20.1	DE	DPM	Inform			
20.2	DPM	DCM	Inform			
20.3	DCM	OM	Inform			
ME now conduct diagnosis and inspection, and MPM identifies and requests the additional resources and parts to effect repair if necessary.						
21.1	ME	MPM	Inform	Send the signal about the additional resource requirements.		
21.2	MPM	MCM	Inform	Send the signal about the additional resource requirements.		
22.0	MCM	OM	Inform	Notify new ATP/CTP (optional)		
23.0	OM	Supported Unit	Inform	(Optional)		
24.0	OM	FM	Inform	(Optional)		
25.0	MCM	xCM	Inform	Signals for additional resources and parts and reserves additional capacity/capability to effect repair. (Optional)		
ME performs repair and conducts quality control.						
26.1	ME	MPM	Inform	Notify repair completion.	- Text (short message)	
26.2	MPM	MCM	Inform	Signals repair completion.	- Text (short message)	
26.3	MCM	OM	Inform	Notify repair completion.	- Text (short message)	
27.0	ME	Supported Unit	Inform	(Notify) Release/delivers repaired item to using unit (physical flow)		
28.0	OM	Supported Unit	Ask	Verifies receipt and satisfactory condition with using unit.		
29.0	MPM	DCM	Inform	Arrange for return of contact teams as required.		
30.0	OM	FM	Inform	Signals receipt verification	- Text, Encryption	

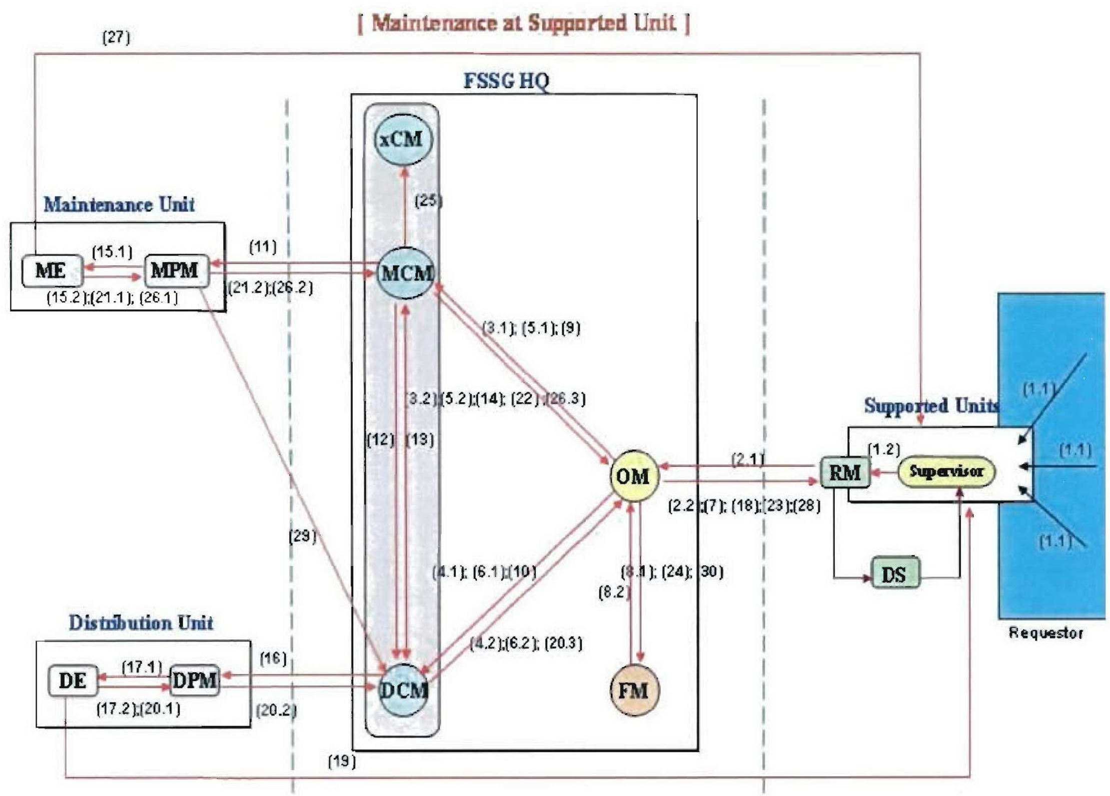


Figure 4.5 Information Flow Diagram for Maintenance at the Supported Unit

4.2.2 Maintenance Scenarios:

A critical analysis of the operational architecture shows that the key issue for maintenance is Service Discovery. When a request is sent by a supported unit, the requirements such as manpower, inventory and facilities have to be first identified. Once the resources are identified decisions have to be made on how to optimally utilize them so as to fulfill the request. This leads to seven possible events that have been identified and explained in Appendix 8.7: IR 2/3 (Executive Summary – Pages 3-7). Scenarios presented by these events were further refined through discussions with the USMC personnel.

The refined scenarios capture the following USMC organizations:

Force Service Support Group (FSSG): The FSSG performs Intermediate and limited Depot level maintenance. Limited Depot Level maintenance will be as directed and capable by the FSSG. This organization includes inventory, facilities and manpower, Order Management (OM) team, and an Expert who does resource allocation.

Combat Service Support Element Detachment (CSSE Det): This organization includes an Expert who handles resource allocation, Inventory, Manpower, facilities.

The request received by the CSSE Det is restricted only to its units that it supports, whereas an FSSG receives a copy of requests sent by all the units.

The Supported Unit (SU): identifies its requirements and submits requests to the CSSE Det and FSSG.

Scenario: 1

This scenario represents the case in which all the resources namely manpower, facilities and inventory are all available within the CSSE Det. Figure 4.6 shows a step-by-step information and physical flow until fulfillment.

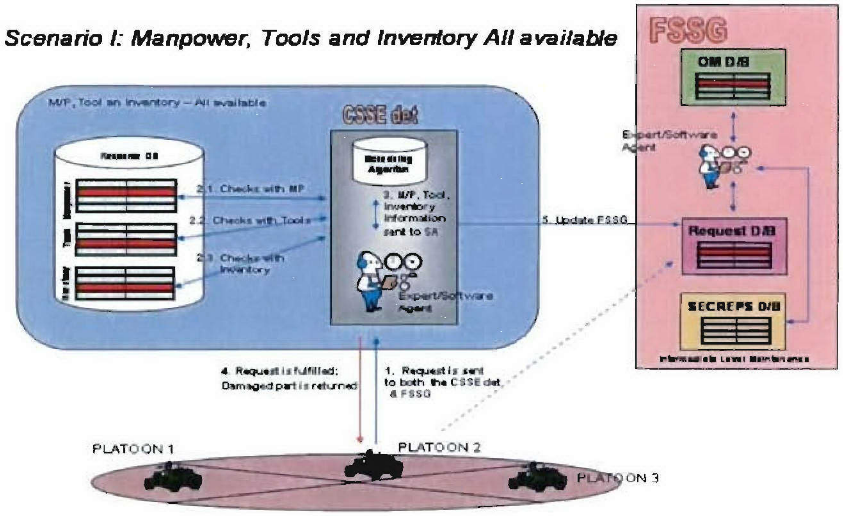


Figure 4.6 Manpower, Tools and Inventory – All Available

Scenario 2:

Figure 4.7 shows the information and physical flows when the part is not available within the CSSE Det but is available at FSSG.

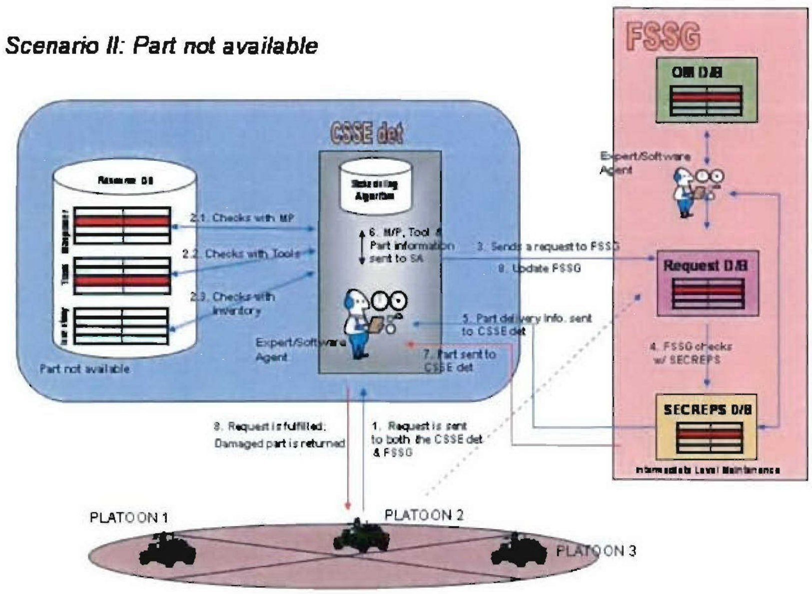


Figure 4.7 Part – Not Available

Scenario 3:

The scenario in Figure 4.8 shows the sequence of events when the part is not available at the CSSE Det and FSSG. The FSSG places an order for the part and also broadcasts the request for the part to the neighboring CSSE Det. If the part is available within a neighboring CSSE Det, it is sent for fulfilling the request.

The FSSG replenishes the part at both the CSSE Dets. If none of the CSSE Dets have the requested part, then the FSSG places an order for the requested part. Once this part is procured, it is sent to the requesting unit. This leads to Scenario 4 shown in Figure 4.9.

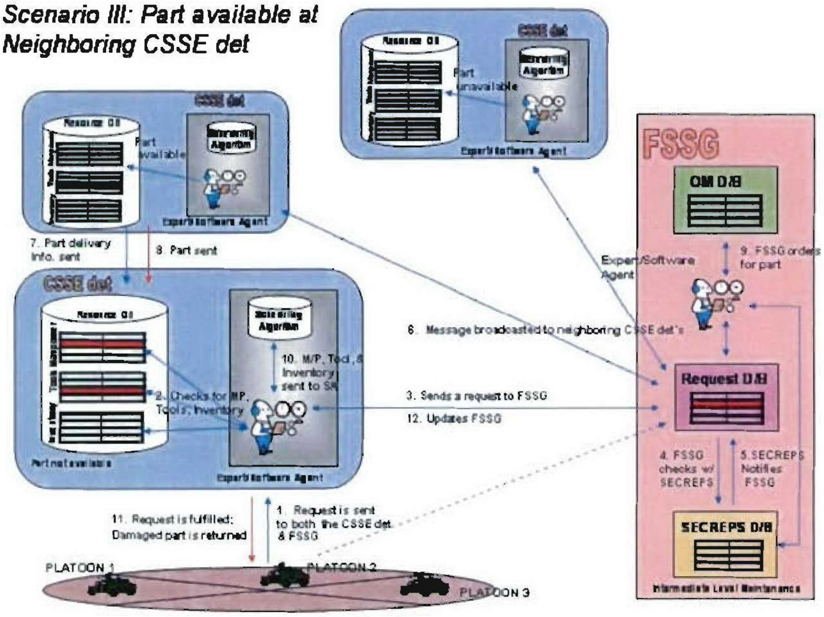


Figure 4.8 Part Available at the Neighboring CSSE Det

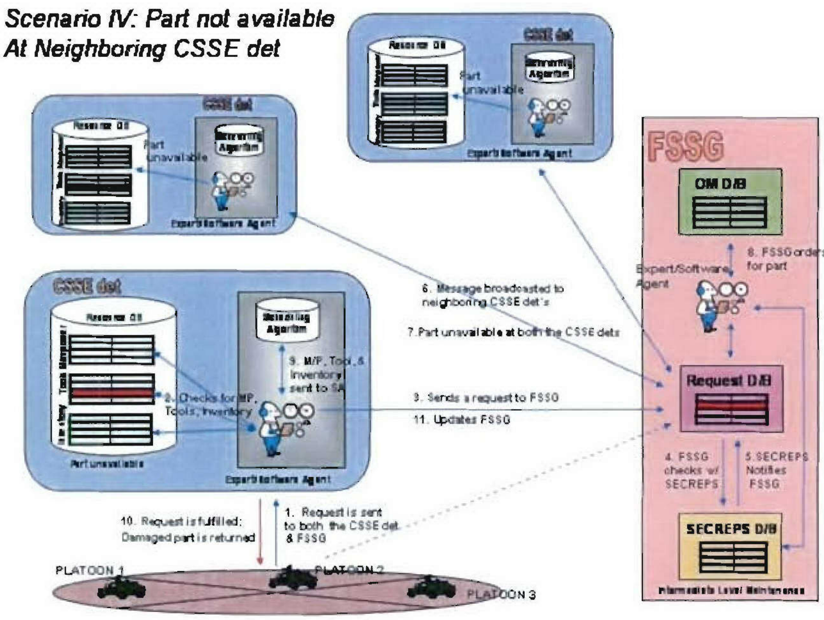


Figure 4.9 Part Not Available at the Neighboring CSSE Det

4.2.3 High Level Systems Implementation View for IDGE:

4.2.3.1 Systems Architecture View

The systems architecture view describes various subsystems considered and the connections among them. The systems architecture view may be used for many purposes, including, for example, making investment decisions concerning cost-effective ways to satisfy operational requirements, and evaluating interoperability improvements. A systems architecture view addresses specific technologies and "systems." These technologies can be existing, emerging, planned, or conceptual, depending on the purpose that the architecture effort is trying to facilitate (e.g., reflection of the "as-is" state, transition to a "to-be" state, or analysis of future investment strategies).

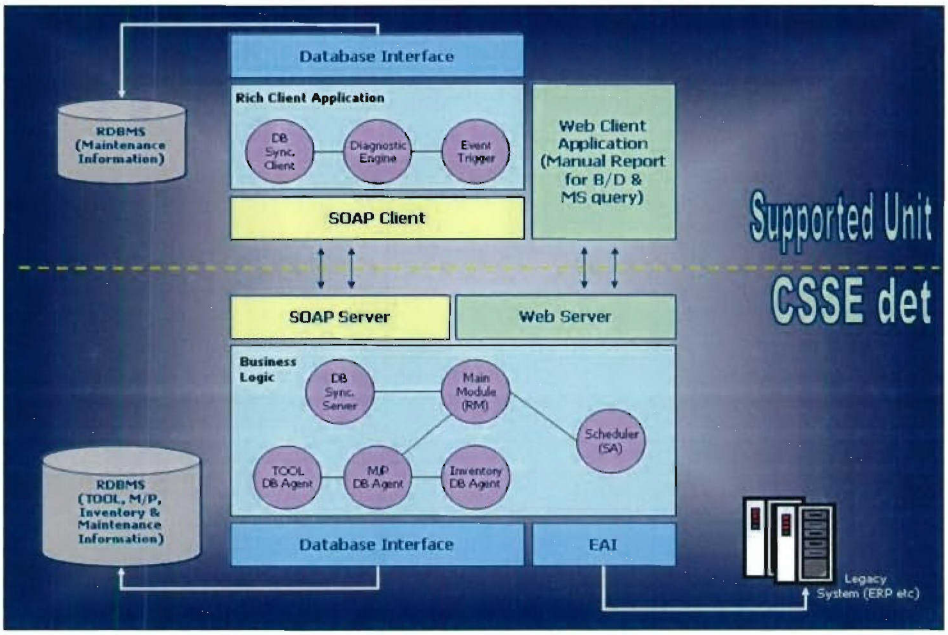


Figure 4.10 Systems view for Supported Unit and CSSE Det

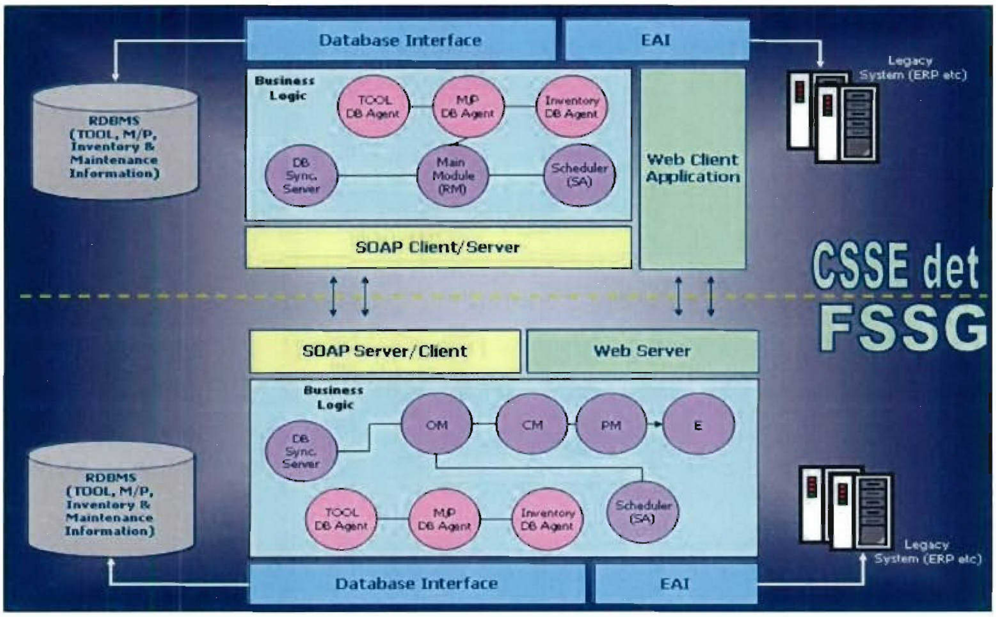


Figure 4.11 Systems View for CSSE Det and FSSG

Figures 4.10 and 4.11 show the system details and form the basis of the web based transactional proof-of-concept system that has been implemented at the Laboratory for Intelligent Systems & Quality (LISQ) at PennState. The implementation uses an n-tier architecture, which includes

- the presentation layer
- the business logic
- the data layer

The details of the architecture, user interfaces and database are described in Chapter 5.

4.3 Data Analysis and Decision Support

As a first step in developing the proof-of-concept, the detailed layout of Scenario 1 described above is used and shown in Figures 4.12 and 4.13. These figures show the participating organizations, relevant databases and interfaces that are used. The requests generated are either done by personnel or by an on-board condition based maintenance system on the LAV's.

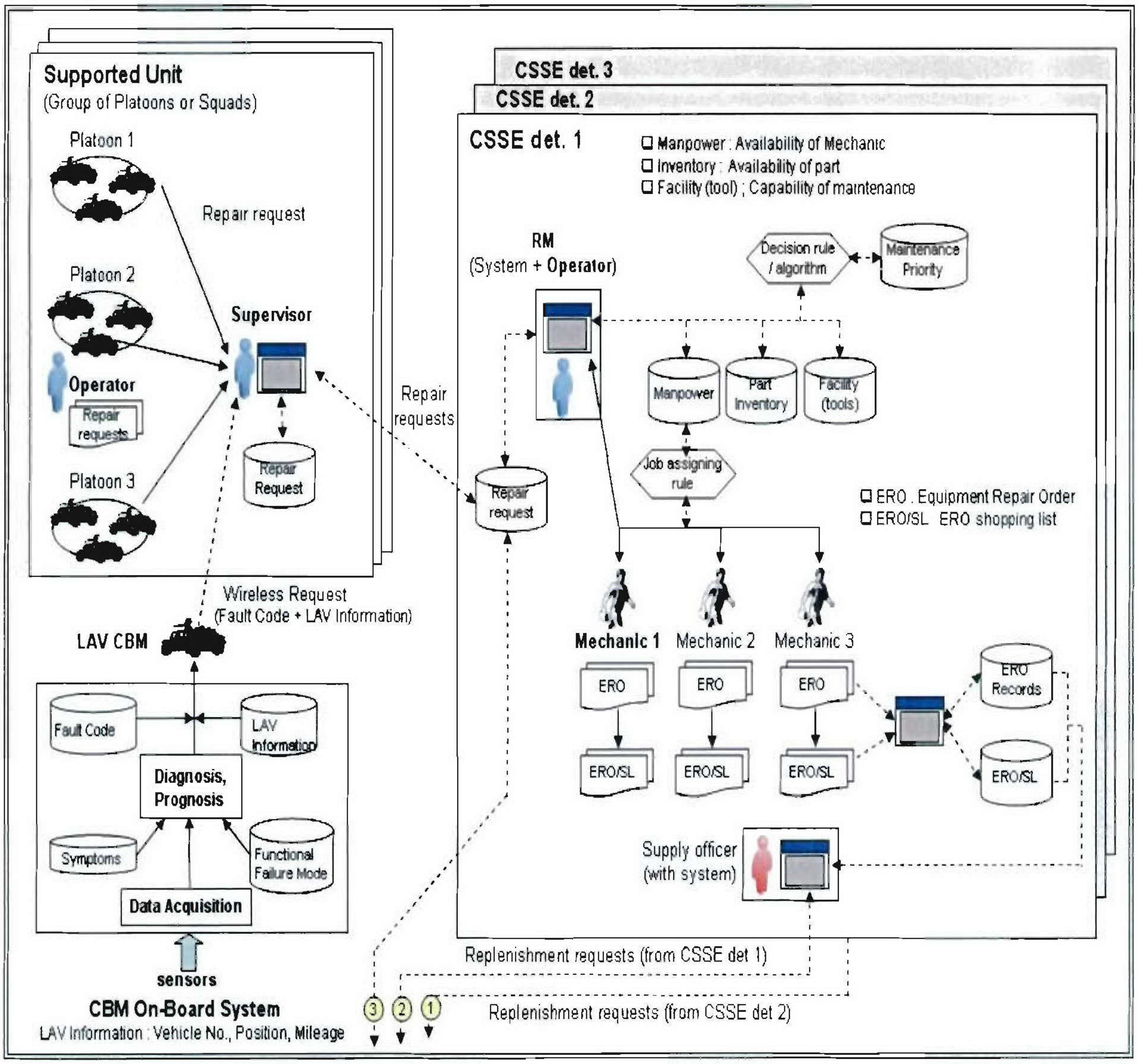


Figure 4.12 Detailed View for Scenario 1--A

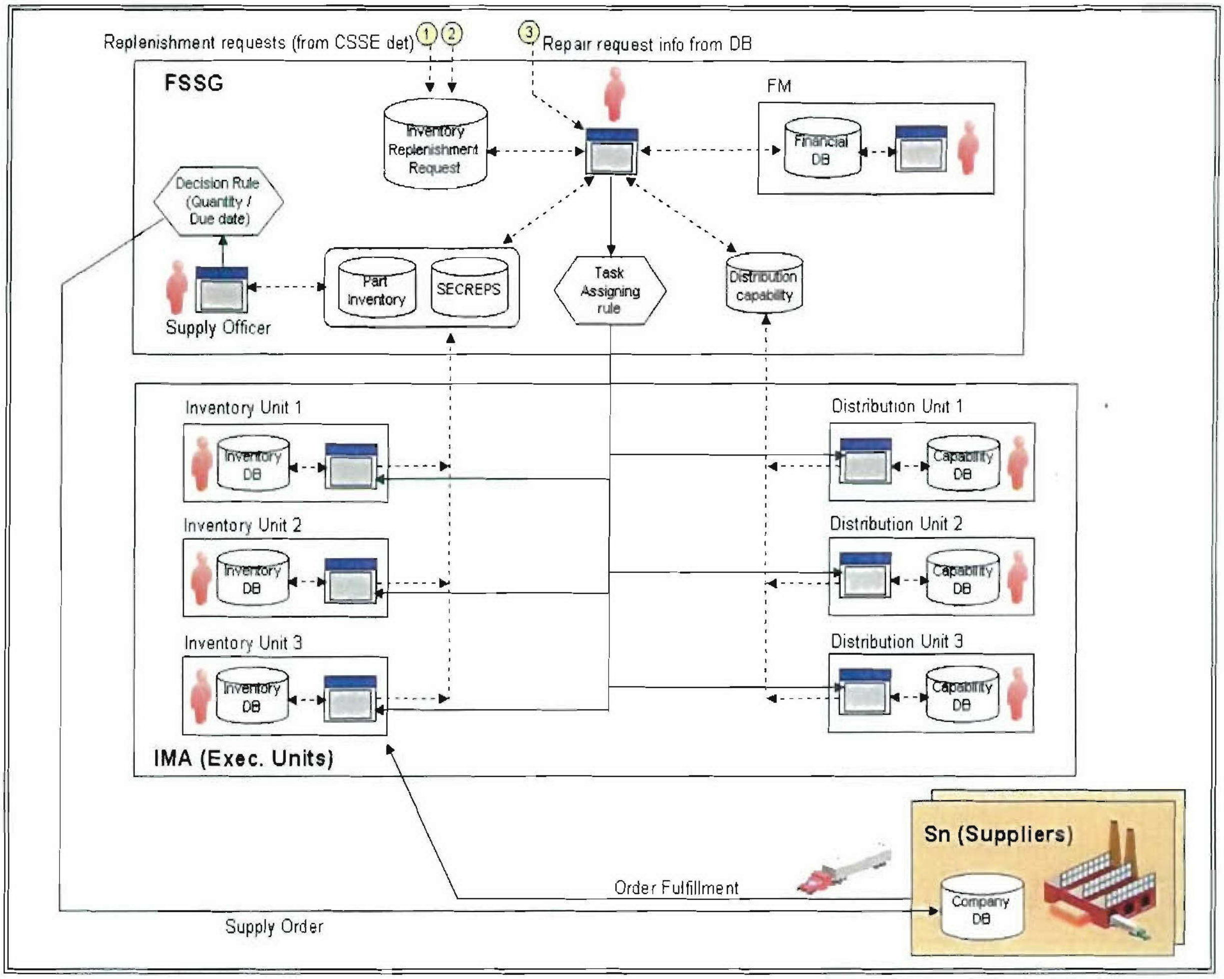


Figure 4.13 Detailed View for Scenario 1--B

Using these detailed layouts the team identified the decisions that need to be made at the different nodes. The data that needs to be collected at these nodes have also been identified and are shown in the Table 4.2 below. The attributes names within each table are self-explanatory. These tables are classified into two categories

- **IDGE Main:** The main database for the IDGE system. It contains the data relevant to all units across maintenance processes.
- **IDGE Client:** A small database used by individual personnel. It contains work order schedule and request information related to those particular personnel.

Table 4.2 shows the data attributes required for distribution (Distribution_Info).

Table 4.2: Distribution Information Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	Distribution_Info	Writer	
Table Description	This gives supply information to order new parts		

No	Field Name	PK	Type	Size	Description
1	DISTRIBUTOR_ID	PK			Distributor In-charge Id
2	WORK_ORDER_ID	PK			(Part distribution; Collection of damaged parts)
3	PRIORITY				Priority number for distribution
4	PER_ASSIGN_ID				Person assigned for work order Id
5	From_Loc_Id				From Location Information
6	To_Loc_Id				Location Information (from – to)
7	Work_Comp_Date				Work order completion or part delivery date (similar to ECD)
8	VEH_Id				Vehicles used for distribution (mode of transport)
9	POC_Id				Additional person (if required)
10	EDD_DATE				Estimated Delivery Date/Time to notify the requestor
11	RRD_DATE				Required Ready Date by the requestor
Particulars					

The Tables 4.3 and 4.4 shows the list of tables that were made for IDGE main and client database. These tables can be found in the Appendix 8.3.

Table 4.3: List of table for the IDGE_Main Database

Table Name	Table Description
Supply_info	This table shows the supply information required to order new parts
RM_Info	This table is related to the information for each request manager (RM)
Repair_Request	This table is related to the information for each repair request
Mechanic_Info	This table is related to the information for each mechanic in the CSSE Det
Part_Info	This table is related to the information for each part
Tool_Info	This table is related to the information for each maintenance tool or facility
User_Info	This table is related to the task information for each mechanic
LAV_BASIC_INFO	This table is related to the LAV Basic information
HISTORY_MAINT	This table is related to the LAV Maintenance History
Related_Part	This table shows the relationship between defect code and part code
Related_Tool	This table shows the relationship between defect code and tool code.
Defect_Code_Info	This is the table consisting defect code.

Table 4.4 List of table for the IDGE_Client Database

Table Name	Table Description
Repair_Request	This table is related to the information for each repair request.
Mechanic_Schedule	This table is related to the work order schedule for each mechanic

4.3.1 Decision Making

The different types of analysis that can be performed on this data for supporting efficient decision-making are shown in the templates (1-15) below.

The data collected at the three significant nodes, namely, Supported Unit, CSSE Det and FSSG is used for further analysis. In the following we show the templates that encapsulate several decision points.

Note: Some elements within the templates/database tables may require encryption as appropriate by the agency. Those elements will require appropriate transmission means such as using Non-classified Internet Protocol Router Network (NIPRNet) or Sensitive Internet Protocol Router Network (SIPRNet).

1. Supported Unit:

Template 1

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Prioritize Request</td></tr>
<tr><td>Purpose:</td><td colspan="2">To decide the priority of request from the supported unit</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- First In First Out (FIFO)
- Criticality criteria</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td>Current available data:</td><td>Data need to be collected:</td></tr>
<tr><td>- LAV Information
- LAV position
- Request data
- Defect code
- Failure part
- Tasks related to LAV</td><td>- Effect of failure
- Average repair time
- Availability of the Part related to failure
- Importance of LAV's tasks</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">The prioritized request orders are sent to RM for effective and swift decision-making.</td></tr>
</table>

Template 2

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Identify the Defect Code</td></tr>
<tr><td>Purpose:</td><td colspan="2">To identify the defect code of unidentified failure including the unknown specific failed part.</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- Intelligent Diagnosis / Prognosis
- Rule Based Diagnosis</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td>Current available data:</td><td>Data need to be collected:</td></tr>
<tr><td>- LAV Information
- Operation opinion
- Mechanic opinion/inspection
- Sensor data related parts
- LAV symptoms/effect
- Functional failure mode</td><td>- Relation with functions and failure parts
- Effects related sensor data</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">The identified defect code is sent to RM for correct maintenance process.</td></tr>
</table>

Template 3

Decision to be Made:	**Failure Trend and Classification**	
Purpose:	To find the failure trend and classify the failure categories	
Analysis Method:	- Reliability analysis - Failure Mode and Effect Analysis (FMEA) - Data Mining - Time series analysis	
Constraints: **Information related:**	Current available data:	Data need to be collected:
	- LAV maintenance history - Defect code - Failure part - LAV mileage - Failure date	- Failure Frequency - Relation with failed parts - Reasons of failure - Statistical Analysis - Parts categories
Next event/Node Triggered:	The results are sent to RM, Mechanic, Operator, and Suppliers for effective maintenance.	

Template 4

Decision to be Made:	**Frequency of Failures**	
Purpose:	To select the specific part for redesigning or considering improvements	
Analysis Method:	- Reliability analysis - FMEA - Durability test - Statistical Analysis	
Constraints: **Information related:**	Current available data:	Data need to be collected:
	- LAV information - Part information - BOM - Repair history and reasons - Defect code - Failure mileage	- Frequency of failure - Relation between part and function - Part durability test result
Next event/Node Triggered:	The frequently failed parts list is sent to RM, Mechanic, and Suppliers for improving the function and durability of the parts.	

2. CSSE Det.:

Template 5

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Prioritize Maintenance Requests Arriving at the RM within the CSSE</td></tr>
<tr><td>Purpose:</td><td colspan="2">Requests are received from different supported units and depending upon their importance has to be prioritized before sending for fulfillment.</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- Score based ranking: linear weighted sum of priority related values
- Deadline analyses with break down date and request date.
- Analysis of mission and risk values
- First in first out (FIFO)</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td><u>Current available data:</u></td><td><u>Data need to be collected:</u></td></tr>
<tr><td>- Supported unit's information (Owner ID, Location, etc.)
- Defect code
- Priority code
- Break down date
- Request date</td><td>- Expected required parts from defect code
- Criticality of the required parts (Quad model)
- Expected required tools and facilities from defect code</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">Once the prioritization is done, the requests are sent to resource (manpower, parts, and tools or facilities) allocation module and depending on the priority they are taken up for fulfillment.</td></tr>
</table>

Template 6

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Manpower (Mechanic) Scheduling within the CSSE</td></tr>
<tr><td>Purpose:</td><td colspan="2">Each prioritized maintenance request has to be assigned to the proper mechanic(s) for the task fulfillment.</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- Job (maintenance request) assignment model with constraints
- Resource (manpower) allocation model with constraints</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td><u>Current available data:</u></td><td><u>Data need to be collected:</u></td></tr>
<tr><td>- Defect code
- Request date
- Labor hours
- Job status
- Supported unit's information</td><td>- Priority level of the request
- Maintenance specialty code of the mechanic
- Number of assigned tasks for the mechanic
- Expected required maintenance specialty from defect code
- Expected available date for the mechanic
- Expected labor hours from defect code</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">Once the manpower is assigned to the request, the request with information is sent to the database or system that assigned mechanic(s) can access.</td></tr>
</table>

Template 7

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Required Parts Assignment Rule within the CSSE</td></tr>
<tr><td>Purpose:</td><td colspan="2">If required for the maintenance, parts (i.e. SECREP, consumable part, or end item) in the inventory have to be assigned to each prioritized maintenance request for the task fulfillment.</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- Resource (part) allocation model with constraints</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td><u>Current available data:</u></td><td><u>Data need to be collected:</u></td></tr>
<tr><td>- Part information (NSN, Cost, etc)
- Available quantity
- Defect code
- Maintenance request date</td><td>- Priority level of the request
- Criticality of the required parts (Quad model)
- Expected required parts from defect code
- Diagnosis result from the mechanic</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">Once the part is assigned to the maintenance request, the request with information is sent to the database or system that part inventory manager can access.</td></tr>
</table>

Template 8

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Required Tools or Facilities Assignment Rule within the CSSE</td></tr>
<tr><td>Purpose:</td><td colspan="2">For proper maintenance activities, required tools or facilities in the inventory have to be assigned to each prioritized maintenance request for the task fulfillment.</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- Resource (tools or facilities) allocation model with constraints</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td><u>Current available data:</u></td><td><u>Data need to be collected:</u></td></tr>
<tr><td>- Tool (facilities) information
- Available quantity
- Defect code
- Maintenance request date</td><td>- Priority level of the request
- Required tools and facilities from defect code
- Required available date for the tool or facility
- Number of requests that are waiting to use the tool or facility</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">Once the tools or facilities are assigned to the maintenance request, the request with information is sent to the database or system that tool or facility inventory manager can access.</td></tr>
</table>

Template 9

Decision to be Made:	**Forecasting Maintenance Requests Arriving at the RM within the CSSE**	
Purpose:	Based on the history of maintenance requests received from different supported units, trends can be analyzed. Furthermore, it will be possible to predict or forecast maintenance request arrivals.	
Analysis Method:	- Time series model - Data mining: pattern analysis, classification	
Constraints: Information related:	Current available data:	Data need to be collected:
	- Supported unit's information - Defect code - Priority code - Maintenance request date - Break down date	- Priority level of the request - MTBF - Average required time for the maintenance
Next event/Node Triggered:	Once the maintenance request forecasting or trend analysis is done, the result can be sent to supervisors and operators in supported units, resource (manpower, parts, and tools) managers, and OM (order manager) and FM (financial manager) in FSSG for efficient planning.	

Template 10

Decision to be Made:	**Manpower (Mechanic) Planning within the CSSE**	
Purpose:	Based on the history of maintenance requests received from the different supported units and analysis of history of manpower scheduling, it is possible to perform better manpower planning and to forecast manpower requirement.	
Analysis Method:	- Time series model - Dynamic programming model	
Constraints: Information related:	Current available data:	Data need to be collected:
	- Supported unit's information - Defect code - Priority code - Maintenance request date	- Priority level of the request - MTBF - Expected labor hours for the maintenance - Average required maintenance specialty code of the mechanic - Average number of assigned tasks for the mechanic
Next event/Node Triggered:	Once the manpower (mechanic) planning analysis is done, the result can be sent to RM or manpower scheduling module, and FM (financial manager) in FSSG for increasing the performance of maintenance request fulfillment.	

Template 11

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Part Inventory Planning within the CSSE</td></tr>
<tr><td>Purpose:</td><td colspan="2">Based on the history of maintenance requests received from the different supported units and analysis of history of part assignment, it is possible to perform better part inventory planning and to forecast part requirement.</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- EOQ (Economic Order Quantity) model
- Time series model
- Dynamic programming model</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td><u>Current available data:</u></td><td><u>Data need to be collected:</u></td></tr>
<tr><td>- Part information (NSN, Cost)
- Available quantity
- Defect code
- Maintenance request date</td><td>- Priority level of the request
- MTBF
- Criticality of the required parts (Quad model)
- Expected required parts from defect code
- Diagnosis result from the mechanic
- Average number of parts used in specific time period</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">Once the part inventory planning analysis is done, the result can be sent to RM, part inventory manager, and OM (order manager) and FM (financial manager) in FSSG for increasing the performance of maintenance request fulfillment.</td></tr>
</table>

3. FSSG:

Template 12

Decision to be Made:	Inventory Planning within the FSSG	
Purpose:	Based on the history of maintenance requests received from the different supported units and the current conditions of the LAV within its supervision the FSSG can predict the demand for various parts for the next specified time window	
Analysis Method:	- EOQ (Economic Order Quantity) model - Time series model - Dynamic programming model - Bayesian Statistical Model	
Constraints: Information related:	Current available data:	Data need to be collected:
	- Part information (NSN, Cost) - Available quantity - Defect code - Maintenance request date	- Priority level of the request - MTBF - Criticality of the required parts (Quad model) - Expected required parts from defect code - Diagnosis result from the mechanic - Average number of part used in specific time period -Distribution showing the failures with time
Next event/Node Triggered:	Once the part inventory planning analysis is done, the result can be sent to OM, Inventory Capacity manager, and FM (financial manager) in FSSG for increasing the performance of maintenance request fulfillment.	

Template 13

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Budget Estimation</td></tr>
<tr><td>Purpose:</td><td colspan="2">Analyzing the historical data to identify the mean time between failures for different NSN will allow the FM to estimate the number of expected failures within a subsystem. Based on the previous repair costs incurred and the cost of parts that will be used the approximate budget that will be required can be estimated</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- Bayesian Statistical models
- Time series model
- Dynamic programming model</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td><u>Current available data:</u></td><td><u>Data need to be collected:</u></td></tr>
<tr><td>- Repair costs
- Defect code
- Maintenance request date</td><td>- Priority level of the request
- MTBF
- Miles of operations of different LAVs
- Average time for repair of each defect code
- Average number of parts used in specific time period</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">Once the budget estimation analysis is done, the results can be sent to FM, and personnel in the strategic level to estimate overall budget required towards maintenance for the next planning horizon.</td></tr>
</table>

Template 14

Decision to be Made:	**Training Decisions for Mechanics**	
Purpose:	Using the frequency of failures within a subsystem and the labor hours spent to repair each of these subsystems, the high risk maintenance repairs can be identified. These inferences can determine the specific maintenance areas where training and facilities can be improved	
Analysis Method:	- Statistical models - Meta Heuristics	
Constraints: Information related:	Current available data:	Data need to be collected:
	- Part information (NSN, Cost) - Labor Hours - Defect code - Maintenance request date	- Priority level of the request - MTBF - Expertise of the mechanic performing the repair on each subsystem - Average time for repair for given subsystem - Number of times there is misdiagnosis by the mechanic/ operator. - Delays due to unavailability of facilities
Next event/Node Triggered:	Once this analysis is done, the strategic level personnel to determine the bottleneck maintenance operations can use the results. Depending on the expertise/experience of the mechanics currently within the organization, training can be planned and facilities can be improved	

Template 15

<table>
<tr><td>Decision to be Made:</td><td colspan="2">Prioritizing the Requests</td></tr>
<tr><td>Purpose:</td><td colspan="2">Based on: 1. The Field activity designator, 2. The urgency of need indicated by the requesting unit and 3. The next move for the unit, the operational level commanders can prioritize the arriving requests.</td></tr>
<tr><td>Analysis Method:</td><td colspan="2">- Ranking based on scores
- Analysis of mission value
- First in first Out
- Expected date of delivery</td></tr>
<tr><td rowspan="2">Constraints:
Information related:</td><td><u>Current available data:</u></td><td><u>Data need to be collected:</u></td></tr>
<tr><td>- Supported unit's information (Owner ID, Location, etc.)
- Defect code
- Priority code
- Break down date
- Request date</td><td>- Effect of failure
- Average repair time
- Availability of Parts
- Importance of units tasks
- Availability of manpower</td></tr>
<tr><td>Next event/Node Triggered:</td><td colspan="2">Once the requests are prioritized they can be executed for fulfillment in the order of importance. This will ensure fair allocation of resources by speedy execution of high priority requests.</td></tr>
</table>

5 Universal Data Support Requirements

Task 4: Establish Universal Data Support Requirements.

- Task 4.1: Identify data support functions for multi-sensor prognostics integration for the selected end item.
- Task 4.2: Recommend candidate web based technologies to facilitate multi-sensor prognostic integration for the selected end item.

This chapter contains the initial templates developed by the PSU team for multi sensor diagnostics/prognostics, and the architecture for the IDGE web based maintenance system.

5.1 Establish Universal Data Support Requirements.

5.1.1 Initial Templates for Implementing Multisensor Diagnostics

A goal of this study was to establish templates that can apply to any piece of ground equipment with a standard means to deploy diagnostics/prognostics, track, evaluate, anticipate failure, activate the supply/maintenance system to request, order and repair the item based upon varying time constraint scenarios. In this section, we present initial templates that show how to implement multi-sensor diagnostics for a chosen type of equipment. These templates use the LAV as the chosen example. However, the templates can be used for other types of equipment.

Template 1

Decision to be Made:	**Identification of Top Faults/Conditions to be Monitored**
Purpose:	To determine the top candidates of faults and/or conditions for monitoring the condition of the chosen equipment
Analysis Method:	• Encapsulate functions to be performed by the equipment • Analyze MIMMS data • Interviews with users, maintainers, and decision-makers
Information Needed / Constraints:	• Vehicle identity information • Vehicle location information • Vehicle task / mission information • Typical events in vehicle life cycle • Criticality of failure, i.e., effect / cost of failure • Maintenance cost / support required • Frequencies at which faults / conditions have been observed • Component reliability / expected life information
Next event/Node Triggered:	Sensor Selection and Placement.

Template 2

Decision to be Made:	**Sensor Selection and Placement**
Purpose:	To decide the sensor suite and the optimum placement of sensors for monitoring faults/conditions for chosen equipment
Analysis Method:	• Failure Modes, Effects, and Criticality Analysis (FMECA) • Physics-based modeling of system hierarchy • Identify cause-effect relationship for each fault / condition
Information Needed / Constraints:	• Vehicle system, subsystem, component, material hierarchy • Differences among vehicle variants • Estimated loads to be experienced by the vehicle • Environmental influences on vehicle operation • Criticality of failure, i.e., effect / cost of failure • Availability of sensors and their quality /reliability • Assess limitations on power, number, and operational mode of sensors • Constraints on ability to place sensors
Next event/Node Triggered:	Selection of Data Analysis Methods for processing Sensor Data.

Template 3

Decision to be Made:	**Selection of Data Analysis Methods for Processing Sensor Data**
Purpose:	To select the data analysis methods for analyzing sensor data for monitoring faults/conditions for chosen equipment
Analysis Method:	• FMECA • Mapping of cause-effect relationship into observables • Examine the correlation between different causes and effects
Information Needed / Constraints:	• Vehicle operational, maintenance, historical data • Sensor types, number, and locations • Sensor performance information • Physics-based model of system hierarchy • Cause-effect relationship for each fault / condition
Next event/Node Triggered:	Architecture and Algorithm Selection for Processing Sensor Data.

Template 4

Decision to be Made:	**Architecture and Algorithm Selection for Processing Sensor Data**
Purpose:	To select the architecture and the algorithms for processing sensor data
Analysis Method:	• Centralized, distributed, or hybrid processing comparison • Analytical modeling methods • Statistical signal processing techniques
Information Needed / Constraints:	• Hierarchical description of system • Bandwidth and throughput of transmission mechanisms • Formats and/or protocols pertaining to existing network components • Availability space, wiring, and power
Next event/Node Triggered:	Selection of Data Collection and Data Processing Hardware and Software.

Template 5

Decision to be Made:	**Selection of Data Collection and Data Processing Hardware and Software**
Purpose:	To select the data collection hardware and data processing hardware and software
Analysis Method:	• Mapping of techniques to appropriate hardware • Speed, power, and cost comparison • Information needed for various algorithms • Features required for fault classification
Information Needed / Constraints:	• Bandwidth and throughput of transmission mechanisms • Formats and/or protocols pertaining to existing network components • Availability and supportability of hardware and software options • Cost of implementation • Availability space, wiring, and power • Environmental requirements (e.g., vibration, corrosive fumes, high temperature, etc.)
Next event/Node Triggered:	Determination of Data Collection Rates and Formats.

Template 6

Decision to be Made:	Determination of Data Collection Rates and Formats
Purpose:	To estimate the rates at which data will be collected from various sensors; to define the data formats for archiving and communicating the data collected and analyzed
Analysis Method:	• Physical analyses of failure propagation • Time intervals required for supporting maintenance and logistical response • Complexity analysis of algorithms • Information requirement of algorithms
Information Needed / Constraints:	• Bandwidth and throughput of transmission mechanisms • Formats and/or protocols pertaining to existing network components • Computation speed and throughput of selected hardware and software • Time intervals required for supporting maintenance and logistical response
Next event/Node Triggered:	Software Implementation and Test and Validation.

These are followed by software implementation of the algorithms and testing and validation of the implementation.

5.2 Proposed System Architecture: n-tier Web-based Architecture

5.2.1 High Level Architecture

The futuristic IDGE maintenance information system's requirements are:

- Information brokerage tools capable of providing instantaneous, automated access to all information required as inputs to decisions or analysis questions.
- Decision making algorithm routines (i.e., quad model and data mining etc.).
- Analysis and sensor signal processing tools to process current or historical, real or simulated data.
- Collaborative planning tools that enable decision-makers in separate hierarchies or organizations (CSSE Dets, FSSG etc) to communicate efficiently, share data, and jointly edit files and run programs to arrive at coordinated decisions visible to all processes involved.

- Historical data (e.g., Maintenance request, manpower requirement, part requirement, and so on) – data storage can be resident either in a centralized or distributed fashion and can be accessed via information brokerage tools.

- Security software, hardware, and protocols to ensure proper access and restrict improper access to all system hardware, software, and information.

- User-friendly graphical user interfaces (GUIs) to control all software, information retrieval, reporting, and collaboration.

- On-line Help, Training, and Process and Software Documentation are required to maximize the productivity of system user and the quality of all decisions.

In this context, the term "architecture" refers to the software and hardware system configuration for accomplishing the objective of maintenance information system. This is a high-level architecture; by definition, the individual software components must be expanded to make each of them fully functional. Our recommendation will serve as a blueprint for the Marine Corps implementation of a futuristic, fully functional, flexible and integrated ground equipment system.

The proposed architecture will have the following characteristics:

- Reduced query retrieval time from databases
- Timeliness of information at decision-making points
- Ease of updating databases
- Ease of adding new applications
- Ease of updating existing applications
- Ease of reconfiguring to support organizational changes within the USMC
- Cost savings in terms of money, time, and manpower
- System robustness (eliminate problems caused by data inconsistencies)
- Information visualization
- Decision making, analyzing, and forecasting capabilities
- Platform independence

5.2.2 n-tier Web-based Architecture

We recommend an *n*-tiered architecture that allows for scalability, reconfigurability, and flexibility. Our proposed architecture is a viable solution to realize the knowledge management architecture envisioned by the Marine Corps. Furthermore, large commercial enterprise systems such as System Application Product (SAP) R/3, PeopleSoft, and Oracle employ such *n*-tiered architectures. Figure 5.1 shows the highest level of abstraction of the proposed architecture. Although this diagram specifically shows three tiers, the architecture can have *n* tiers, with *n* determined through the sub-process decomposition.

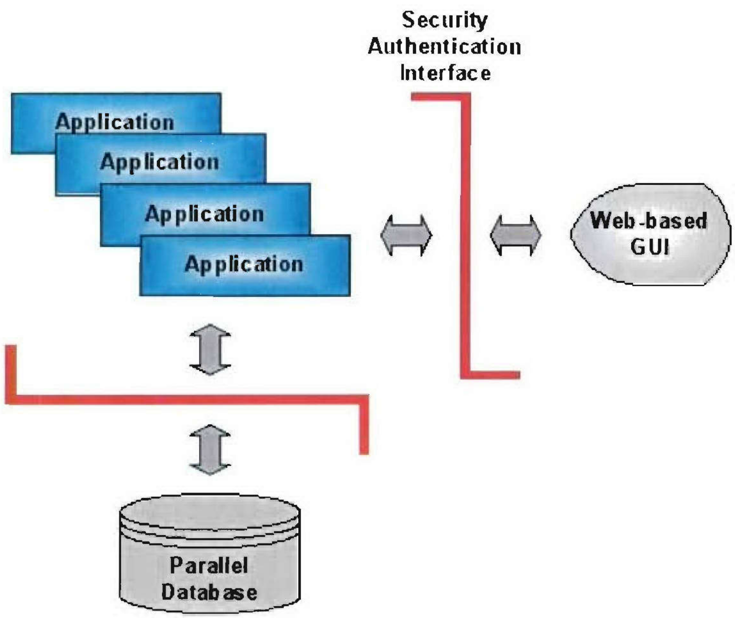


Figure 5.1 System Architecture

The various components of the architecture are:

- Application
- Database
- Graphical User Interface (GUI)
- Hardware
- Security
- Analysis
- Help/Documentation/Training

5.2.2.1 Application

Application refers to the computational model (software + algorithms) for each of the processes and sub-processes identified. The software components (applications) each will have inter-application communication, database interface, and a graphical user interface. This definition of application is consistent with the terminology used in database literature. Our configuration of the architecture will allow:

- Interactivity
- Plug-and-play functionality
- Functional independence
- Platform independence

5.2.2.2 Database

To address the need for distributed control of information and to ensure adaptability to future reorganizations, we separated the databases, applications, and graphical user interfaces (GUIs) in our architecture. This provides flexibility, adaptability, and scalability. A generic interface for each data source will be used by all applications that require access to the data source. Like other applications, these interfaces will support varying levels of access and other security measures. Information Brokerage tools will be used to facilitate access to the wealth of data that is used at present due to a lack of awareness by the user community. Although several database technologies (e.g., Informix, Microsoft, and SyBase) exist, Oracle offers a number of advantages. A robust database, it is one of the few systems that can fully benefit from parallelism and server clusters.

5.2.2.3 Graphical User Interface (GUI)

The GUI is the interface between the user and the applications. GUIs can customize information content and presentation to the needs and abilities of the user. The proposed architecture will have the web browser GUIs.

It is envisioned as a browser-based interface that will enhance the customization required and will help in visualization of the user elements required. The GUI's HTML compatibility will enable users to open it within any common web browser such as Netscape or Internet Explorer. This will allow software upgrades to be administered efficiently because user software does need to change. The following approach was developed.

5.2.2.4 Hardware

The required computer hardware can be specified for each application (or group of applications), based on algorithmic complexities, user loads, and other variables. This naturally leads to a cluster approach to building the network topology. Figure 5.2 shows the proposed candidate hardware architecture. Recognizing the rapidly changing nature of the hardware market, we specified conceptual hardware, rather than exact model numbers. The recommended cluster is a group of symmetric multi processor (SMP) servers over a Gigabit network using the Virtual Interface Architecture (VIA). VIA is a cost-effective scaling of computing hardware. We further recommend that each application be provided with an SMP server (4-way or 8-way) sized to fit the expected computing load. The Oracle database can be a limiting factor in responsiveness of the overall architecture; therefore, we recommend that the database be partitioned on a cluster to speed up query processing through parallelization and distribution of computing. Furthermore, Oracle is one of few software programs that can effectively exploit parallel query processing on SMP clusters. This would be the ideal configuration.

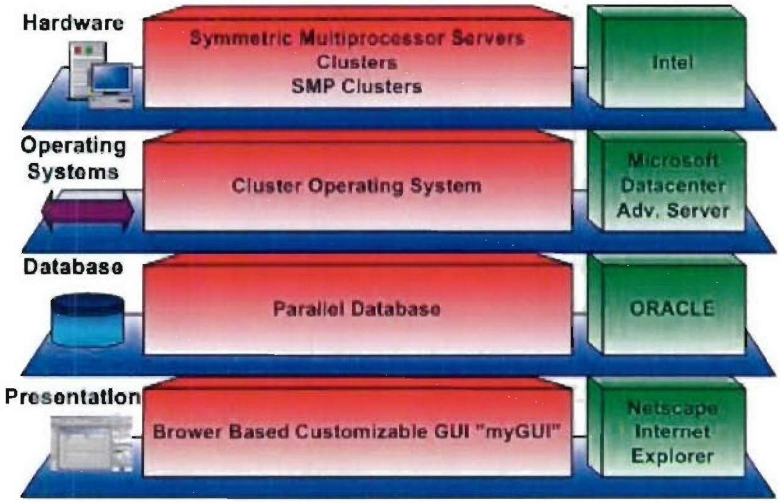


Figure 5.2 Candidate Hardware Architecture

5.2.2.5 Security

The three components of the system architecture are software, hardware, and people. Securing the computer system involves ensuring the security of the software and hardware, as well as the trustworthiness of the people who use it. For the proposed architecture, key security aspects can be broken down as follows:

- Application-Level and User-Level Security
- Internet and Intranet Security
- Access Control

5.2.2.6 Analysis

Considerable data will be generated through various decision-makings and forecasting. Analysis will depend on the context and what is needed in the context. Several visualization algorithms for displaying trends and patterns can be incorporated into the architecture. More advanced data mining algorithms like sequential pattern analyzer, neural networks, and adaptive clustering can easily be incorporated into the architecture. Analysis software will be sub-applications in the system.

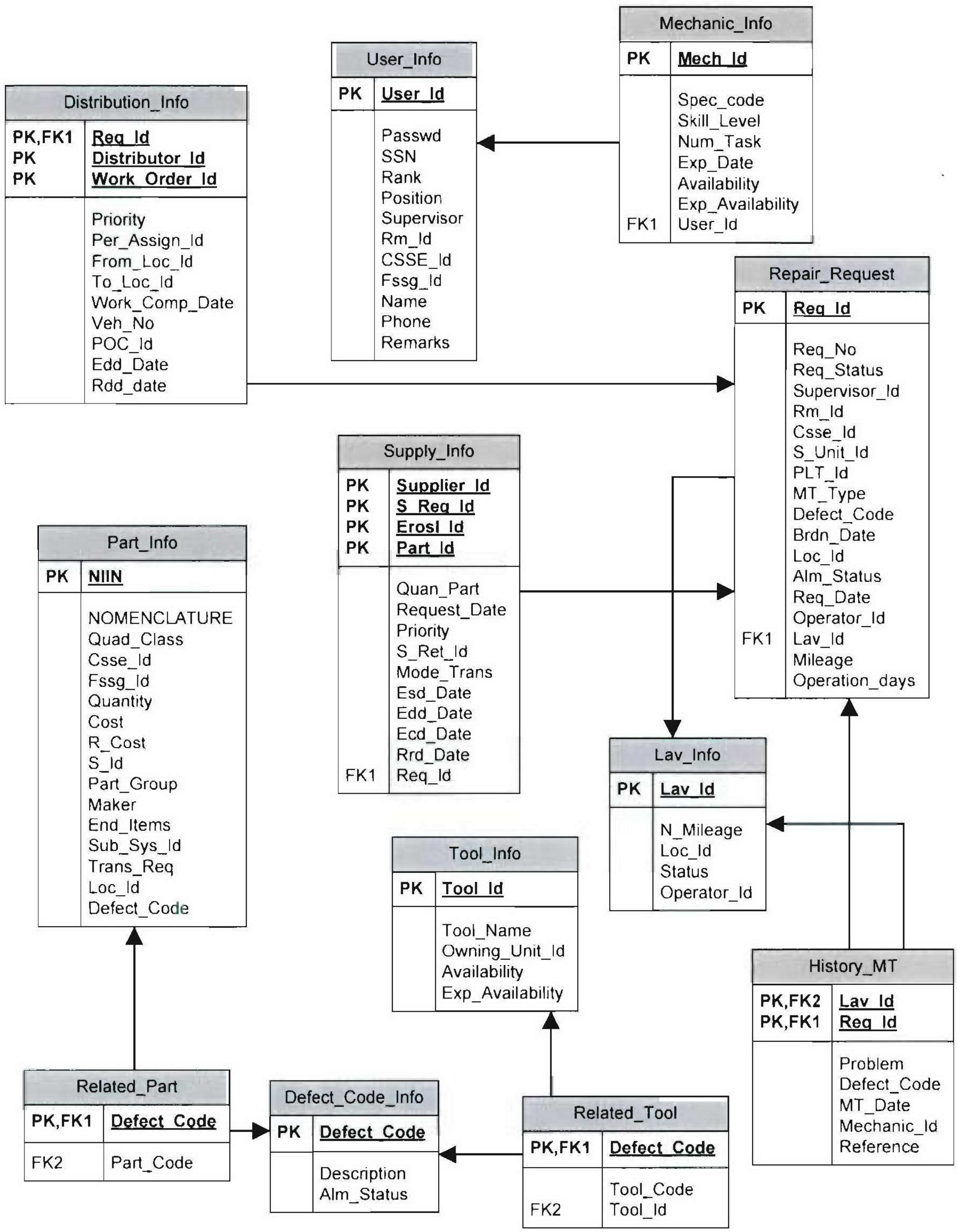
5.2.2.7 Help/Documentation/Training

These help sessions will be available on request or on trigger by events (monitoring of user activities). Appropriate computer-assisted instruction (CAI) based GUIs will be suggested and the architecture will incorporate on-line help.

5.3 Database Model Diagram

This diagram shows the connectivity between elements of the tables listed in the Table 5.1.

Table 5.1 Database Model Diagram



5.4 Proof-of-Concept Maintenance Information System – A Conceptual View

One of the most important aspects of our design is the ease of use of the proposed computing system for the maintenance request fulfillment. This proposed architecture has GUI, which enables the user (RM or other users) to query the required information from the database, to perform related tasks for the maintenance fulfillment, and to analyze the data. This information is then stored in the database for future retrieval processes /analysis.

In this section we (1) present how a user can navigate through the proposed maintenance information system and (2) illustrate the major features of our proposed architecture.

Our hypothetical user, RM, performs the tasks in this animation. In the real system, some of the tasks will be performed by other users and/or software agents representing the other users.

The GUI's shown in Figure 5.3 are relevant to the Request Management. The team is currently working to generate similar GUI's for Supervisor at the tactical level and FSSG.

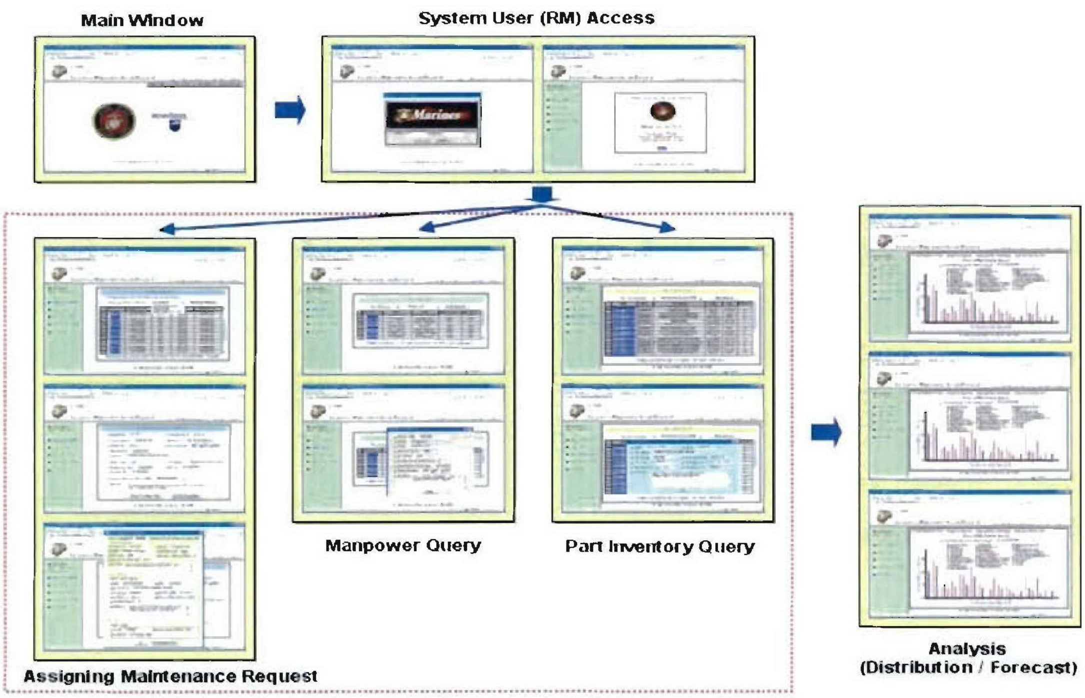


Figure 5.3 Process Flow Overview - Web Based System

Main Window: Figure 5.4 shows the Main Window for the Proof-of-concept web-based system.

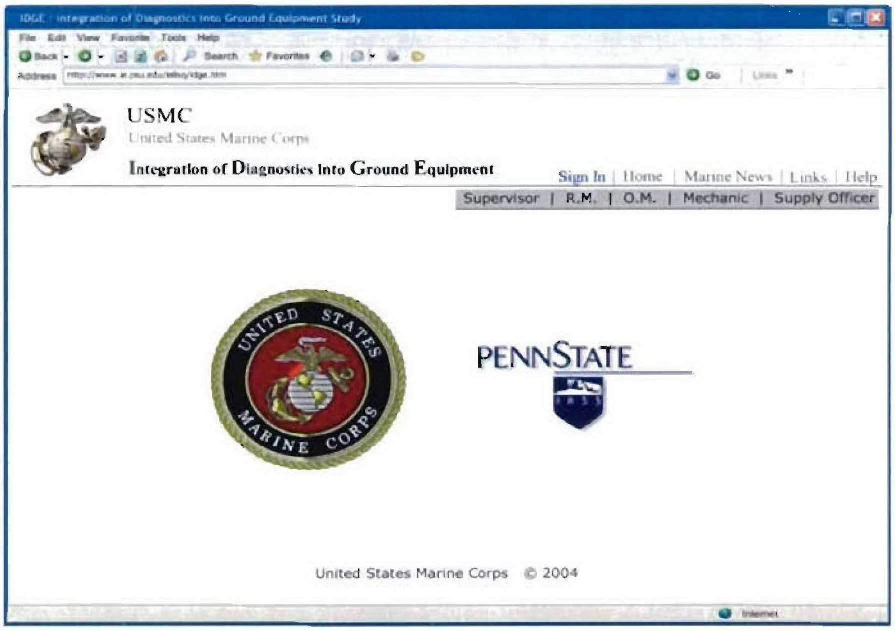


Figure 5.4 Main Windows

The users can log on into the system using their userid and password as shown in Figure 5.5

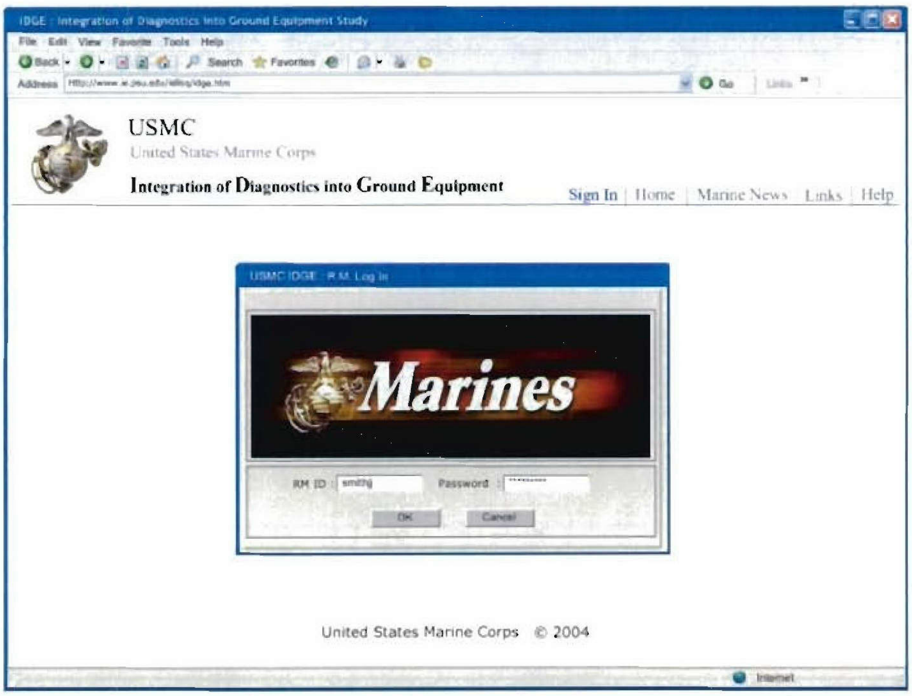


Figure 5.5 Login Windows

Once the user logs onto the system he or she is informed the details of the last login session. Depending on the MOS and responsibility of the particular user he is presented with the appropriate menu options. The Figure 5.6 shown below presents the layout for a Request Manager within a CSSE Det.

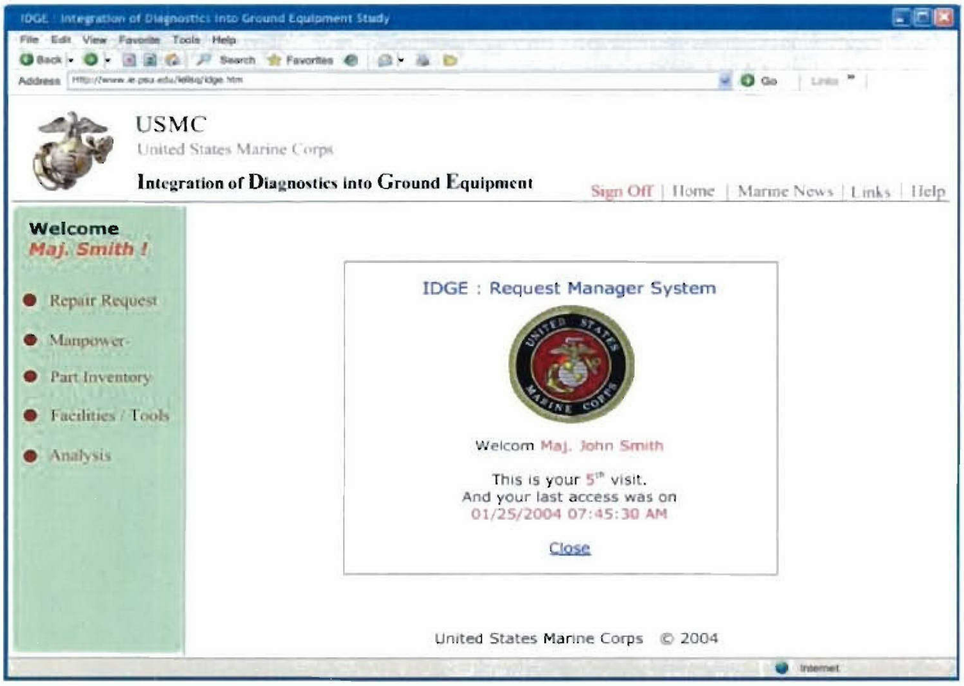


Figure 5.6 Request Manager Window within a CSSE Det

The request Manager will be able to view the requests that have been received. The system also shows the current status of these requests (Figure 5.7). The request manger can view the detailed information for a particular request as shown in Figure 5.8.

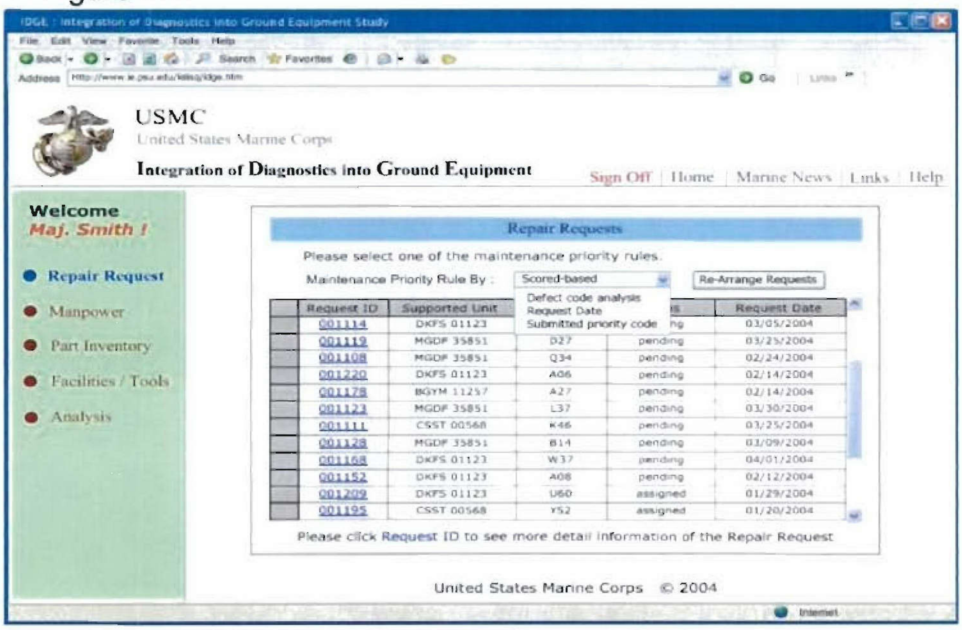


Figure 5.7 Request Status Windows

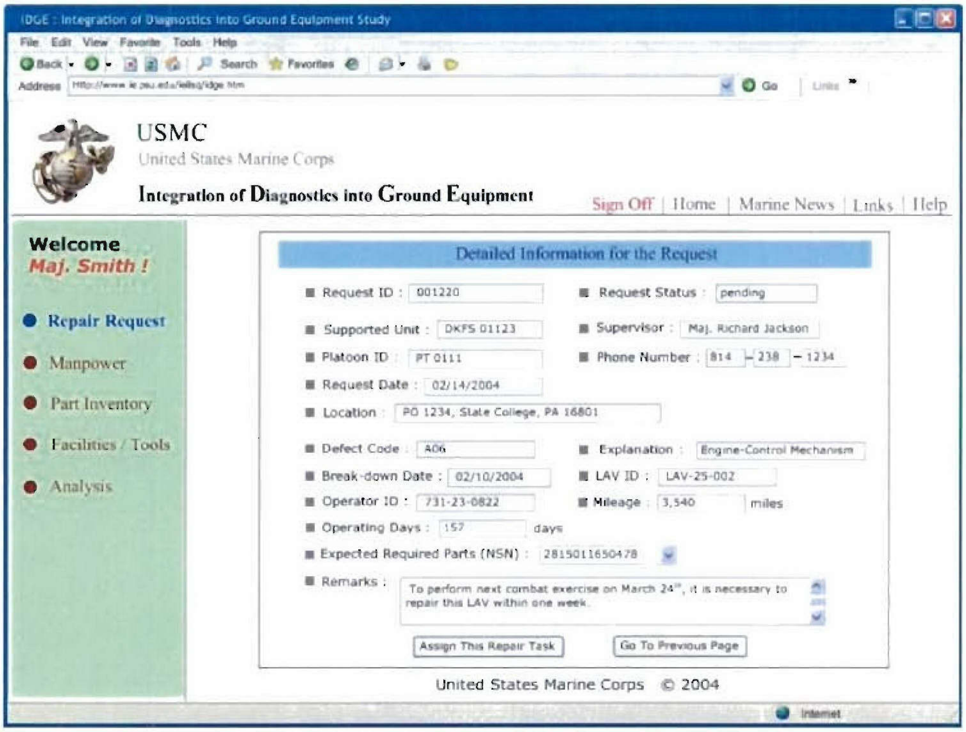


Figure 5.8 Detailed Information for the Request

When the request manager clicks the button to allocate resources for a particular request, a software agent; queries the relevant databases for the availability of resources. These are passed onto the scheduling algorithm that makes schedules and allocates resources optimally in order to fulfill the request. The resulting information is presented as shown below in Figure 5.9.

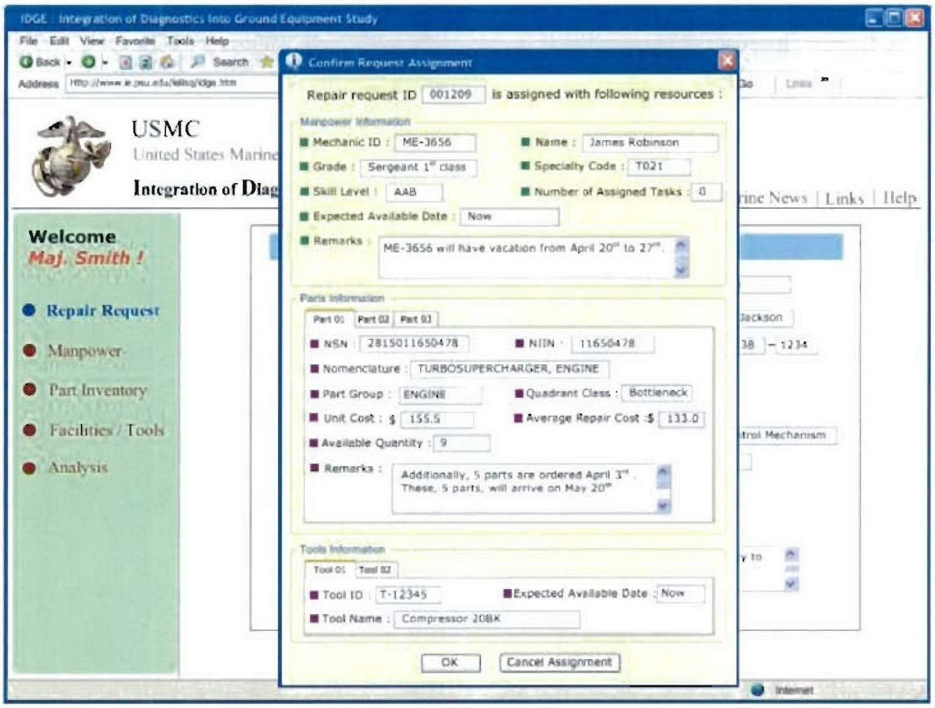


Figure 5.9 Request Assignment Windows

The request manager can also query the current status of the different mechanics within the particular CSSE Det. He or She can also click the link to obtain detailed information about a particular mechanic as shown in Figures 5.10 and 5.11.

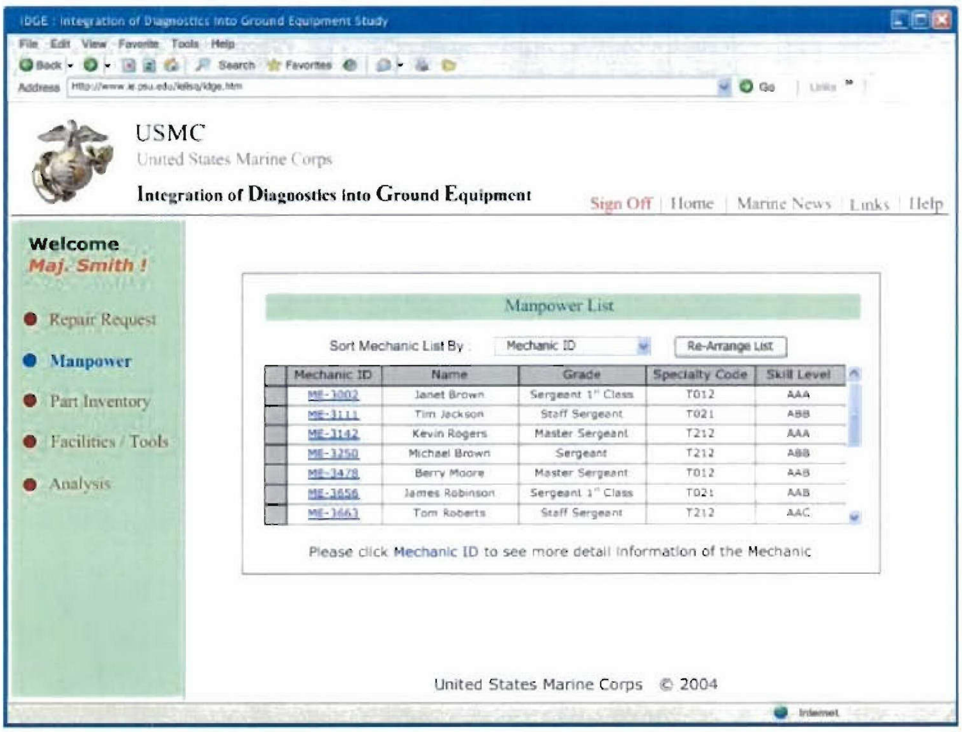


Figure 5.10 Mechanic (Manpower) Status Window-A

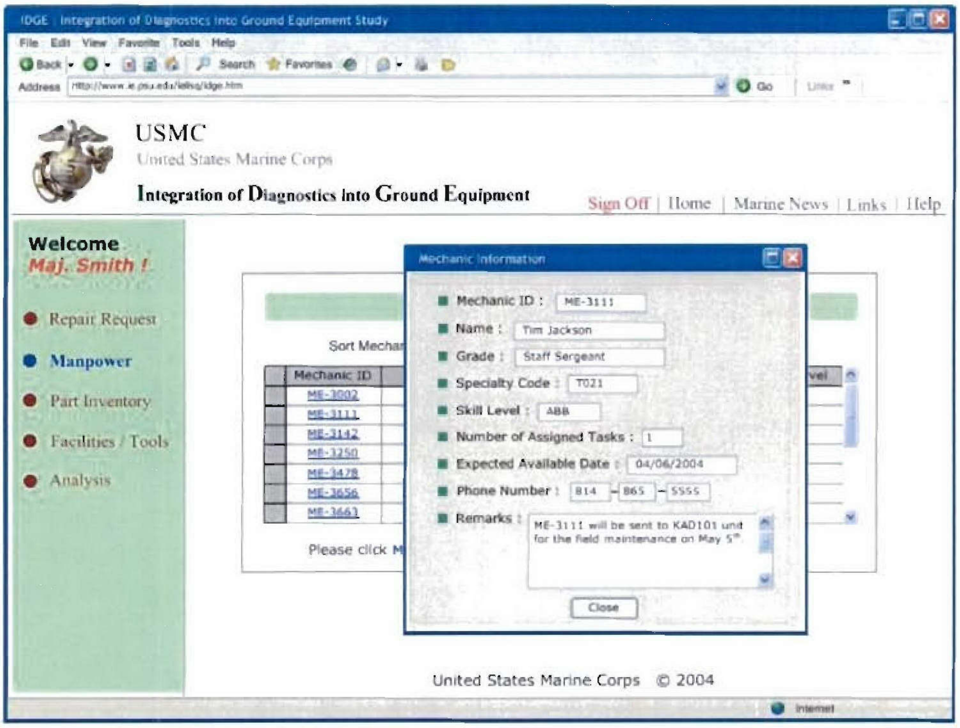


Figure 5.11 Mechanic (Manpower) Status Windows-B

The request manager can view the information regarding the status of parts (NSN) internally available within the CSSE Det as shown in Figure 5.12.

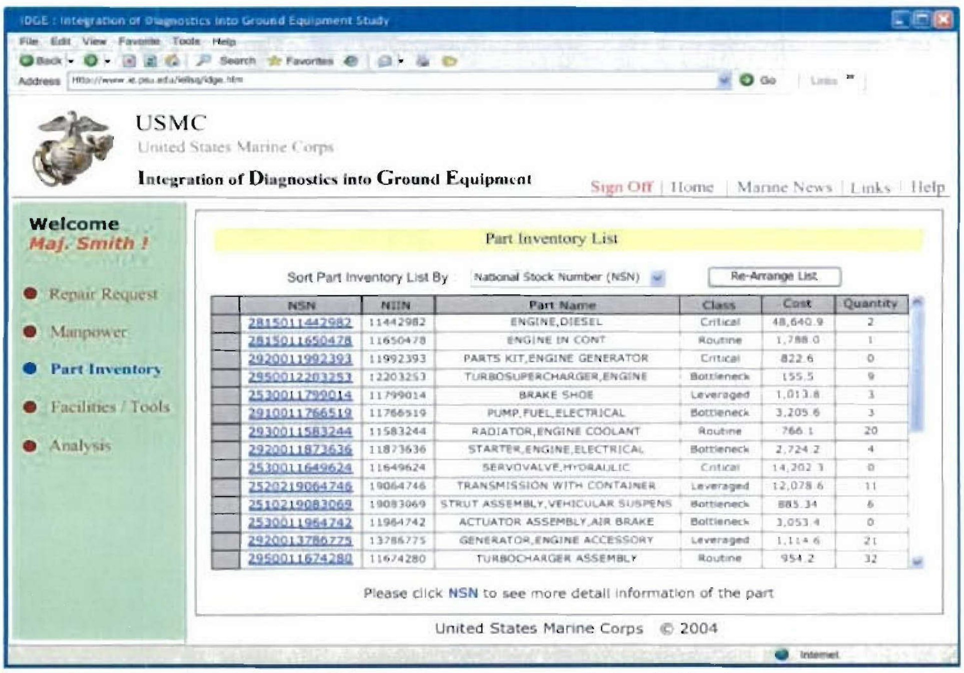


Figure 5.12 Part Inventory List Window

The detailed information for a particular NSN as shown in Figure 5.13 can also be viewed.

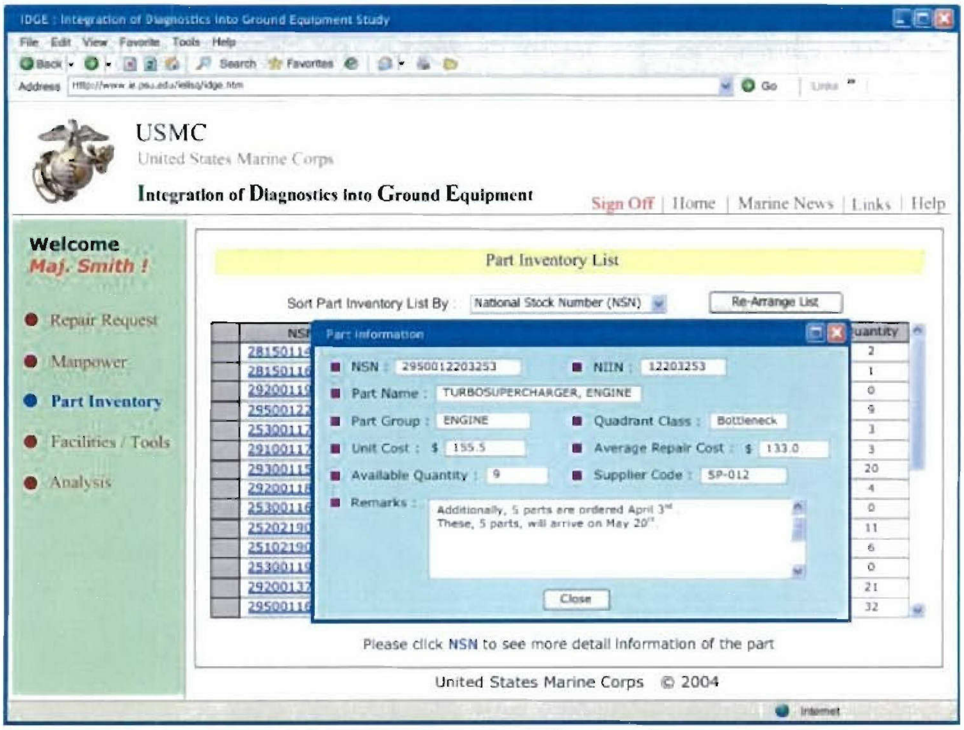


Figure 5.13 Detailed Part Information Window

The request manager can analyze the history of requests that he/she has received. Each type of request and its corresponding frequency are shown in Figure 5.14 after the analysis agent queries the request history database and generates the results.

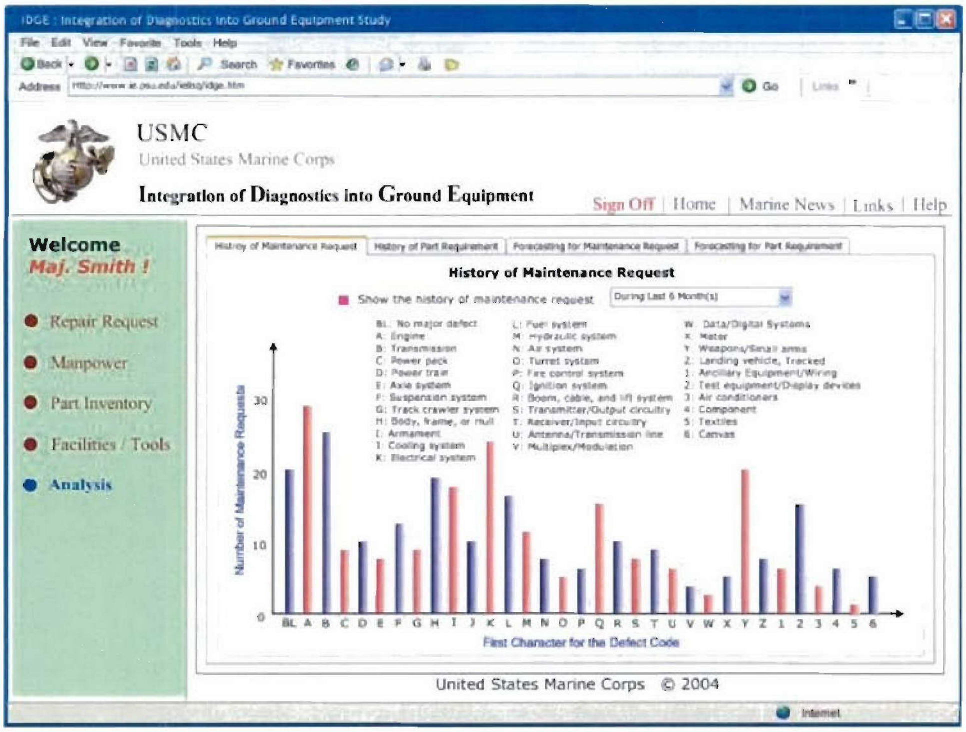


Figure 5.14 Analyses for the Type of Request and its Frequency

6 Critical Paths and Risks

Task 5: Identify Critical Path and Risks for One (1) Candidate System. Interpret and correlate the results of tasks 1-4 and depict/present the information in a way that identifies a critical path for implementation of a USMC Autonomic Logistics Support System by FY 2008.

6.1 Integration Issues

Integration of both applications and databases has been an ongoing problem in today's commercial world. Several industries, academicians and non-profit research organizations are developing novel techniques for integrating entire systems, developed on different platforms, across an enterprise. The issue of integration becomes prominent when an organization is planning to transform its information technology infrastructure and operating policies. The integration of diagnostics to ground equipment and the concept of autonomic logistics demand a host of new systems that need to be developed. Depending on the budget constraints and organizational issues the USMC might replace some or all of the legacy systems. Since the envisioned systems are transactional in nature and will provide visibility of assets and operations across the USMC, they need to be tightly integrated. The migration to this new set of systems will pose challenges if either all or few of the legacy systems are replaced.

Migration could be through two different methods – one is to build an entirely new infrastructure the other would be replace only some of the legacy systems. In both these cases integration issues arise. In the first case, the USMC needs to ensure that the data currently available is transferred from the legacy systems to the newly developed system. Currently this cannot be achieved through automated means. The difference in database schema between the legacy and new systems will cause difficulty for data migration. Though the migration can be achieved through semi-automated or manual means these methods are error prone and tedious. Therefore the existing database has to be clearly mapped to the schema that will be used in future systems. Most industries today are adopting the XML schema for specifying data. This being an emerging standard need to be used in the future logistics systems that will be developed.

In the case where both legacy and future systems will be in place, the applications that will be developed for the future need to access the data from both these databases. Owing to the difference in the type of interfaces that these databases present, a number of application program interfaces will have to be developed so as keep the system integrated. Another method will be to wrap the legacy systems and interface the wrappers with the new development.

In the context of maintenance and CBM the sensor signals and the related diagnostics/prognostics information have to be stored and integrated with logistics systems. This would be a challenge as the type of database architecture and schema that is used to store sensor signal data and that of enterprise systems differ considerably. Most current day health monitoring systems are not tied in with the logistics systems. This needs to be achieved in order to enable the concept of autonomic logistics.

Critically analyzing the current day technologies show that the future web based applications have to be enabled with sufficient metadata that need to be compliant with XML specifications. Most data integration and schema matching tools that are developed today assume XML data and so using this approach will ensure easy migration of information between systems in future. A Review on Enterprise Application Integration (EAI) has been documented in Appendix 8.6:IR 1: Appendix 9, Pages 181-187.

6.2 Distributed vs. Centralized Signal Processing

The envisioned IDGE system requires sensors to be placed onboard the ground equipment. The sensor signals detected from these sensors can be processed onboard or sent to a centralized signal data repository for analysis. Owing to the highly dynamic environment and high mobility of the ground equipment a distributed sensor-processing paradigm is more suitable for the IDGE system. Each end item will have to process the signals generated by the sensors and detect anomalies, the inferences that is made through sensor processing is then transmitted to the relevant nodes (RM) in the form of a request. The use of a distributed computing paradigm requires a number of additional functionalities within the end items, such as sufficient processing power, appropriate memory capacity and most importantly connectivity. The templates that have been developed in this study can be applied to different end-items, but a constant connectivity with the RM nodes is required throughout the operation of the vehicles. The requirements for enabling such communication are described in the next section.

6.3 Communication Load

An analysis of the data generated and used by the use cases i.e. transmitted across different levels of the infrastructure has been completed. The process followed for this was described in Section 4.1.5 and the results of the aggregated data requirements are shown in Appendix 8.4.2. As expected, these results indicate that the bulk of the communication is likely to occur between the vehicle and the O-level. A caveat in interpreting these results is that the frequencies estimated for these use cases were obtained from potential users, who indicated that these should be considered tentative. Before infrastructure decisions can be made based on this analysis of communication load, it is necessary, therefore, to further validate these either via simulation or by corroborating them with additional input from a larger set of users. A second caveat is that these aggregated data transmission results do not reveal any burst nature of communication that may be required. These can be identified to further characterize the communication load across different levels of the infrastructure.

6.4 Unique Military Considerations and Survivability

The primary consideration for deployed operations is to be able to gather information about the health of the ground equipment in real-time and trigger the relevant maintenance actions. The IDGE system relies on the communication network to transmit the information gathered by the sensors. The reliability of the communication network will therefore play an important role in the efficient functioning of the IDGE system. It must be noted that sufficient redundancy has to be built into the communication network so that ground equipment have alternate means to communicate their health information to the relevant nodes within the operational architecture. In addition we recommend that I/O port be built into the onboard system so that in the absence of communication channels the maintenance personnel can collect the relevant data by connecting the hand held devices to the I/O ports.

6.5 Transition Plans

Transition plans for a proposed IDGE system can be identified in at least three directions.

First, we recommend that an incremental strategy be employed for implementing a proposed IDGE system. The incremental strategy can be operationalized in several ways. Clearly, some platforms may be more viable for the proposed system than others. For example, the LAV platform that is used in this report as an exemplar may be a suitable platform for implementation because of an already strong history including service-life extension plan (SLEP) and considerable presence.

Second, the scenarios painted should be considered as the basis for determining the infrastructure, which may evolve from simple to more complex. Some decisions about the infrastructure are, however, stable and endure over time. These should be identified early following an analysis of the use cases. Based on these, the infrastructure can be designed so that it evolves is the desired direction. If the infrastructure decisions indicate that the most preferred alternative is not available, it may be necessary to revise the use cases. For example, a prerequisite for some of the use cases is wireless technology. If the most preferred wireless alternative is not available for any reason, it may be necessary to revise the use cases devised.

Third, changes to the work practices should be identified and proactively planned for during a successful transition plan. The proposed IDGE system will push more intelligence to lower levels of the organizational hierarchy. In many ways, this is in direct contrast to the command and control mechanisms put in place.

This will require changes to work procedures and reward mechanisms. Contemporary research on workflow management and collaborative systems can be leveraged towards this purpose.

6.6 Future Directions

Comments provided on the draft final report indicate possible future steps for this study that correspond to some of our suggestions for future plans. In particular, it may be possible to develop prototypes for different aspects of the proposed system. These can include prototyping novel user interfaces for computer-human interactions to investigate concerns such as will PDAs work in this context. This can also include creating simulations at the workflow / scenario levels of the IDGE system as well as the potential users and structures to ensure that key issues such as motivators etc are taken into account.

The system requirements that have been developed for the IDGE system have to be used to first develop a prototype system. The prototype system will have all the functionalities but can be scaled up after sufficient validation. Building a prototype system help in the following aspects

- Will help refine the requirements specification to greater detail
- Conformance to the operational architecture of the working system can be ascertained
- The performance of the system can be analyzed and specific modules can be redesigned to improve performance
- The prototype can be used to train the users while transitioning to large scale deployment

7 References

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8 Appendices

8.1 Maintenance

8.1.1 Maintenance Practices in USMC

a) Equipment Repair Order (ERO):

- It is a paper based form within a unit, which is used for request modification, calibration, corrective maintenance, preventive maintenance checks and services and technical inspections on all ground equipment
- Can also be used to transfer work to higher echelons of maintenance and for recording and reporting the maintenance that has been performed.

b) Equipment Repair Order Shopping/Transaction List (EROSL):

- The EROSL will be used in conjunction with the ERO to requisition, receipt for, cancel, and record partial issues and credits of repair parts associated with ground equipment undergoing repairs.
- The ERO holder is responsible for initial preparation of the EROSL to include the required information.
- To input MIMMS data into the system, either automated or manual.

c) Equipment Records: There are many records but the two most predominant ones are: preventive maintenance checks and services (PMCS) records and corrective maintenance (CM) records.

- PMCS record ensures that the PM is systematically scheduled and recorded when complete
- CM record ensures that a history is established for the piece of ground equipment that requires to be maintained.

d) Calibration control Program:

- It ensures that all Test, Measurement and Diagnostic Equipment (TMDE) is calibrated within certain range of scale.

e) Tool Control:

- Ensures accountability of all tools in stand-alone sets, chests or kits and or if they belong to a PEI.

f) Product Quality Deficiency Report (PQDR):

- Provides information to activities responsible for development, procurement, or management of equipment concerning deficiencies in material, design, or procurement
- It enables the activities to initiate action to correct the reported deficiency.

g) Modification Control: This program gives the equipment owner the means of accurately determining the modification status on assigned equipment. There are two types of modification: Urgent and Normal.

- Normal: modification lend themselves to acceptance scheduling usually within one year
- Urgent: modification requires that the equipment be dead lined or sharply curtailed until the modification is applied.

h) Publication Libraries: The publications fall into two categories:
- Technical (Marine Corps Orders, Bulletins, etc.)
- Non-technical (Technical Manuals, Stock Listings, Modification Instructions, etc.).

8.1.2 Maintenance Systems

Marine Corps Integrated Maintenance Management Systems (MIMMS) and Field Maintenance Systems

The Marine Corps Integrated Maintenance Management System is an automated management system. It is organized into three subsystems: the Headquarters Maintenance Subsystem, the Depot Maintenance Subsystem, and the Field Maintenance Subsystem.

The Headquarters Maintenance Subsystem supports commodity managers at Headquarters Marine Corps. It allows commodity managers (i.e., motor transport, communications-electronics, engineer, and ordnance) to enter standard data into the Marine Corps Integrated Maintenance Management System and to maintain a database of selected maintenance information. This data base is comprised of information extracted from the Field Maintenance Subsystem. It facilitates selective maintenance engineering analysis, logistic readiness evaluation, and maintenance management for specified functions required by the Headquarters Maintenance Subsystem user.

The Depot Maintenance Subsystem supports the materiel functions of the two Marine Corps depot maintenance activities. It provides materiel and production control information and cost and labor accounting information

The Field Maintenance Subsystem was developed to improve and standardize equipment status reporting and management, while reducing and consolidating manual reporting requirements. It provides commanders with timely and accurate information concerning the status of equipment currently in the maintenance cycle. This system provides maintenance and repair parts information, supply transactions, historical costs, and tracking of maintenance engineering and modification control information. The primary inputs to this system are the ERO and the EROSL.

From the above review, we have identified the need for an integrated system that can handle transactions in addition to storing and cataloguing information. This will provide greater visibility for all three levels of maintenance.

Marine Corps Equipment Readiness Information Tool (MERIT)

MERIT is a non-transactional web based tool currently in use at the USMC. Its key functions include enabling visualization of the equipment readiness status by using detailed supply and maintenance information. MERIT transforms the maintenance data into relevant information that provides a near real time view of equipment readiness. It presents a comprehensive Marine Corps readiness posture while presenting detailed information about the availability of specific parts. It contains a graphical user interface in combination with a readiness analysis tool. It essentially automates the process of developing detailed readiness maps. Thus it reduces the workload on the analysis experts.

MERIT uses an open source java-based programming technique. The delivery method uses a web browser using java applet running on a server, this is connected to the data source such as Oracle, XML or delimited text. MERIT also uses a combination of filters; labels and search tools to either group the data in numerous desired ways or for presenting multiple calculations for current and historical USMC readiness data. It also uses different color schemes for representing the data element and thus enables easy visualization.

A critical review of the MERIT system helped the team identify the different maintenance data that the system is currently capturing. It also helped the team review the techniques that are used to store/catalogue the data elements.

8.2 *Future Marine Corps Maintenance Logistics*

8.2.1 Maintenance at Intermediate Maintenance Activity (IMA)

Supported unit identifies a need for a maintenance service that must be fulfilled by the logistics chain (Garrison or deployed). Intermediate maintenance activity (IMA) has capability to perform this service. Service performed at maintenance site. This scenario applies to both parts on hand and for parts out of stock, and applies both scheduled and unscheduled maintenance.

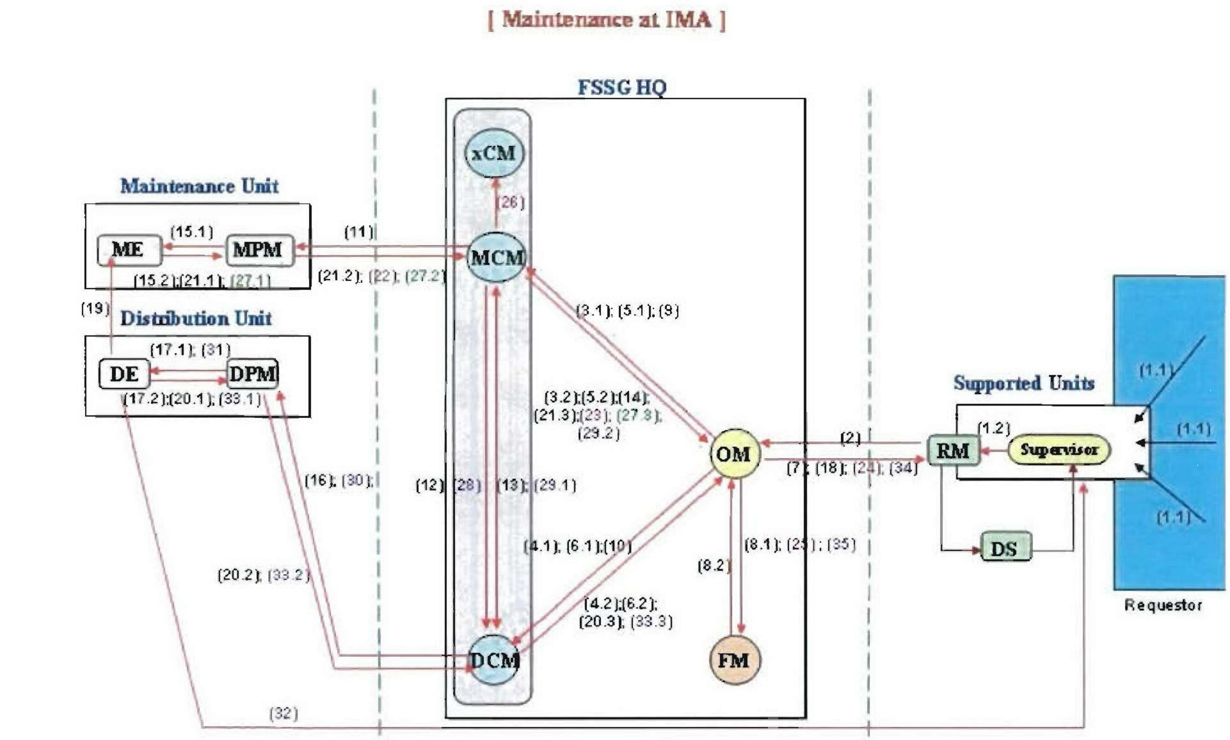
Table 8.1: Maintenance at IMA

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Comments
1.1	Supported Unit	Supervisor	Ask	The supported unit identifies requirement and a request is sent to the supervisor for validation.	Unit Identification, Location; - Text, Digital, Voice	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	The supervisor validates and prioritizes the requirement and sends it to RM	Secure signature - Encryption	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the supported unit if unable to source internally.	Request Identification + 1.1 - Text, Digital	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	MCM	Ask	Ask the availability of resources (tools, man power, parts) and MCM either accepts or rejects.		
3.2	MCM	OM	Accept	MCM accepts or rejects the request.		
4.1	OM	DCM	Ask	Ask the availability of the Transportation for the pick up of products from the using unit.		
4.2	DCM	OM	Accept	DCM accepts or rejects the request		
5.1	OM	MCM	Ask	Assess the capability of ICM to accepting the products.		
5.2	MCM	OM	Accept			
6.1	OM	DCM	Ask / Accept	Assess the capability of DCM for making the		

				distribution resources available.		
6.2	DCM	OM	Accept			
7.0	OM	Supported Unit	Inform	Confirm with the using unit by reiterating the requirement and the terms and conditions for the maintenance.	Request ID confirmation - Text (short message) Voice	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.1	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the maintenance then OM asks FM about availability of the funds.	- Text, encryption, digital.	The total cost repair is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
8.2	FM	OM	Accept			
9.0	OM	MCM	Inform	Inform MCM to reserve and schedule the maintenance.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the maintenance.		
11.0	MCM	MPM	Inform	Inform MPM to reserve and schedule the relevant resources to fulfill the work order.	Order ID, Requirements - Text, Voice	The specific list of resources is sent so as to enable the MPM to reserve the resources.
12.0	MCM	DCM	Inform	Inform the relevant shipping requirements.		
13.0	MCM/ DCM	DCM/MCM	Inform / Accept	Co-ordination for pick up		
14.0	MCM	OM	Inform	Signal the delivery requirements	Order ID, Shipping requirements - Text, Voice	
15.1	MPM	ME	Inform	Assigns the resources from the execution element for this particular task.	Work order ID, Item ID - Text, Voice	Generated work order is sent to the ME so as perform the required tasks.
15.2	ME	MPM	Inform			
16.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - Text, Voice, Digital	The identified products are listed out and sent.
17 1	DPM	DE	Inform	Place a work order for the pick-up from using unit and delivery to the MCM of the products to be repaired.	Item ID, Location, Destination location - Text, Voice	The location from where to pick-up the item and product lists are sent using the e-forms.
17.2	DE	DPM	Inform			

18.0	OM	Supported Unit	Inform	Signals to stage product so that it can be taken by DE to the ME site.	Signal - Text (short message)	
ME remove the items requiring repair to the maintenance site.						
19.0	DE	ME	Inform	Signal delivery of the item	Signal - Text (short message)	
20.1	DE	DPM	Inform	Signal delivery of the item	Signal - Text (short message)	
20.2	DPM	DCM	Inform	Passes on the signal from DE to DCM	Signal - Text (short message)	
20.3	DCM	OM	Inform	The signal taken from DPM is informed to OM.		
ME receive item.						
21.1	ME	MPM	Inform	Informs MPM about the receipt of the item		
21.2	MPM	MCM	Inform	MPM forwards the signals about receipt of item to MCM.		
21.3	MCM	OM	Inform	MCM informs OM about the receipt of the item.		
ME now conduct disassembly if required, diagnosis and inspection, and capture the cause of failure. MPM identifies and requests the additional resources and parts to effect repair if necessary.						
22.0	MPM	MCM	Ask	Send the signal about the additional resource and parts requirements to affect repair.		
23.0	MCM	OM	Inform	Based on the need for additional resources MCM now reiterates the need capability of fulfilling the request on time.		
24.0	OM	Supported Unit	Inform	If required OM now notifies the supported unit about the new ATP/CTP conditions and its capability to fulfill the request.		
25.0	OM	FM	Inform	Fund requirements are informed to FM if needed, Optional.		
26.0	MCM	xCM	Inform	Signals for additional resources and parts and reserves these resources. This is done only if the additional resources are not available internally.		
ME performs repair and conducts quality control.						
27.1	ME	MPM	Inform	Notify repair completion.		
27.2	MPM	MCM	Inform	Signal repair completion.		

27.3	MCM	OM	Inform	Forward the signal received from MPM about the completion of the task to OM.		
ME stages repaired item for return to customer, and MPM releases repaired item.						
28.0	MCM	DCM	Inform	Notify shipping requirements.		
29.1	DCM/ MCM	MCM/ DCM	Inform/Accept	Co-ordination for pick-up to meet delivery requirements.		
29.2	MCM	OM	Inform	Notify about the release of item from MCM and requirements of pick up.		
30.0	DCM	DPM	Inform	Reserve and schedule the resources to transport the item back to the supported unit.		
31.0	DPM	DE	Inform	DPM generates and sends the relevant work order to DE so as to carry out the return.		
DE delivers the repaired item back to the supported unit.						
32.0	DE	Supported Unit	Inform	Fulfills delivery of repaired item		
33.1	DE	DPM	Inform	Signal item delivery.		
33.2	DPM	DCM	Inform	Signal item delivery.		
33.3	DCM	OM	Inform	Signal item delivery.		
34.0	OM	Supported Unit	Inform	Verify receipt and condition of the item from Supported unit.		
35.0	OM	FM	Inform	Send invoice – optional.		



-[22]-[26] ME conducts diagnosis & inspection and captures the cause of failure; MPM identifies & requests additional resources & parts to effect repair (if needed)
-[27.1]-[27.3] → ME performs repair and conducts quality control
-[28]-[35] → ME stages repair item for return to customer, and MPM releases repaired item

Figure 8.1 Information Flow Diagram for Maintenance at IMA

8.2.2 Return of MRO to Stock

Supported unit identifies a need for a product return due to MRO (Garrison or Deployed). Product is a cataloged item.

Table 8.2: Return of MRO to Stock

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement to put away/return the items from local inventory to the stock. Ask supervisor for validation.	Unit Identification, NSNs Quantity, Location, Expected time for replenishment. - Text, Digital, Voice	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the need to return the items	Secure signature - Encryption	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the using unit.	Request Identification + 1.1 - Text, Digital	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	MCM	Ask / Accept	Ask the availability of resources (Tools and man power) and MCM either accepts or rejects.		
3.2	MCM	OM	Accept			
4.1	OM	ICM	Ask / Accept	Ask the availability of resources to receive the product.		
4.2	ICM	OM	Accept			
5.1	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it.		
5.2	DCM	OM	Accept			
6.1	OM	MCM	Ask / Accept	Assess the capability of MCM to make the repair within the relevant conditions of time.		
6.2	MCM	OM	Accept			
7.1	OM	ICM	Ask / Accept	Assess the availability of resources at ICM to receive the product within specified conditions.		

7.2	ICM	OM	Accept			
8.1	OM	DCM	Ask / Accept	Assess the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it		
8.2	DCM	OM	Accept			
9.0	OM	Supported Unit	Inform	Confirm with the Supported unit by reiterating the requirement and the terms and conditions for pick up and repair.	Request ID confirmation - Text (short message) Voice	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
10.1	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about availability of the funds.	- Text, encryption, digital.	The total cost repair is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
10.2	FM	OM	Accept			
11.0	OM	MCM	Inform	Inform MCM to reserve and schedule the resources.		
12.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the products to be returned.		
13.0	OM	ICM	Inform	Informs in advance the need for resources to receive the product.		
14.0	MCM	MPM	Inform	Inform MPM to reserve and schedule the resources for fulfilling the repair.	Order ID, NSNs - Text, Voice	The specific list of resources is sent so as to enable the IPM to reserve the resources.
15.0	MCM	DCM	Inform	Inform the relevant shipping requirements.		
16.1	MCM/ DCM	DCM/MCM	Inform / Accept	Co-ordination for pick up		
16.2	DCM/MC M	MCM/ DCM	Accept			
16.3	MCM	OM	Inform	Signal the delivery requirements		
17 1	MPM	ME	Inform	Assigns the resources from the execution element for this particular task.	Work order ID, Item ID - Text, Voice	Generated work order is sent to the ME so as perform the required tasks.
17.2	ME	MPM	Accept			
18.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location	The identified products are listed out and sent.

					- Text, Voice, Digital	
19.1	DPM	DE	Inform	Place a work order for the pick-up from using unit and delivery to the MCM of the products to be repaired.	Item ID, Location, Destination location - Text, Voice	The location from where to pick-up the item and product lists are sent using the e-forms.
19.2	DE	DPM	Accept			
20.0	OM	Supported Unit	Inform	Inform the Supported unit to stage the product for pick-up by DE.	Signal -Text (Short message), Voice	Message asking the using unit to stage item.
DE now picks up the staged product from the supported unit and delivers it to the assigned ME unit.						
21.1	DE	DPM	Inform	Inform the delivery of the product.	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID and signaled back upon delivery.
21.2	DPM	DCM	Inform	Route the signal from DE to DCM	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID
21.3	DCM	OM	Inform	Route the signal received from DPM to OM and inform the delivery of the product.		
22.1	MCM/ ICM	ICM/MCM	Inform / Accept	Co-ordination for taking custody of the assets.		
22.2	ICM/MCM	MCM/ ICM	Accept			
ME now conducts diagnosis and inspection						
23.0	ME	MPM	Inform	It conveys to MPM the additional resource requirements if necessary.		Optional
MPM identifies and requests the additional resources and parts to effect repair if necessary.						
24.0	MPM	MCM	Inform	Send the signal about the additional resource requirements.		Optional
25.1	MCM	ICM	Ask/Accept	Request for the additional resources that are required.		Optional
25.2	ICM	MCM	Accept			
ME then perform the repair and checks for quality.						
26.1	MCM	ICM	Inform	Requirements for returning the item.		
26.2	ICM	IPM	Inform	Ask IPM to reserve and schedule the resources for accepting the repaired item.	NSNs, Quantity, Order ID, Time frame.	The list and quantity of items and time frame can be sent using text forms.

					- Text, Voice	
27.0	ICM	DCM	Inform	Notify DCM about the shipping requirements.		
28.1	DCM/ ICM	ICM/DCM	Inform / Accept	Co-ordination for pick up and delivery of the repaired item.		
28.2	ICM/DCM	DCM/ ICM	Accept			
28.3	ICM	MCM	Inform	Inform that the item is ready for return.		
28.4	ICM	OM	Inform	Inform that the item is ready for return.		
29.1	IPM	IE	Inform	Generate and direct IE to schedule resources for receiving the returned item..	NSNs, quantity, packing rqmts, Time to receive, Priority - Text, Voice, Digital	The work order that contains the resources to be made ready for receiving can be sent again as an e-form. The priority is a machine generated digital code.
29.2	IE	IPM	Accept			
30.0	DCM	DPM	Inform	Reserve and schedule the resources for pickup and delivery of the repaired item.	Transporting unit ID, Time to pick-up, Location - Text, Voice, Digital	The identified products are listed out and sent.
31.0	DPM	DE	Inform	Generate and direct work order to pick up and deliver the repaired item to IE.	Item ID, Location, Destination location - Text, Voice	The location from where to pick-up the item and product lists are sent using the e-forms.
The Item is picked up and returned to the designated IE/IPM by the distribution execution element.						
32.1	DE	DPM	Inform	Signal about the delivery of the item	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID and signaled back upon delivery.
32.2	DPM	DCM	Inform	Route the signal received from DE to DCM	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID and signaled back to DCM.
32.3	DCM	OM	Inform	Route the signal received from DPM to OM and confirm delivery.		
33.1	IE	IPM	Inform	Verifies records and reports discrepancies about the item received	NSN, Description of item quality - Text, Voice, Digital	The condition of the received item is sent as text.

33.2	IPM	ICM	Inform	Routes the information about the received product to ICM	NSN, Description of item quality - Text, Voice, Digital	The condition of the received item is sent as text.
33.3	ICM	OM	Inform	The information about received item is notified to OM. Receipt		
34.0	OM	FM	Inform	Liquidate funds if required.	Invoice - Text, Encryption, Digital	The invoice is sent as text with encryption.

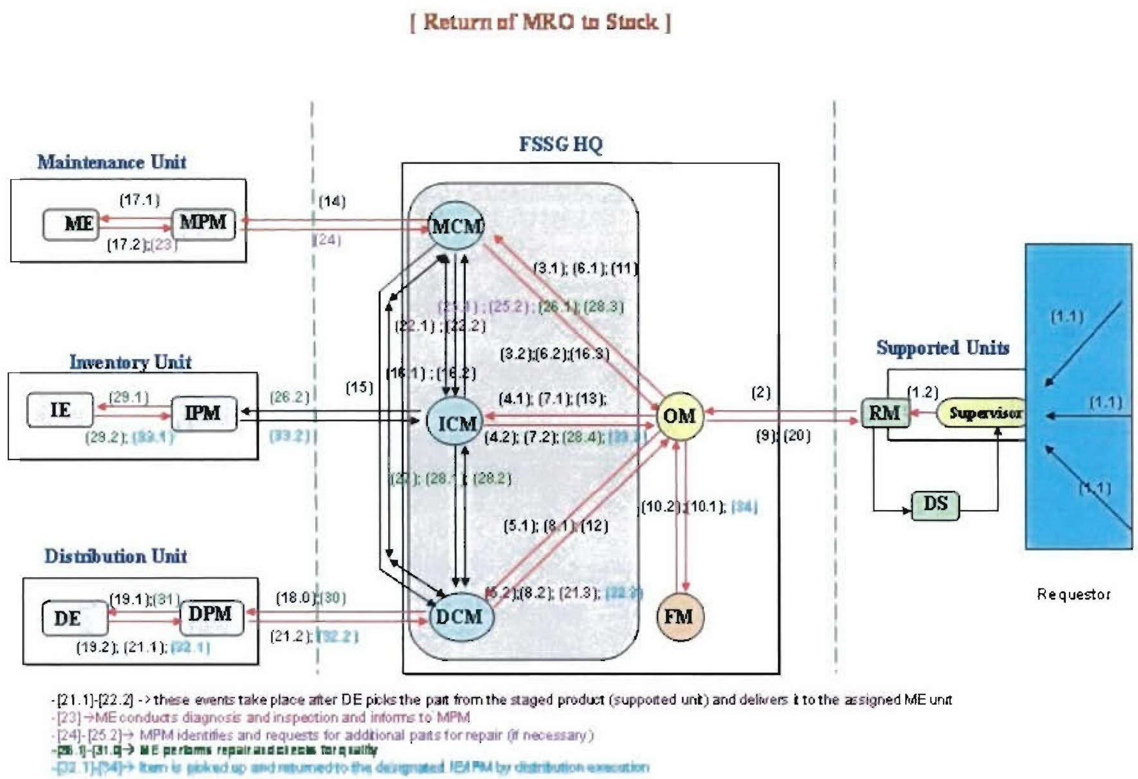


Figure 8.2 Return of MRO to Stock

8.3 Database Tables

Table 8.3: Supply Information Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	Supply_info	Writer	
Table Description	This gives supply information to order new parts		

No	Field Name	PK	Type	Size	Description
1	SUPPLIER_ID	PK			Supplier Id
2	S_REQ_ID	PK			Supply Request Id (create new supply id)
3	EROSL_ID	PK			EROSL identification number
4	PART_ID	PK			Required Part Id (Serial No. of the part)
5	Quan_Part				Required Part Id (in Quantities)
6	REQUEST_DATE				Part requirement date
7	PRIORITY				Priority number for supply request
8	S_RET_ID				Supply Retailers like DoD etc. Identification
9	MODE_TRANS				Mode of Transportation for shipment
10	ESD_DATE				Estimated Shipping Date
11	EDD_DATE				Estimated Delivery Date
12	ECD_DATE				Estimated Complete Date
13	RRD_DATE				Required Ready Date
Particulars					

Table 8.4: RM Information Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	RM_Info	Writer	
Table Description	This table is related to the information for each request manager (RM).		

No	Field Name	PK	Type	Size	Description
1	RM_ID	PK			Request manager's ID. (it also can be used as a system access ID.)
2	RM_PASS				Password for the system access.
3	NAME				Name
4	RM_GRADE				Grade (i.e. Sergeant, lieutenant, etc.)
5	CSSE_ID				His/her home unit (i.e. CSSE Det. 1)
6	PHONE				Phone number
7	REMARKS				Descriptions

Particulars
Instead of RM_ID, SSN also can be used as an alternative. (since, it follows uniqueness property.)

Table 8.5: Repair Request Table for Main Database Description

Database Name	IDGE_MAIN			Date	
Table Name	REPAIR_REQUEST			Writer	
Table Description	This is related to the information for each repair request.				
No	**Field Name**	**PK**	**Type**	**Size**	**Description**
1	REQ_ID	PK			Repair request ID
2	REQ_NO.				Repair order number from supported unit.
3	REQ_STATUS				Request state (i.e. pending or assigned)
4	SUPERVISOR_ID				Supervisor ID
5	RM_ID				Request manager ID
6	CSSE_ID				CSSE det. ID. (if there is only one RM for each CSSE Det, this attribute may be redundant.)
7	S_UNIT_ID				Supported unit ID. (if there is only one supervisor for each supported unit, this attribute may be redundant.)
8	PLT_ID				Platoon Id
9	MT_TYPE				Maintenance Type (Periodic:0, Aperiodic:1)
10	DEFECT_CODE				Defect Code (or Failure Code)
11	BRDN_DATE				Break Down Date
12	LOC_CODE				Location Code (probably redundant, if PLT_ID is included in this table.)
13	ALM_STATUS				Alarm Status
14	REQ_DATE				Requested date from a supervisor
15	OPERATOR_ID				LAV operator ID
16	LAV_ID				LAV ID
17	MILEAGE				MILEAGE for LAV
18	OPERATING_DAY S				NUMER OF OPERATING DAYS

Particulars
It should be considered that there might be several redundant attributes.
Should we consider all CSSE Dets share only one table for the repair request? Or each CSSE Det. has its own repair request table.

Table 8.6: Mechanic Information Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	Mechanic_Info	Writer	
Table Description	This is related to the information for each mechanic in CSSE Det.		

No	Field Name	PK	Type	Size	Description
1	MECH_ID	PK			Request manager's ID. (it also can be used as a system access ID.)
2	ME_GRADE				Grade (i.e. Sergeant, etc.)
3	SPEC_CODE				His/her maintenance specialty.
4	SKILL_LEVEL				His/her maintenance skill level.
5	NUM_TASK				Number of assigned tasks (repair requests)
6	EXP_DATE				Expected available date.
7	PHONE				Contact phone number (or e-mail)
8	AVALIABILITY				Quantity of tool available
9	EXPECTED_AVALIABILITY				Number of queue for reserve this tool

<u>Particulars</u>
Instead of RM_ID, SSN also can be used as an alternative. (Since, it follows uniqueness property.)

Table 8.7: Part Information Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	Part_Info	Writer	
Table Description	This is related to the information for each part.		

No	Field Name	PK	Type	Size	Description
1	NSN	PK			National stock number
2	NIIN				National item identification number
3	NOMENCLATURE				Part name
4	QUAD_CLASS				Quadrant (priority) class (if necessary)
5	QUAN_CSSE_01				Quantity of this part the CSSE Det 1 has
6	QUAN_CSSE_02				Quantity of this part the CSSE Det 2 has.
7	QUAN_CSSE_03				Quantity of this part the CSSE Det 3 has.
8	QUANTITY				Total quantities of this part
9	COST				Cost
10	R_COST				Repair cost for this part
11	S_Id				Supplier code
12	PART_GROUP				Part group (i.e. group tech.)
13	MAKER				
14	END ITEMS				
15	SUBSYSTEM_ CODE				
16	TRANSPORTATION_ REQUIREMENTS				
17	LOCATION ID				Warehouse id, Shelves id, etc
Particulars					

Table 8.8: Tool Information Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	Tool_Info	Writer	
Table Description	This is related to the information for each maintenance tool or facility.		

No	Field Name	PK	Type	Size	Description
1	TOOL_ID	PK			Tool or facility ID
2	TOOL_NAME				Tool or facility name
3	OWNING_UNIT_ID				
4	AVAILABITITY				Quantity of tool available
5	EXPECTED_AVAILABI LITY				Number of queue for reserve this tool
6	REMARKS				Descriptions
Particulars					

Table 8.9: User Information Table for Main Database Description

Database Name	IDGE_MAIN		Date		
Table Name	User_Info		Writer		
Table Description	This is related to task information for each mechanic.				
No	Field Name	PK	Type	Size	Description
1	User_ID				User Id
2	Passwd				Password
3	SSN				Social Security Number
4	RANK				Colonel, Major, Captain, etc
5	Position				Supervisor, RM, OM, etc
6	Supervisor_Id				Supervisor_Id
7	RM_Id				RM Id
8	CSSE_Id				CSSE Id
9	FSSG_Id				FSSG Id
Particulars					

Table 8.10: LAV Information Table for Main Database Description

Database Name	IDGE_MAIN			Date	
Table Name	LAV_INFO			Writer	
Table Description	This is the table for LAV Basic Information.				
No	Field Name	PK	Type	Size	Description
1	LAV_ID	*			LAV Id
2	N_Mileage				LAV Mileage
3	POSITION_LAV				Position or Location of LAV (GPS)
4	STATUS				LAV statues – Normal or Failure
5	OPERATOR				Operator
Particulars					

Table 8.11: History of Maintenance Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	HISTORY_ MAINT	Writer	
Table Description	This is the table for Maintenance History of LAV.		

No	Field Name	PK	Type	Size	Description
1	LAV_ID	*			LAV Id
2	Req_Id				Request Id
3	N_Mileage				LAV Mileage
4	PROBLEM				Title of Problem
5	DEFECT_CODE				Defect Code
6	DATE_MAINT				Date of Maintenance
7	REPAIRED_PART				Parts related Maintenance
8	MECHANIC				Mechanics related maintenance
9	REFERENCE				Mechanic's Comments
Particulars					

Table 8.12: Related Part Table for Main Database Description

Database Name	IDGE_MAIN	Date	
Table Name	Related_Part	Writer	
Table Description	This table shows the relationship between defect code and part code.		

No	Field Name	PK	Type	Size	Description
1	DEFECT_CODE	PK			Defect Code
2	Part_Code				Part List and NSN of related with Defect Code.
Particulars					

Table 8.13: Related Tool Table for Main Database Description

Database Name	IDGE_MAIN			Date	
Table Name	Related_Tool			Writer	
Table Description	This table shows the relationship between defect code and tool code.				
No	Field Name	PK	Type	Size	Description
1	DEFECT_CODE	*			Defect Code
2	Tool_Code				Part List and NSN of related with Defect Code.
Particulars					

Table 8.14: Defect Code Information Table for Main Database Description

Database Name	IDGE_MAIN			Date	
Table Name	Defect_Code_Info			Writer	
Table Description	This is the table consisting defect code.				
No	Field Name	PK	Type	Size	Description
1	DEFECT_CODE	*			Defect Code
2	Description				Part List and NSN of related with Defect Code.
3	Aim_Status				
Particulars					

Table 8.15: Repair Request Table for CLIENT Database Description

Database Name	IDGE_CLIENT	Date	
Table Name	Repair_Request	Writer	
Table Description	This table is related to the information for each repair request.		

No	Field Name	PK	Type	Size	Description
1	REQ_ID	PK			Repair request ID
2	REQ_NO.				Repair order number from supported unit.
3	REQ_STATUS				Request state (i.e. pending or assigned)
4	SUPERVISOR_ID				Supervisor ID
5	RM_ID				Request manager ID
6	CSSE_ID				CSSE Det. ID. (if there is only one RM for each CSSE Det, this attribute may be redundant.)
7	S_Unit_Id				Supported unit ID. (if there is only one supervisor for each supported unit, this attribute may be redundant.)
8	PLT_ID				Platoon Id
9	MT_TYPE				Maintenance Type (Periodic:0, Aperiodic:1)
10	DEFECT_CODE				Defect Code (or Failure Code)
11	BRDN_DATE				Break Down Date
12	LOC_CODE				Location Code (probably redundant, if PLT_ID is included in this table.)
13	ALM_STATUS				Alarm Status
14	REQ_DATE				Requested date from a supervisor
15	OPERATOR_ID				LAV operator ID
16	LAV_ID				LAV ID

Particulars
It should be considered that there may be several redundant attributes.
Should we consider all CSSE Dets share only one table for the repair request? Or each CSSE Det. has its own repair request table.

Table 8.16: Mechanic Schedule Table for CLIENT Database Description

Database Name	IDGE_CLIENT	Date	
Table Name	Mechanic_Schedule	Writer	
Table Description	This table is related to the work order schedule for each mechanic		

No	Field Name	PK	Type	Size	Description
1	Mechanic_Id	PK			Mechanic ID
2	Task_Id.				
3	Loc_Id				Location Code (probably redundant, if PLT_ID is included in this table.)
4	LAV_Id				LAV ID
5	Defect_Code				Defect Code (or Failure Code)
6	CSSE_ID				CSSE Det. ID. (if there is only one RM for each CSSE Det, this attribute may be redundant.)
7	FSSG_ID				FSSG ID
8	MT_TYPE				Maintenance Type (Periodic:0, Aperiodic:1)
9	ALM_STATUS				Alarm Status
10	REQ_DATE				Requested date from a supervisor

Particulars

8.4 *Use Cases*

8.4.1 Use Case Documentation and User Interfaces

Use Case 1: Record Sensor Data in Black Box

Preconditions:
- Sensors in place at the LAV to collect data streams.

Actors:
- Sensors

Goal:
To gather sensor data from sensors in each vehicle and store it in the black box on board of the vehicle.

Flow of events:
1 Each sensor in the vehicle gathers and transmits data via hardwired link into the black box that is onboard the vehicle.
2. The data is stored using a predetermined structure in the black box.
3. If the capacity of the black box is exceeded before upload (see use case 2: periodically upload sensor data from black box in each LAV) the oldest data is overwritten to maintain the most recent data stream from each sensor in the black box.

Related Use-Cases:
Periodically upload sensor data from black box in each LAV

Frequency and Levels

Frequency of usage:
Once a day for each LAV

Level of operation: Vehicle ~~C1 — M1~~
~~C2 — M2~~
~~C3 — M3~~

Data transmitted

None across the levels

Algorithms and Decision Support Tools

Algorithms used:
Data compression and storage algorithm as needed.

Decision support tools:
None

User Interface: None

Use Case 2: Query a Sensor

Precondition:

- Employment of some wireless technology and multiplexing technique for communication between vehicle system processor and the maintenance analysts (O-level).
- Transmitter system is in place at the mechanic location (O-level) to send query signal to the vehicle system processor.
- Query to be sent only if normal periodic upload of data from vehicle system processor to O-level does not take place for a particular subsystem.

Actors:

- Maintenance analyst at O-level
- Sensor

Goal:
To ping/ trigger the vehicle system processor to upload the sensor data stream of the "missing" vehicle subsystem to O-level.

Flow of events:

1 O-level system processor checks O-level database to determine the time stamp on the last reception from a particular subsystem sensor emanating from the vehicle level.
2. (If pre-determined time limit elapsed) O-level system processor retrieves vehicle, subsystem id and criticality index from database.
3. System alerts O-level maintenance analyst
4. O-level system processor initiates query to vehicle system processor about "missing" subsystem sensor and stamps priority code on query (depending on criticality index)
5. O-level system processor queues such outgoing queries depending on the priority code
6. O-level system processor records the query time in database
7 O-level system processor transmits query signal

Alternative Flows:

1. (If time limit not elapsed) System rests

Related Use-Cases: Periodically upload sensor data from black box in each vehicle

Frequency and Levels

Frequency of usage: 10% of use case: "upload sensor data from black box in each vehicle"

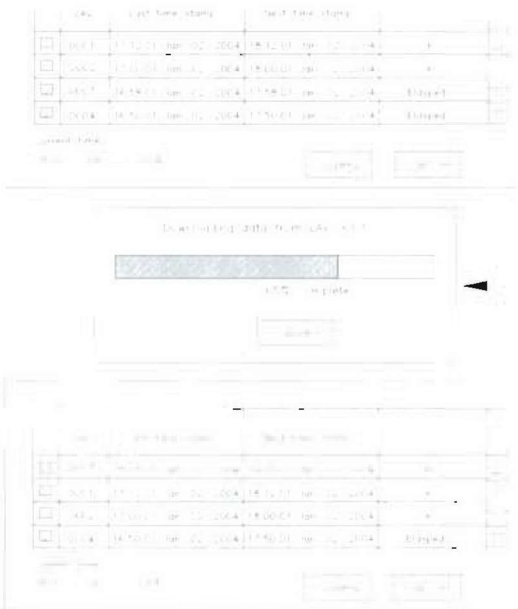
Level of operation: Vehicle C1 ~~M1~~
~~C2 M2~~
~~C3 M3~~

Data Implications

Vehicle → C1 20k
C1 → vehicle: 1k

Algorithms and Decision Support Tools

Algorithms used: O-level database monitoring to determine any "missing" subsystem sensors (sensor signal reception overdue)



Use Case 3: Periodically Upload Sensor Data from Black Box in Each Vehicle

Preconditions:
- Existing wireless technology for communication between the field and the O-level.
- Black box in place at the vehicle to collect the data from multiple sensors in the vehicle.
- Transmitter system in place at the vehicle to transmit sensor signals from the black box.
- Receiver system is in place at the O-level to receive the signals and pre-process.

Actors:
- Vehicle mechanic
- Maintenance analyst at O-level

Goal:
To upload sensor data from each vehicle at predetermined intervals.

Flow of events:
4. Transmitter at the vehicle uploads, at a predetermined time, sensor data collected over the last period, currently specified at 24 hours. (Note: This is the preferred course of action, when the vehicle is engaged in a battle situation and has traveled far from the base.)
5. Receiver at the O-level authenticates the source of the data stream from the field to ensure that it originates from validated vehicle/personnel.
6. The system processor at O-level automatically verifies/decodes the signal from the vehicle (the signal contains the authenticated code).
7. If successful, the O-level maintenance analyst releases the data stream for storage and update of the database. (Note: This step is a manual check to ensure that correct data is

uploaded to the database. Though this has a cost i.e. time, it ensures the integrity of the database.)

Alternative Flow 1:

1. If the vehicle operator notices something wrong with the vehicle but does not know the cause, he/she may initiate an upload from the black box even if it the upload is not due.
2. The remaining steps for a wireless upload remain the same.

Alternative Flow 2:

1. If an upload could not be attempted (e.g. because of being in the battle or out of range from wireless communications) or was not successful for any reason, the black box in the vehicle stores the last 24 hours of the sensor data.
2. At the next predetermined time, the upload is again attempted.
3. The remaining steps for a wireless upload remain the same.

Alternative Flow 3:

1. Every day, a vehicle mechanic visits front where the vehicles are deployed with a notebook. (Note: This is the preferred course of action, when the vehicle has not traveled far from the base and is not in active battle. The desire to present a friendly face to the vehicle crew on a daily basis drives this step.)
2. The vehicle mechanic downloads the contents of the black box from each vehicle into the notebook using a hardwired connection.
3. The vehicle mechanic returns to the base, and connects the Notebook to the database to upload the data to the history database. (Note: No further check from the mechanic is needed – like the last step in the main flow – using this alternative because the data is gathered from the vehicles using a hardwired connection i.e. the integrity of the database is not likely to be compromised.)

Related Use-Cases:
Report out of ordinary event

Frequency and Levels

Frequency of usage:
Once a day for each vehicle

Level of operation:	Vehicle	C1	~~M1~~
		~~C2~~	~~M2~~
		~~C3~~	~~M3~~

Data Implications

Vehicle → C1: 20Mb (data stream from sensors, e.g. date, time, number of vehicle, etc.)
C1 → vehicle: 0.5k (user ID, number, etc.)

Algorithms and Decision Support Tools

Algorithms used:
Authentication procedure to validate data source
Wireless reception and decoding techniques

Decision support tools:
Alert to mechanic at Battalion level of incoming data stream

Use Case 4: Report a Breakdown

Precondition:

- The operator in the vehicle has detected the malfunctioning sub system and determined that he needs assistance from the Battalion level mechanic.
- Existing wireless technology for communication between the field and the Battalion level.
- Transmitter system in place at the vehicle to transmit the breakdown report.
- Receiver system is in place at the Battalion to receive the signals and pre-process.

Actors:

- Vehicle operator

Goal:

To seek assistance from Battalion level in troubleshooting/ diagnosis of the faulty sub system if the vehicle operator is unable to troubleshoot it himself

Flow of events:

1. The vehicle operator describes the breakdown such as the subsystem abnormality observed, time observed and other details as comments. A proposed implementation of this is with a form on a Personal Digital Assistant (PDA) such as a Palmtop PC.
2. The system prompts for information such as vehicle id, date, time, mileage.
3. The system presents a menu of choices for subsystems (e.g. Alternator, Brake Systems, Carburetion) that map to MIMMS codes (available on pages 24-3 to 24-5 of the MIMMS AIS Field Maintenance Procedures User Manual).
4. The operator selects from this menu, and enters further description of the problem, if necessary.
5. The operator 'sends' the form using available wireless technology to the team of mechanics at the Battalion level.

Related Use-Cases:

Process PDA form at the Battalion level

Frequency and Levels

Frequency of usage:
One breakdown per vehicle per week

Level of operation: Vehicle C1 ~~M1~~
~~C2 M2~~
~~C3 M3~~

Data Implications

Vehicle ➔ C1: 20k (vehicle ID, date, time, problem description, etc.)
C1 ➔ vehicle: none

Algorithms and Decision Support Tools

Algorithms used:
System assistance (user prompts) in filling PDA form

Decision support tools:
None (Personal decision by vehicle mechanic)

Use Case 5: Process a Breakdown Report at O-Level

Precondition:

- Breakdown reports are received from a vehicle in the field and authenticated, decoded and available for processing.
- Existing wireless technology for communication between the field and the O level.
- Transmitter system in place at the vehicle to transmit the breakdown from the vehicle.
- Receiver system is in place at the O level to receive the signals and pre-process.

Actors:

- Maintenance analyst at O level

Goal:

To attempt to analyze the information received from the PDA that gives further description about the failure (or impending failure) of the subsystem, with a view to diagnose the problem successfully.

Flow of events:

1. The system stores the received breakdown reports into the database.
2. The system alerts the mechanic about receipt of breakdown reports from vehicles.
3. The system displays a list of breakdowns reported to the mechanic.
4. The mechanic can select a breakdown reported to see further information about it such as the problem description received from the vehicle.
5. The mechanic schedules a mechanic visit to the affected vehicle to perform diagnosis (see "diagnosis of subsystem at O-level")
6. The system stores the schedule and alerts the mechanic, whose responsibility it is to visit the vehicle – either in the field or when the vehicle returns to base.
7. The system stores the status of the breakdowns reported as 'visit scheduled from the mechanic.'

Alternative Flows:

None

Related Use-Cases:

Report out of ordinary event
Authenticate received field signals
Diagnosis of subsystem at O-level

Frequency and Levels

Frequency of usage:

One breakdown per vehicle per week

Level of operation:	~~Vehicle~~	C1	~~M1~~
		~~C2~~	~~M2~~
		~~C3~~	~~M3~~

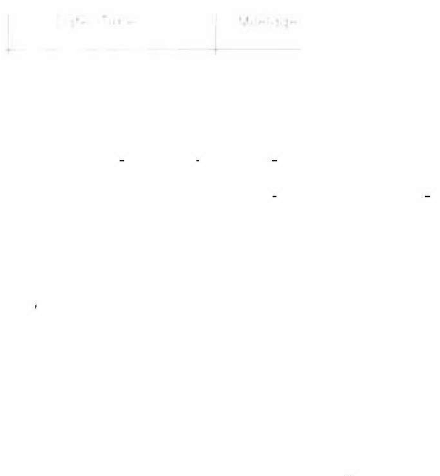
Data Implications

Vehicle → C1 none
C1 → vehicle: none

Algorithms and Decision Support Tools

Algorithms used: O-level database search and retrieval of LAV subsystem data
System analysis algorithm of PDA form, Database update on information received

Decision support tools: Display of analysis results (Front end), Alert to O-level mechanic of analysis results/ potential corrective solutions



Use Case 6: Perform Diagnosis of a Subsystem at O-Level

Precondition:

- Sensor data stream of an vehicle (for the past 24 hours) has been uploaded to the O-level (see use case "Periodically upload sensor data from black box in each vehicle") or

- A breakdown reported from the vehicle operator has been processed at the Battalion level (see use case "Process reported breakdowns at the O-level").

Actors:

- Maintenance person at the O-level

Goal:

- To diagnose the health of a subsystem of an vehicle based on information received from the vehicle (either uploaded data stream or reported breakdown from the vehicle operator) to determine component failure.

Flow of events:

1. The maintenance person at the O-level retrieves vehicle and subsystem information from the database (see precondition above, which indicates the use case, which has previously populated the database).
2. The maintenance person performs a physical inspection of the vehicle, called a Limited Technical Inspection (LTI), which is stored into the database.
3. The maintenance person studies the information retrieved and the LTI to determine the nature of problem (diagnosis) and resolution measures.
4. If the diagnosis is successful, the maintenance person triggers the use case "Initiate Repairs by filling out an Equipment Repair Order (ERO)."
5. If he is unable to diagnose, he triggers the use case "Escalate diagnosis from O-level to I-level" and this use case stops.
6. System records the action in database, and tags the vehicle as 'waiting for maintenance.'

Alternative Flows:
None

Related Use-Cases:

- Periodically upload sensor data from black box in each vehicle
- Process a breakdowns report at the O-level
- Initiate Repairs by filling out an Equipment Repair Order (ERO)
- Escalate diagnosis from O-level to I-level

Frequency and Levels

Frequency of usage:
One breakdown per vehicle per week

Level of operation: ~~Vehicle~~	C1	M1
	~~C2~~	~~M2~~
	~~C3~~	~~M3~~

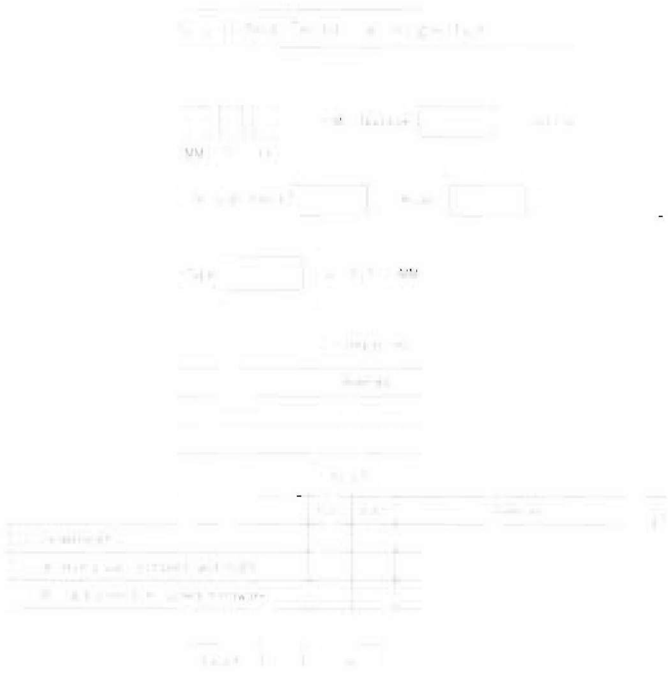
Data Implications

C1 → M1: 20k (processed information for the vehicle)
M1 → C1: 20k (ERO description)

Algorithms and Decision Support Tools

Algorithms used: Database updates on entering of action taken.

Decision support tools: View historical and previous diagnosis data for each component.



Use Case 7: Escalate Diagnosis from O-Level to I-Level

Precondition:
- Existing wireless technology for communication between the O-level and the I-level.
- Maintenance person at the O-level has failed to diagnose the problem with the vehicle.

Actors:
- Maintenance person at the O-level

Goal:
To enlist help from the I-level in diagnosing a problem that cannot be diagnosed at the O-level.

Flow of events:
1. The mechanics at the O-level uploads sensor data stream and supplementary information (e.g. the breakdown report), if any to the I-level.
2. The information uploaded is stored in the database for retrieval by the maintenance person at the I-level.
3. If the mechanics decides to keep the vehicle at the O-level, it is tagged as awaiting diagnosis from the I-level, and the information is recorded in the database.
4. If the mechanics decides that the faulty subsystem should be physically shipped to the I-level, the vehicle is tagged as awaiting diagnosis and repairs from the I-level, the subsystem is physically sent to the I-level, and the information is recorded in the database.
5. If the mechanics that the vehicle should be physically shipped to the I-level, it is tagged as awaiting diagnosis/repairs from the I-level, sent to the I-level, and the information is recorded in the database.

Alternative Flows:
None

Related Use-Cases:
Perform diagnosis at O-level
Perform diagnosis at I-level

Frequency and Levels

Frequency of usage:
10% of frequency of use case 5

Level of operation:	~~Vehicle~~	C1	~~M1~~
		C2	~~M2~~
		~~C3~~	~~M3~~

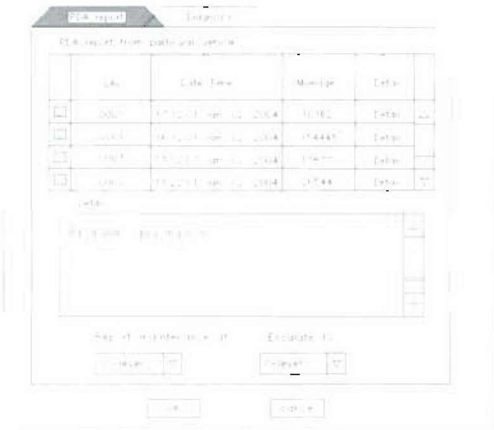
Data Implications

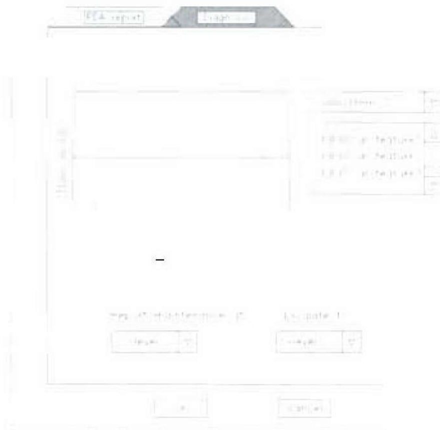
C1 → C2: 50k (vehicle ID, date, time, problem description, prognosis results, etc.)
C2 → C1: none

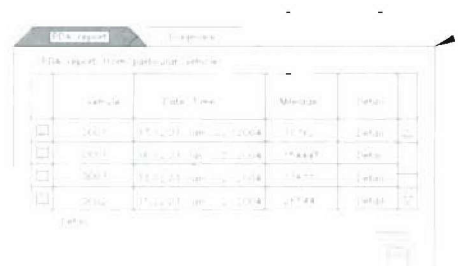
Algorithms and Decision Support Tools

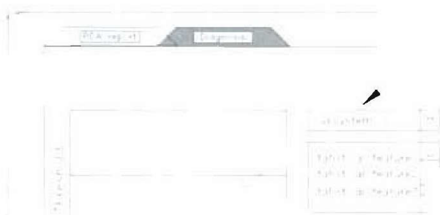
Algorithms used: Data uploads on manual triggers (Diagnosis fails at O-level)

Decision support tools: Diagnosis results at O-level









Use Case 8: Perform Diagnosis of a Subsystem at the I-Level

Precondition:

- The O-level has escalated the diagnosis to the I-level (see use case "Escalate diagnosis to I-level) i.e. sensor data stream (for the past 24 hours) and the breakdown report, if any, have been uploaded to the I-level
- It is possible that the vehicle or the subsystem have also been shipped to the I-level though this is not necessary because the O-level may be simply waiting for diagnosis to be sent back to them so they can perform the maintenance.

Actors:

- Maintenance person at I-level

Goal:

- To diagnose the health of a subsystem of an vehicle based on information received from the vehicle (either uploaded data stream or reported breakdown from the vehicle operator) to determine component failure, because it was not possible to perform the diagnosis at the O-level and the I-level may have additional facilities to perform diagnosis

Flow of events:

7. The maintenance person at the I-level retrieves vehicle and subsystem information from the database (see precondition above, which indicates the use case, which has previously populated the database).
8. The maintenance person at the I-level studies the information received from the O-level to determine the nature of problem (diagnosis) and resolution measures.
9. The maintenance person sends the diagnosis results to the O-level and this use case stops.
10. If he is unable to diagnose, he triggers the use case "Escalate diagnosis from I-level to D-level (including sea-base)" and this use case stops.

Alternative Flow 1:

2. If the vehicle or the subsystem was also physically shipped, the maintenance person at the I-level performs a physical inspection, called a Limited Technical Inspection (LTI), which is stored into the database.
3. The maintenance person at the I-level studies the information received from the O-level along with the LTI performed in the previous step to determine the nature of problem (diagnosis) and resolution measures.
4. If he is unable to diagnose, he triggers the use case "Escalate diagnosis from I-level to D-level (including sea-base)" and this use case stops.
5. If the diagnosis is successful, the maintenance person triggers use case: "Trigger maintenance action at I-level."
6. System records the action in database, and tags the vehicle as 'waiting for maintenance.'

Related Use-Cases:

- Escalate diagnosis from O-level to I-level
- Escalate diagnosis from I-level to D-level
- Trigger maintenance action by I level

Frequency and Levels

Frequency of usage: TBD
One breakdown per vehicle per week

Level of operation: ~~Vehicle C1 M1~~
C2 M2
~~C3 M3~~

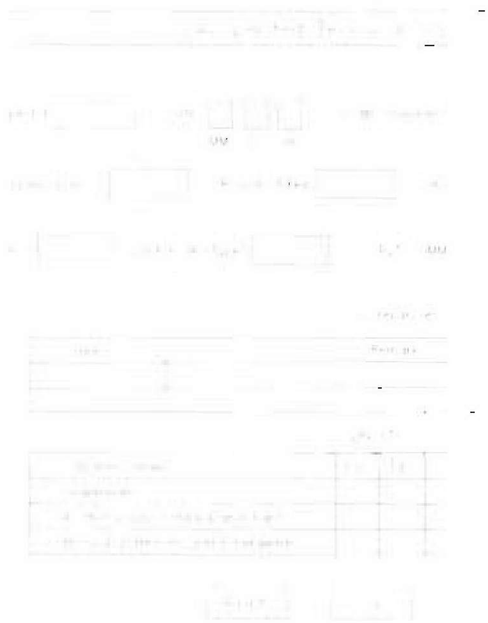
Data Implications

C2 → M2: 20k (processed information for the vehicle)
M2 → C2: 20k (ERO description)

Algorithms and Decision Support Tools

Algorithms used: Database updates on entering of action taken.

Decision support tools: View historical and previous diagnosis data for each component.



Use Case 9: Escalate Diagnosis from I-Level to D-Level

Precondition:

- Existing wireless technology for communication between the I-level and the D-level.
- Maintenance person at the O-level has failed to diagnose the problem with the vehicle.

Actors:

- Maintenance analyst at I-level

Goal: To enlist help from the D-level in diagnosing a problem that cannot be diagnosed at the I-level.

Flow of events:

1. The maintenance analyst at the I-level uploads sensor data stream and supplementary information (e.g. the breakdown report), if any to the I-level.
2. The information uploaded is stored in the database for retrieval by the maintenance analyst at the D-level.
3. If the maintenance analyst decides to keep the vehicle at the I-level, it is tagged as awaiting diagnosis from the D-level, and the information is recorded in the database.
4. If the maintenance analyst decides that the faulty subsystem should be physically shipped to the D-level, the vehicle is tagged as awaiting diagnosis and repairs from the D-level, the subsystem is physically sent to the D-level, and the information is recorded in the database.
5. If the maintenance analyst decides that the vehicle should be physically shipped to the D-level, it is tagged as awaiting diagnosis/repairs from the D-level, sent to the D-level, and the information is recorded in the database.

Alternative Flows:

None

Related Use-Cases: Diagnosis of subsystem at I-level, Diagnosis of subsystem at D-level

Frequency and Levels

Frequency of usage:
10% of frequency of use case 8:"Performs diagnosis of a subsystem at the I-level"

Level of operation:	~~Vehicle~~	~~C1~~	~~M1~~
		C2	~~M2~~
		C3	~~M3~~

Data Implications

C2 → C3: 50k (vehicle ID, date, time, problem description, prognosis results, etc.)
C3 → C2: none

Algorithms and Decision Support Tools

Algorithms used: Data uploads on manual triggers (Diagnosis fails at I level)

Decision support tools: Diagnosis results at I level

Algorithms and Decision Support Tools

Algorithms used: Data uploads on manual triggers (Diagnosis fails at I-level)

Decision support tools: Diagnosis results at I-level

Use Case 10: Perform Diagnosis of a Subsystem at the D-Level

Precondition:

- The I level has escalated the diagnosis to the D level (see use case "Escalate diagnosis to D-level) i.e. sensor data stream (for the past 24 hours) and the breakdown report, if any, have been uploaded to the I-level
- It is possible that the vehicle or the subsystem have also been shipped to the D-level though this is not necessary because the Battalion level may be simply waiting for diagnosis to be sent back to them so they can perform the maintenance.

Actors:

- Maintenance person at D-level

Goal:

- To diagnose the health of a subsystem of an vehicle based on information received from the vehicle (either uploaded data stream or reported breakdown from the vehicle operator) to determine component failure, because it was not possible to perform the diagnosis at the I-level and the D-level may have additional facilities to perform diagnosis

Flow of events:

11 The maintenance person at the D-level retrieves vehicle and subsystem information from the database (see precondition above, which indicates the use case, which has previously populated the database).

12. The maintenance person at the D-level studies the information received from the I-level to determine the nature of problem (diagnosis) and resolution measures.

13. The maintenance person sends the diagnosis results to the I-level and this use case stops.

Alternative Flow 1:

7 If the vehicle or the subsystem was also physically shipped, the maintenance person at the D-level performs a physical inspection, called a Limited Technical Inspection (LTI), which is stored into the database.

8. The maintenance person at the D-level studies the information received from the I-level along with the LTI performed in the previous step to determine the nature of problem (diagnosis) and resolution measures.

9. If the diagnosis is successful, the maintenance person <u>triggers use case: "Trigger maintenance action at D-level."</u>

10. System records the action in database, and tags the vehicle as 'waiting for maintenance.'

Related Use-Cases:

- Escalate diagnosis from I-level to D-level
- Trigger maintenance action by D level

Frequency and Levels

Frequency of usage: TBD
10% of frequency of use case 8:"Performs diagnosis of a subsystem at the I-level"

Level of operation: ~~Vehicle~~ ~~C1~~ ~~M1~~
~~C2~~ ~~M2~~
C3 ~~M3~~

Data Implications

C3: none

Algorithms and Decision Support Tools

Algorithms used: Database updates on entering of action taken.

Decision support tools: View historical and previous diagnosis data for each component.

Use Case 11: Perform Prognosis of the Health of a Subsystem at O-Level

Precondition:

- Sensor data stream of a vehicle (for the past 24 hours) has been uploaded to the O-level

Actors:

- Maintenance analyst at O-level

Goal:

- To attempt to prognostic the health of a vehicle subsystem based on subsystem sensor data stream that has been recorded into the database in the past 24 hours.

Flow of events:

14. The maintenance analyst at the O-level retrieves vehicle and subsystem information from the database.
15. The system processor checks database to determine critical parameters and failure range for the sub system.
16. The system processor extracts appropriate critical parameters from sensor data stream.
17. The system processor checks if extracted parameters fall in failure range.
18. If extracted parameters fall in failure range; the system processor alerts the O-level mechanic.
19. The system processor time stamps sensor data stream reception and records it as well as other messages e.g. threshold breach, mechanic alert etc. in the central database.

Alternative Flows:

5. If extracted parameters do not fall in failure range; the system processor continues recording data stream

Related Use-Cases:
- Periodically upload sensor data from black box in each vehicle
- Perform diagnosis of a subsystem at the O-level

Frequency and Levels

Frequency of usage:
Once a day

Level of operation: ~~Vehicle~~ C1 ~~M1~~
~~C2~~ ~~M2~~
~~C3~~ ~~M3~~

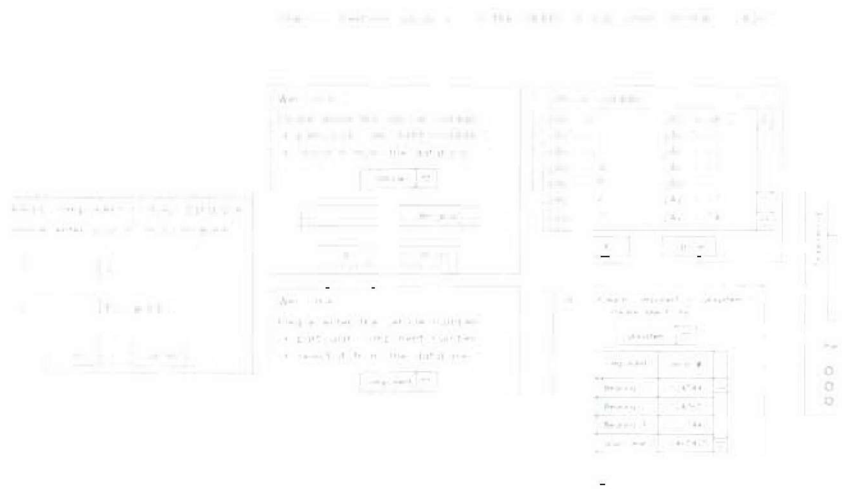
Data Implications

C1 none

Algorithms and Decision Support Tools

Algorithms used: Threshold detection in subsystem sensor data stream, Data stream storage in LAV database, Database search and retrieval of subsystem details, Extraction of critical parameters from sensor data stream

Decision support tools: Visual representations of the critical parameters being monitored in the sensor data stream (Front end) and other subsystem details to vehicle mechanic, Alert to vehicle mechanic when breach occurs



Use Case 12: Initiate CBM by Filling the ERO at the O-Level

Precondition:
- Prognosis of a subsystem has been performed at the battalion level, it has been determined repairs will be performed (see use case "Do prognostic of a subsystem at the battalion level"), and the information has been stored in the database.

Actors:
- Maintenance person at the O-level

Goal:
- To initiate condition-based maintenance based on prognosis results.

Flow of events:

20. The maintenance person at the Battalion level retrieves information about the vehicle and the prognosis from the database (see use case completed in the precondition)
21. The maintenance person opens a new Equipment Repair Order (ERO) for the work to be performed based on the diagnosis.
22. A new ERO is created in the database.
23. The maintenance person determines what work must be performed based on the prognosis and enters the status and code for each item of work to be performed. Additional information required for the ERO is also entered.
24. The information is stored in the database.
25. The maintenance person checks the inventory and manpower available to him at the O-level.
26. The maintenance person enters the SM&R code to indicate the characteristic of maintenance that need to be performed.
27. If either the parts or the tools or the manpower are not available, he triggers futuristic scenarios for collaborating with neighboring Battalions or the FSSG (reported elsewhere).
28. Based on the results of the previous step, the maintenance person fills out the ERO Shopping List (EROSL) for parts that must be acquired for performing the maintenance action. The EROSL is created and stored in the database.

Related Use-Cases:
- Do prognostic of a subsystem at I level

Frequency and Levels

Frequency of usage:
10% of frequency for use case 11: "Perform prognosis of the health of a subsystem at O-level"

Level of operation:	~~Vehicle~~	C1	M1
		~~C2~~	~~M2~~
		~~C3~~	~~M3~~

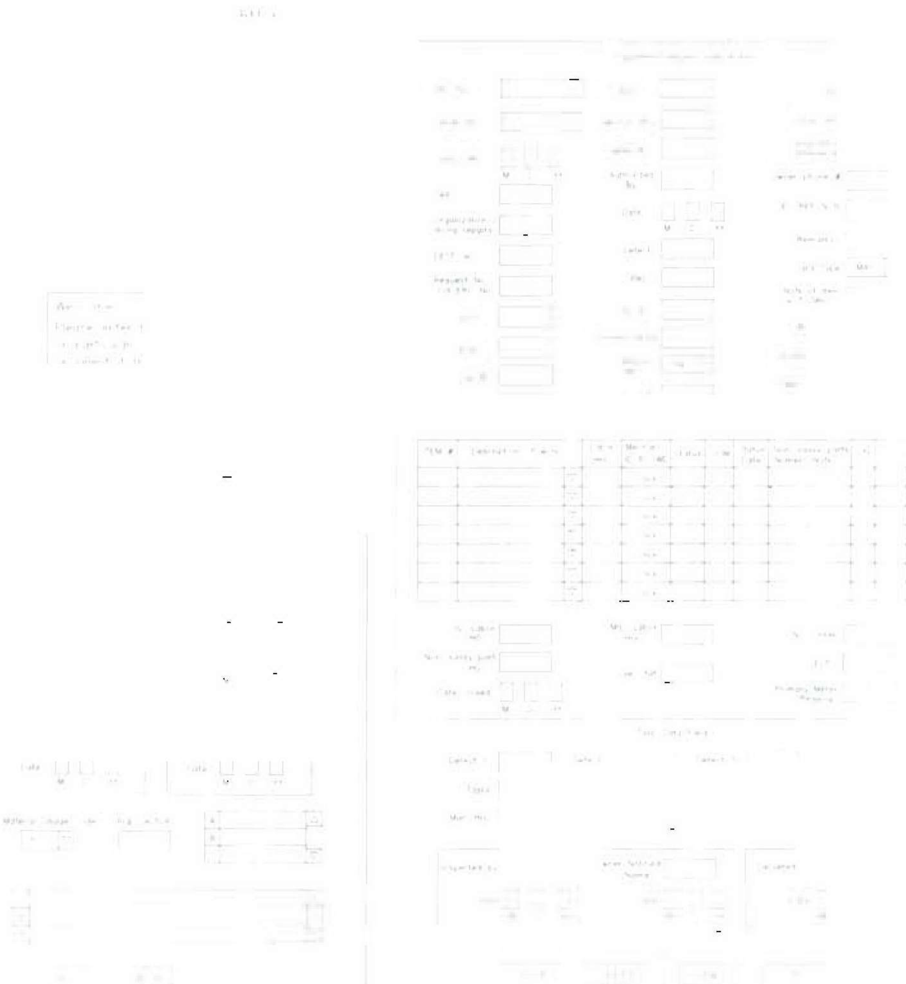
Data Implications

C1 → M1: 20k (prognosis result from database)
M1 → C1. 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None



Use Case 13: Perform Prognosis of Subsystem at I-Level

Precondition:
- Sensor data stream of a vehicle (for the past 24 hours) has been uploaded to the I-level

Actors:
- Maintenance analyst at I level

Goal:
- To attempt to prognostic the health of a vehicle subsystem based on subsystem sensor data stream that has been recorded into the database in the past 24 hours.

Flow of events:

29. The maintenance analyst at the I-level retrieves vehicle and subsystem information from the database.
30. The system processor checks database to determine critical parameters and failure range for the sub system.
31. The system processor extracts appropriate critical parameters from sensor data stream.
32. The system processor checks if extracted parameters fall in failure range.
33. If extracted parameters fall in failure range; vehicle system processor alerts the I level mechanic.
34. The system processor time stamps sensor data stream reception and records it as well as other messages e.g. threshold breach, mechanic alert etc. in the central database.

Alternative Flows:

6. If extracted parameters do not fall in failure range; the system processor continues recording data stream

Related Use-Cases: perform diagnosis of a subsystem at the I level

Frequency and Levels

Frequency of usage:
Once a day

Level of operation: ~~Vehicle~~ ~~C1~~ ~~M1~~
C2 ~~M2~~
~~C3~~ ~~M3~~

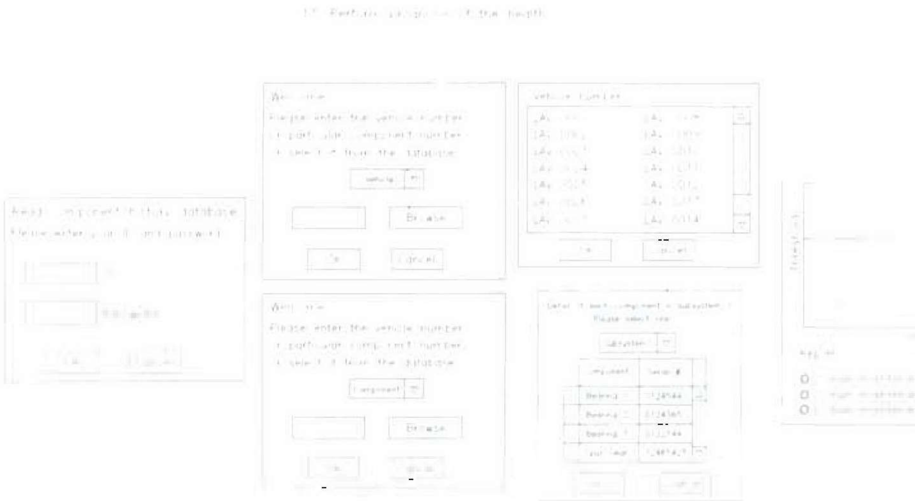
Data Implications

C2: none

Algorithms and Decision Support Tools

Algorithms used: Threshold detection in subsystem sensor data stream, Data stream storage in LAV database, Database search and retrieval of subsystem details, Extraction of critical parameters from sensor data stream

Decision support tools: Visual representations of the critical parameters being monitored in the sensor data stream (Front end) and other subsystem details to LAV mechanic, Alert to LAV mechanic when breach occurs



Use Case 14: Initiate CBM Action by Filling the ERO at I-Level

Precondition:

- Prognosis of a subsystem has been performed at I level, it has been determined repairs will be performed (see use case "Do prognostic of a subsystem at I level"), and the information has been stored in the database.

Actors:

- Maintenance person at the I level

Goal:

- To initiate condition-based maintenance based on prognosis results.

Flow of events:

35. The maintenance person at the I level retrieves information about the vehicle and the prognosis from the database (see use case completed in the precondition)
36. The maintenance person opens a new Equipment Repair Order (ERO) for the work to be performed based on the diagnosis.
37 A new ERO is created in the database.
38. The maintenance person determines what work must be performed based on the prognosis and enters the status and code for each item of work to be performed. Additional information required for the ERO is also entered.
39. The information is stored in the database.
40. The maintenance person checks the inventory and manpower available to him at the I-level.
41 The maintenance person enters the SM&R code to indicate the characteristic of maintenance that need to be performed.
42. If either the parts or the tools or the manpower are not available, he triggers futuristic scenarios for collaborating with neighboring Battalions or the FSSG (reported elsewhere).
43. Based on the results of the previous step, the maintenance person fills out the ERO Shopping List (EROSL) for parts that must be acquired for performing the maintenance action. The EROSL is created and stored in the database.

Related Use-Cases:

- Do prognostic of a subsystem at I level

Frequency and Levels

Frequency of usage:
10% of frequency for use case 13: "Perform prognosis of the health of a subsystem at I-level"

Level of operation: ~~Vehicle C1 M1~~
C2 M2
~~C3 M3~~

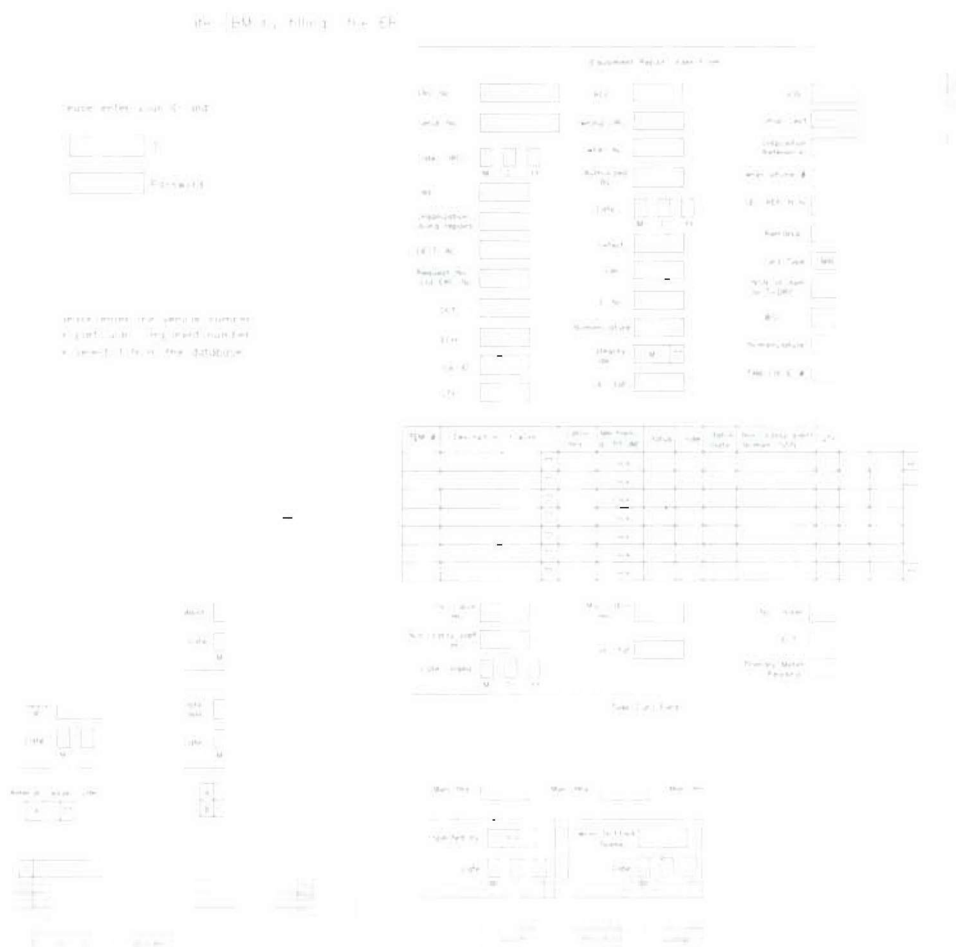
Data Implications

C2 ➔ M2: 20k (prognosis result from database)
M2 ➔ C2: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None



Use Case 15: Perform Prognosis of Subsystem at D-Level

Precondition:
- Sensor data stream of a vehicle (for the past 24 hours) has been uploaded to the D level

Actors:
- Maintenance analyst at D level

Goal:
- To attempt to prognostic the health of a vehicle subsystem based on subsystem sensor data stream that has been recorded into the database in the past 24 hours.

Flow of events:

44. The maintenance analyst at the D level retrieves vehicle and subsystem information from the database.
45. The system processor checks database to determine critical parameters and failure range for the sub system.
46. The system processor extracts appropriate critical parameters from sensor data stream.
47. The system processor checks if extracted parameters fall in failure range.
48. If extracted parameters fall in failure range; vehicle system processor alerts the D level mechanic.
49. The system processor time stamps sensor data stream reception and records it as well as other messages e.g. threshold breach, mechanic alert etc. in the central database.

Alternative Flows:

6. If extracted parameters do not fall in failure range; vehicle system processor continues recording data stream

Related Use-Cases: Diagnosis of subsystem at vehicle level

Frequency and Levels

Frequency of usage:
Once a day

Level of operation:	~~Vehicle~~	~~C1~~	~~M1~~
		~~C2~~	~~M2~~
		C3	~~M3~~

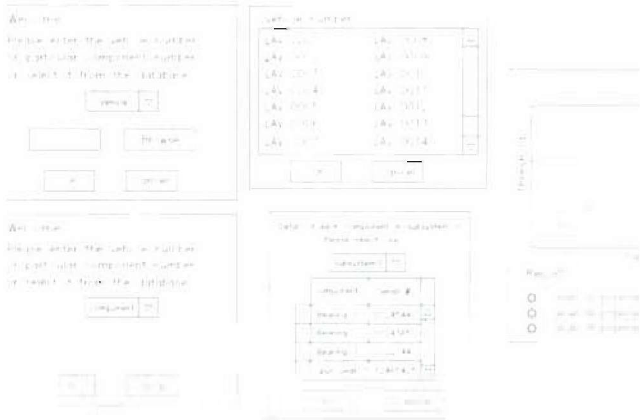
Data Implications

C3: none

Algorithms and Decision Support Tools

Algorithms used: Threshold detection in subsystem sensor data stream, Data stream storage in LAV database, Database search and retrieval of subsystem details, Extraction of critical parameters from sensor data stream

Decision support tools: Visual representations of the critical parameters being monitored in the sensor data stream (Front end) and other subsystem details to LAV mechanic, Alert to LAV mechanic when breach occurs



Use Case 16: Initiate CBM Action by Filling ERO at D-Level

Precondition:
- Prognosis of a subsystem has been performed at the D level, it has been determined repairs will be performed (see use case "Perform diagnosis of a subsystem at the battalion level"), and the information has been stored in the database.

Actors:
- Maintenance person at the D level

Goal:
- To initiate condition-based maintenance based on prognosis results.

Flow of events:
50. The maintenance person at the D level retrieves information about the LAV and the diagnosis from the database (see use case completed in the precondition)
51. The maintenance person opens a new Equipment Repair Order (ERO) for the work to be performed based on the diagnosis.
52. A new ERO is created in the database.
53. The maintenance person determines what work must be performed based on the prognosis and enters the status and code for each item of work to be performed. Additional information required for the ERO is also entered.
54. The information is stored in the database.
55. The maintenance person checks the inventory and manpower available to him at the D-level.
56. The maintenance person enters the SM&R code to indicate the characteristic of maintenance that need to be performed.
57. If either the parts or the tools or the manpower are not available, he triggers futuristic scenarios for collaborating with neighboring Battalions or the FSSG (reported elsewhere).

58. Based on the results of the previous step, the maintenance person fills out the ERO Shopping List (EROSL) for parts that must be acquired for performing the maintenance action. The EROSL is created and stored in the database.

Related Use-Cases:

- Do prognostic of a subsystem at I level

Frequency and Levels

Frequency of usage:
10% of frequency for use case 15: "Perform prognosis of the health of a subsystem at D-level"

Level of operation~~: Vehicle C1 M1~~
~~C2 M2~~
C3 M3

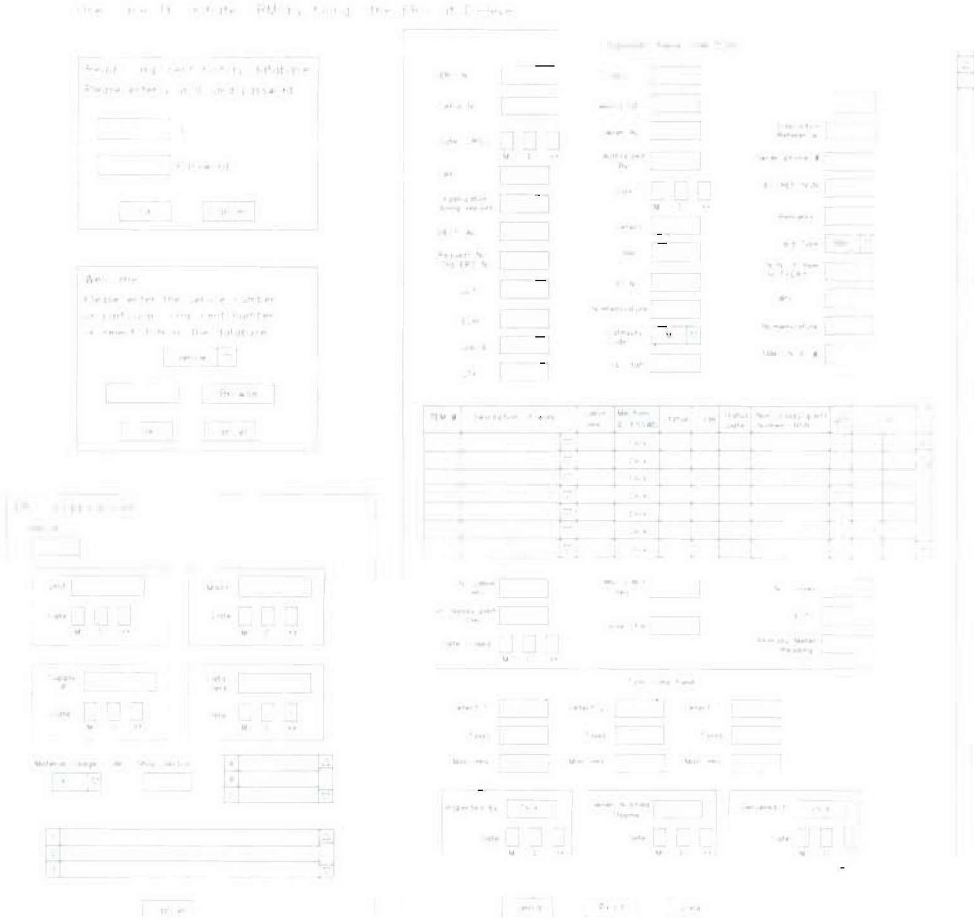
Data Implications

C3 ➔ M3: 20k (prognosis result from database)
M3 ➔ C3: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None



Use Case 17: Direct Vehicle Movement

Precondition:

- Prognosis has been performed on the vehicle (see use case 11 "perform prognosis of subsystem at O-level")
- It has been determined that CBM will be performed on the vehicle (See use case 12 "Initiate CBM by filling the ERO at O-level")
- The vehicle can be stopped in the field for repair or maintenance.

Actors:

- Maintenance analyst at the O-level
- Maintenance person at the O-level

Goal:

To direct a vehicle in the field to a specific location for anticipated repairs prognosis.

Flow of events:

59. The maintenance analyst at the O-level retrieves the ERO created by the maintenance person (see use case 12 "Initiate CBM by filling the ERO at O-level")
60. If either the parts or the tools or the manpower are not available, he triggers futuristic scenarios for collaborating with neighboring Battalions or the FSSG (reported elsewhere).
61. The maintenance analyst chooses a location where s/he would ask the vehicle to move based on its current location and direction (provided by the system).

62. The maintenance analyst sends a message to the vehicle to move to that location.

Related Use-Cases:

- Perform prognosis of a subsystem at the O-level

Frequency and Levels

Frequency of usage:
10% of frequency for use case 11 "Perform prognosis of the health of a subsystem at O-level"

Level of operation:	Vehicle	C1	M1
		~~C2~~	~~M2~~
		~~C3~~	~~M3~~

Data Implications

Vehicle → C1: none
C1 → vehicle: 0.5k (location name)
C1 → M1: none
M1 → C1: 20k (ERO description, ID, password, location to perform maintenance action.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None

Use Case 18: Dispatch Crew and Resources for Repair/Maintenance

Precondition:
- Vehicle has been directed to a location for repair (see use case 17: "direct vehicle movement").

Actors:
- Maintenance analyst at O-level
- Maintenance person at O-level

Goal:
To successfully perform the maintenance action based on information given

Flow of events:

1 The maintenance analyst assigns the maintenance person to perform the repair
2. The maintenance person reads the expected location of the vehicle from the system (see use case 17: "direct vehicle movement")
3. The system alerts the maintenance personnel and dispatches them to the location along with required parts and tools.
4. The system records the dispatch.

Alternative Flows:
None

Related Use-Cases:
- Direct vehicle movement

Frequency and Levels

Frequency of usage:
10% of frequency for use case 11: "Perform prognosis of the health of a subsystem at O-level"

Level of operation:	~~Vehicle~~	C1	M1
		~~C2~~	~~M2~~
		~~C3~~	~~M3~~

Data Implications

C1 ➔ M1. 20k (the message to the maintenance person at O-level)
M1 ➔ C1 0

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None

Use Case 19: Initiate Repairs of Vehicle at O-Level

Precondition:

- Diagnosis of a subsystem has been performed at the O-level, it has been determined repairs will be performed (see use case "Perform diagnosis of a subsystem at the O-level"), and the information has been stored in the database.

Actors:

- Maintenance person at the O-level

Goal:

- To successfully inspect the problems that occurs in the vehicle and fills the problem into the ERO form.

Flow of events:

63. The maintenance person at the O-level retrieves information about the vehicle and the diagnosis from the database (see use case completed in the precondition)
64. The maintenance person opens a new Equipment Repair Order (ERO) for the work to be performed based on the diagnosis. A new ERO is created in the database.
65. The maintenance person determines what work must be performed based on the diagnosis and enters the status and code for each item of work to be performed. Additional information required for the ERO is also entered. The information is stored in the database.
66. The maintenance person checks the inventory and manpower available to him at the O-level.
67. The maintenance person enters the SM&R code to indicate the characteristic of maintenance that need to be performed.
68. If either the parts or the tools or the manpower are not available, he triggers futuristic scenarios for collaborating with neighboring O-level or the FSSG (reported elsewhere).
69. Based on the results of the previous step, the maintenance person fills out the ERO Shopping List (EROSL) for parts that must be acquired for performing the maintenance action. The EROSL is created and stored in the database.

Related Use-Cases:

- Perform diagnosis of a subsystem at the O-level

Frequency and Levels

Frequency of usage:
90% of use case 6 (perform diagnosis of subsystem at O-level)

Level of operation: ~~Vehicle~~ C1 M1
~~C2~~ ~~M2~~
~~C3~~ ~~M3~~

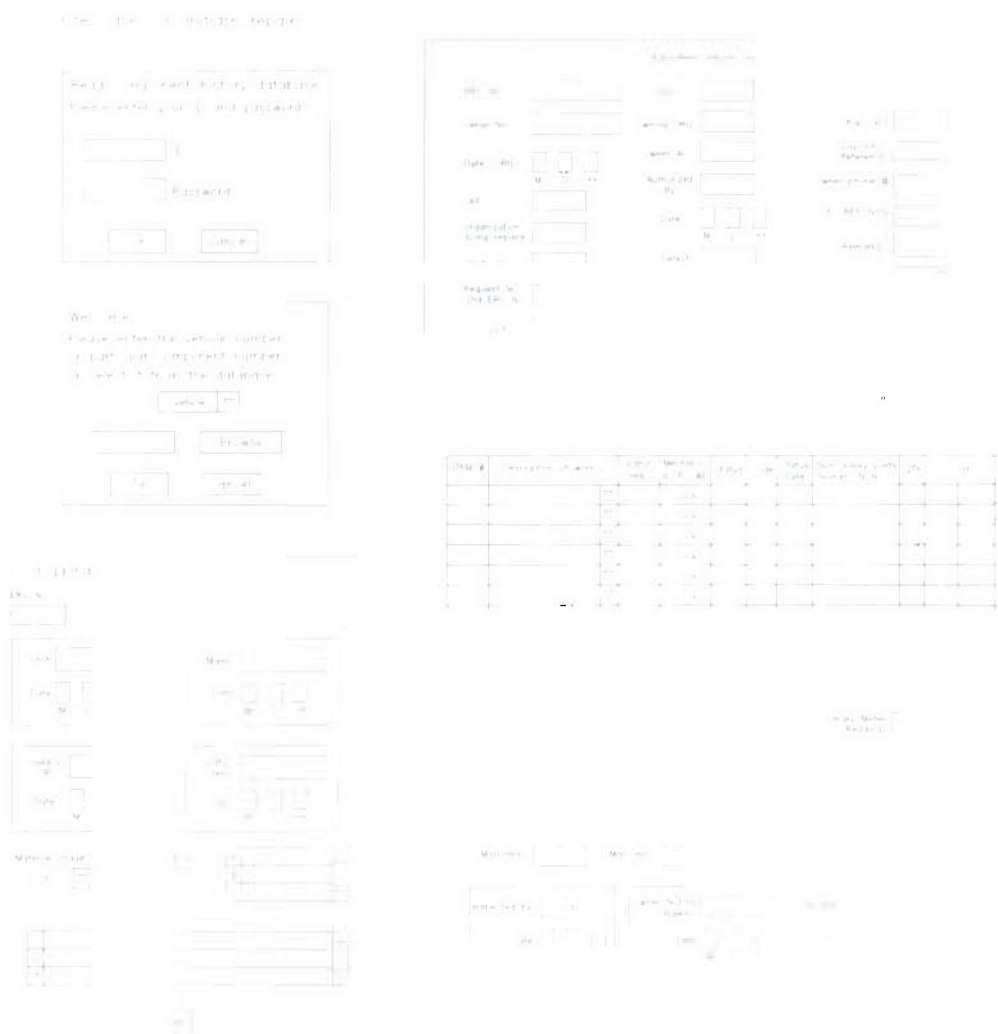
Data Implications

C1 → M1: 20k (diagnosis result from database)
M1 → C1: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used:

Decision support tools:



Use Case 20: Perform Maintenance Action at the O-Level

Precondition:
- The problem at the vehicle has been diagnosed either at the O-level (see use case "Perform diagnosis at O-level") or a level above (see use case "Perform diagnosis at the I-level")
- The maintenance person has already filled the ERO and specified the characteristic of the maintenance to be performed by filling the SM&R code (see use case 19: "initiate repair of vehicle at O level")

Actors:
- Maintenance personnel at the O level

Goal:
To successfully perform the maintenance action based on information given

Flow of events:

1. The maintenance person retrieves the diagnosis result that has been diagnosed from the database.
2. The maintenance person examines the information from the LTI that has been specified along with MIMMS codes prior the maintenance action.
3. The maintenance person performs the maintenance action based on information given.
4. The maintenance person tags the repaired tag into the vehicle and also fills the ERO form to indicate the maintenance actions that has been performed.
5. The system updates the database

Alternative Flows:
None

Related Use-Cases:
- Initiate repair of vehicle at O-level

Frequency and Levels

Frequency of usage:
Same as use case 19 (initiate repair of vehicle at O-level)

Level of operation: ~~Vehicle~~ C1 M1
~~C2 M2~~
~~C3 M3~~

Data Implications

C1 → M1: 20k (diagnosis result from database)
M1 → C1: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None

Use Case 21: Initiate Repairs of Vehicle at I-Level

Precondition:

- Diagnosis of a subsystem has been performed at the I-level, it has been determined repairs will be performed (see use case "Perform diagnosis of a subsystem at the I level"), and the information has been stored in the database.

Actors:

- Maintenance person at the I-level

Goal:

- To successfully inspect the problems that occurs in the vehicle and fills the problem into the ERO form.

Flow of events:

70. The maintenance person at the I level retrieves information about the vehicle and the diagnosis from the database (see use case completed in the precondition)

71. The maintenance person opens a new Equipment Repair Order (ERO) for the work to be performed based on the diagnosis. A new ERO is created in the database.
72. The maintenance person determines what work must be performed based on the diagnosis and enters the status and code for each item of work to be performed. Additional information required for the ERO is also entered. The information is stored in the database.
73. The maintenance person checks the inventory and manpower available to him at the I-level.
74. The maintenance person enters the SM&R code to indicate the characteristic of maintenance that need to be performed.
75. If either the parts or the tools or the manpower are not available, he triggers futuristic scenarios for collaborating with neighboring Battalions or the FSSG (reported elsewhere).
76. Based on the results of the previous step, the maintenance person fills out the ERO Shopping List (EROSL) for parts that must be acquired for performing the maintenance action. The EROSL is created and stored in the database.

Related Use-Cases:

- Perform diagnosis of a subsystem at the I level

Frequency and Levels

Frequency of usage:
90% of use case 8 (perform diagnosis of subsystem at I-level)

Level of operation:	~~Vehicle~~	~~C1~~	~~M1~~
		C2	M2
		~~C3~~	~~M3~~

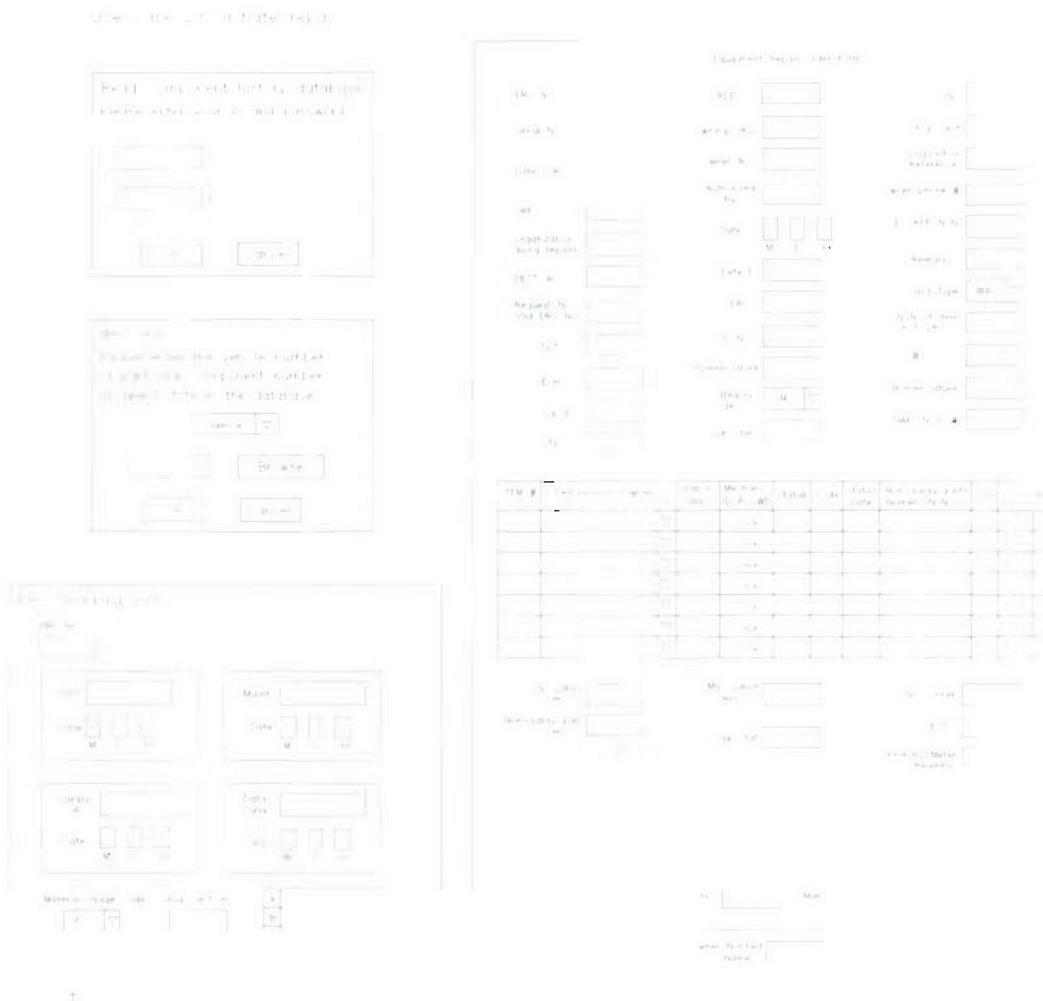
Data Implications

C2 → M2: 20k (diagnosis result from database)
M2 → C2: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None



Use Case 22: Perform Maintenance Action at the I-Level

Precondition:

- The problem at the vehicle has been diagnosed either at the I-level (see use case "Perform diagnosis at I-level") or a level above (see use case "Perform diagnosis at the D-level")
- The maintenance person has already filled the ERO and specified the characteristic of the maintenance to be performed by filling the SM&R code (see use case 19: "initiate repair of vehicle at I-level")

Actors:

- Maintenance person at the I-level

Goal:

To successfully perform the maintenance action based on information given

Flow of events:

6. The maintenance person retrieves the diagnosis result that has been diagnosed from the database.
7. The maintenance person examines the information from the LTI that has been specified along with MIMMS codes prior the maintenance action.
8. The maintenance person performs the maintenance action based on information given.
9. The maintenance person tags the repaired tag into the vehicle and also fills the ERO form to indicate the maintenance actions that has been performed.
10. The system updates the database

Alternative Flows:
None

Related Use-Cases:
- Initiate repair of vehicle at I-level

Frequency and Levels

Frequency of usage:

Level of operation:	~~Vehicle~~	~~C1~~	~~M1~~
		C2	M2
		~~C3~~	~~M3~~

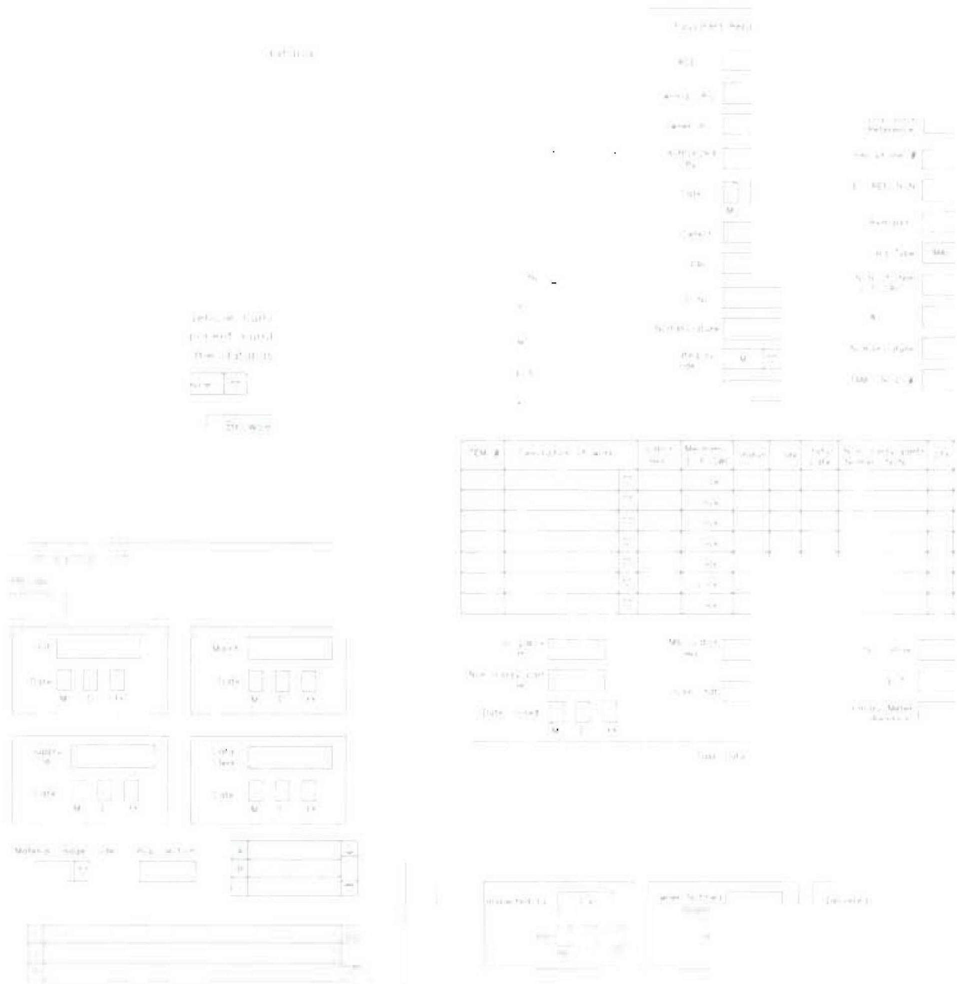
Data Implications

C2 ➔ M2: 20k (diagnosis result from database)
M2 ➔ C2: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None



Use Case 23: Initiate Repairs of Vehicle at D-Level

Precondition:

- Diagnosis of a subsystem has been performed at the D level, it has been determined repairs will be performed (see use case "Perform diagnosis of a subsystem at the D level"), and the information has been stored in the database.

Actors:

- Maintenance person at the D level

Goal:

To successfully inspect the problems that occurs in the vehicle and fills the problem into the ERO form.

Flow of events:

77. The maintenance person at the Battalion level retrieves information about the vehicle and the diagnosis from the database (see use case completed in the precondition)

78. The maintenance person opens a new Equipment Repair Order (ERO) for the work to be performed based on the diagnosis. A new ERO is created in the database.
79. The maintenance person determines what work must be performed based on the diagnosis and enters the status and code for each item of work to be performed. Additional information required for the ERO is also entered. The information is stored in the database.
80. The maintenance person checks the inventory and manpower available to him at the D-level.
81. The maintenance person enters the SM&R code to indicate the characteristic of maintenance that need to be performed.
82. If either the parts or the tools or the manpower are not available, he triggers futuristic scenarios for collaborating with neighboring Battalions or the FSSG (reported elsewhere).
83. Based on the results of the previous step, the maintenance person fills out the ERO Shopping List (EROSL) for parts that must be acquired for performing the maintenance action. The EROSL is created and stored in the database.

Related Use-Cases:
- Perform diagnosis of a subsystem at the D level

Frequency and Levels

Frequency of usage:
Same as use case 10 (perform diagnosis of subsystem at D-level)

Level of operation: ~~Vehicle C1 M1~~
~~C2 M2~~
C3 M3

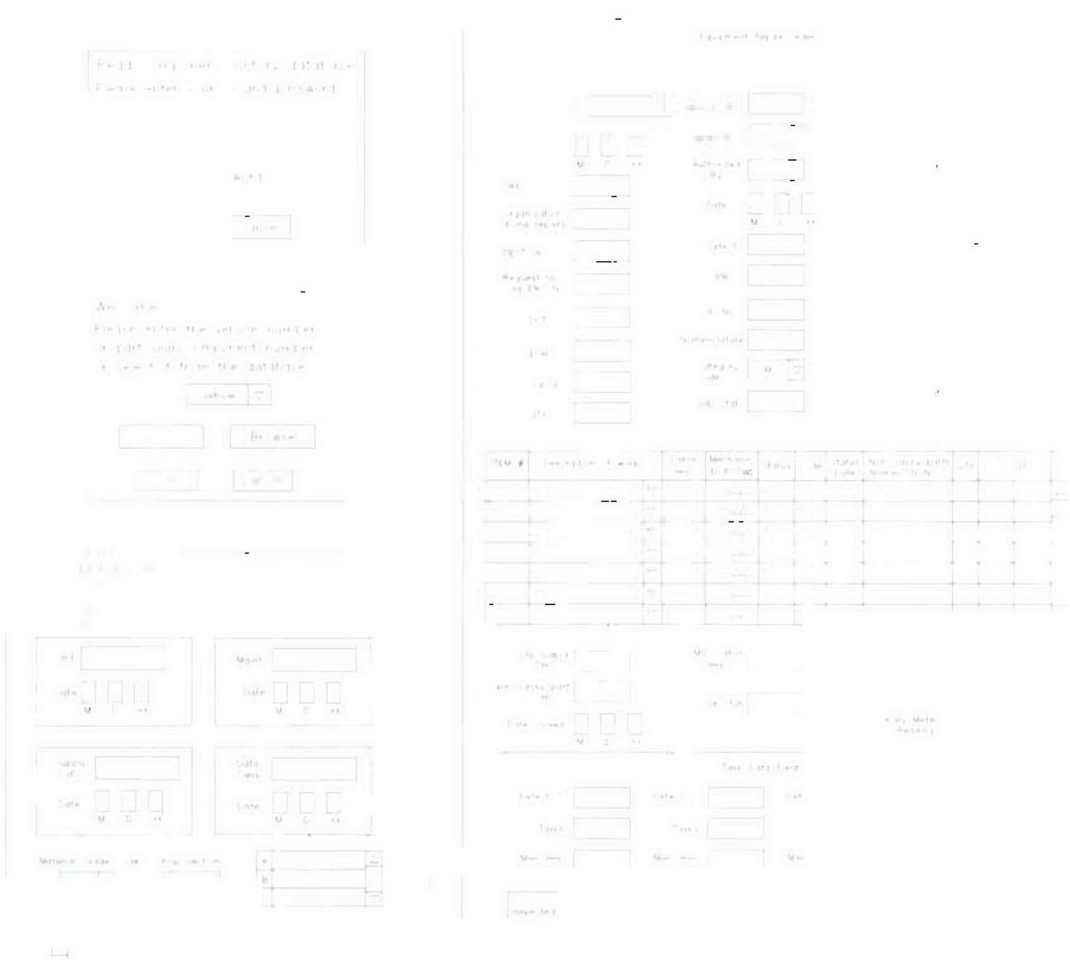
Data Implications

C3 → M3: 20k (diagnosis result from database)
M3 → C3: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: none



Use Case 24: Perform Maintenance Action at the D-Level

Precondition:

- The problem at the vehicle has been diagnosed either at the D-level (see use case "Perform diagnosis at D-level")
- The maintenance person has already filled the ERO and specified the characteristic of the maintenance to be performed by filling the SM&R code (see use case 19: "initiate repair of vehicle at I-level")

Actors:

- Maintenance personnel at the D-level

Goal:

To successfully perform the maintenance action based on information given

Flow of events:

11. The maintenance person retrieves the diagnosis result that has been diagnosed from the database.
12. The maintenance person examines the information from the LTI that has been specified along with MIMMS codes prior the maintenance action.
13. The maintenance person performs the maintenance action based on information given.
14. The maintenance person tags the repaired tag into the vehicle and also fills the ERO form to indicate the maintenance actions that has been performed.
15. The system updates the database

Alternative Flows:
None

Related Use-Cases:
- Initiate repair of vehicle at D-level

Frequency and Levels

Frequency of usage:
Same as use case 10 (perform diagnosis of subsystem at D-level)

Level of operation:	~~Vehicle~~	~~C1~~	~~M1~~
		~~C2~~	~~M2~~
		C3	M3

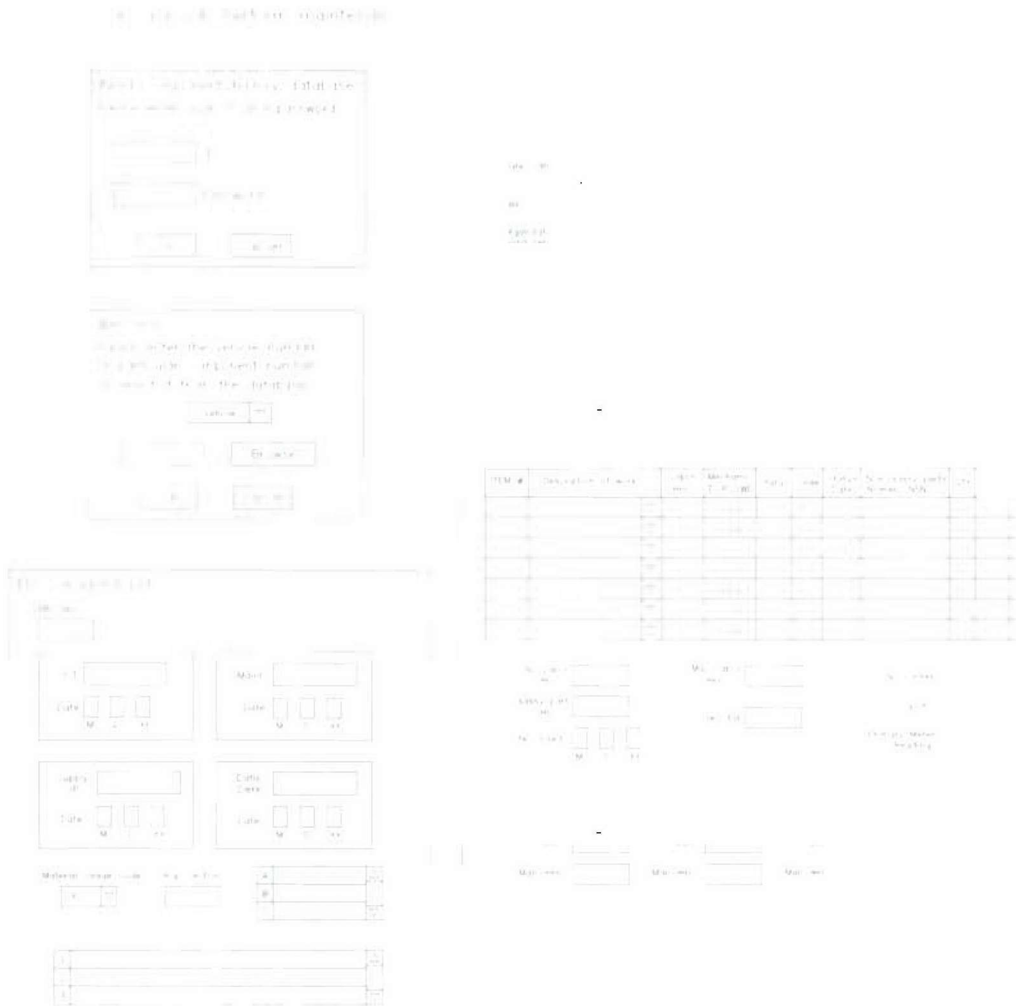
Data Implications

C3 → M3: 20k (diagnosis result from database)
M3 → C3: 20k (ERO description, ID, password, etc.)

Algorithms and Decision Support Tools

Algorithms used: None

Decision support tools: None



Use Case 25: View Health of a Vehicle at O-Level

Precondition:
The IDGE system (at various levels) is monitoring the health status of a subsystem/component in the vehicle and storing this data in the component history database as well as all the previous diagnosis results and other component level details.

Actors:
- Maintenance analyst at O-level
- Commander of platoon/company/battalion in field

Goal:
To allow viewing history of a component or subsystem or a vehicle including past diagnosis results, component specifications and other details. The use case allows the actor to move from an vehicle perspective to a component perspective and vice versa.

Flow of events:

1 The actor logs into the history database to view history/diagnosis results.
2. System asks for the vehicle id.
3. The actor may browse vehicle id numbers displayed by the system.
4. Actor provides the vehicle id to the system either by entering the id or by clicking on one of the displayed id's.
5. System displays the list of components/subsystems along with basic information within the vehicle selected.
6. Actor selects a component/subsystem by clicking the desired component/subsystem.
7. System computes basic statistical measures (e.g. averages) based on information contained in the database, as necessary.
8. System displays history, including diagnoses, inspection performed, vehicle mileage, and maintenance performed, of that component/subsystem along with any basic statistical features computed in the previous step.

Related Use-Cases:
View health summary of vehicle at O-level

Frequency and Levels

Frequency of usage:
Five times a day for each vehicle

Level of operation: ~~Vehicle~~ C1 M1
~~C2 M2~~
~~C3 M3~~

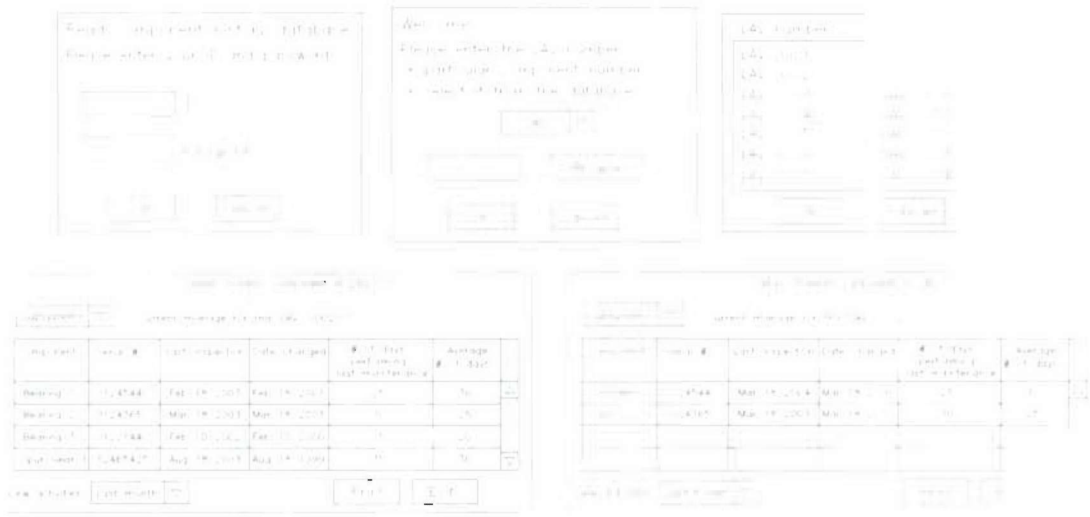
Data Implications

C1 → M1: 20k (diagnosis result from database, avg. mean time between failure of vehicle, etc.)/1 vehicle
M1 → C1 0.5k (ID, password, etc.)/1 vehicle

Algorithms and Decision Support Tools

Algorithms used:
Database search and retrieval of vehicle component details

Decision support tools:
Display of results (Front end)



Use Case 26: View Health of a Vehicle at I-Level

Precondition:
The IDGE system (at various levels) is monitoring the health status of a subsystem/component in the vehicle and storing this data in the component history database as well as all the previous diagnosis results and other component level details.

Actors:
- Maintenance analyst at I level
- Commander of division/FSSG in field

Goal:
To allow viewing history of a component or subsystem or a vehicle including past diagnosis results, component specifications and other details. The use case allows the actor to move from an vehicle perspective to a component perspective and vice versa.

Flow of events:
1 The actor logs into the history database to view history/diagnosis results.
2. System asks for the vehicle id.
3. The actor may browse vehicle id numbers displayed by the system.
4. Actor provides the vehicle id to the system either by entering the id or by clicking on one of the displayed ids.
5. System displays the list of components/subsystems along with basic information within the vehicle selected.
6. Actor selects a component/subsystem by clicking the desired component/subsystem.
7. System computes basic statistical measures (e.g. averages) based on information contained in the database, as necessary.
8. System displays history, including diagnoses, inspection performed, vehicle mileage, and maintenance performed, of that component/subsystem along with any basic statistical features computed in the previous step.

Related Use-Cases:
View health summary of vehicle at I level

Frequency and Levels

Frequency of usage:
Five times a day for each vehicle

Level of operation: ~~Vehicle C1 M1~~
C2 M2
~~C3 M3~~

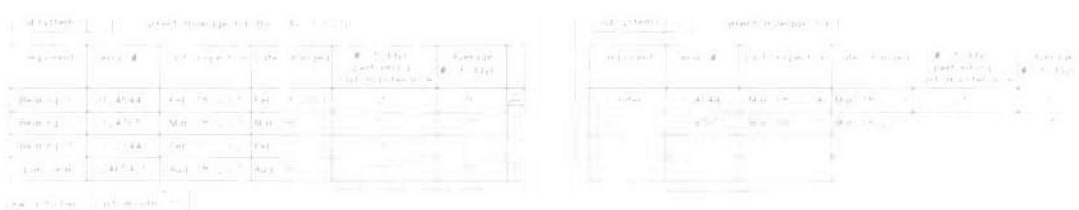
Data Implications

C2 → M2: 20k (diagnosis result from database, avg. mean time between failure of vehicle, etc)/1 vehicle
M2 → C2: 0.5k (ID, password, etc.)/1 vehicle

Algorithms and Decision Support Tools

Algorithms used:
Database search and retrieval of vehicle component details

Decision support tools:
Display of results (Front end)



Use Case 27: View Health of a Vehicle at D-Level

Precondition:
The IDGE system (at various levels) is monitoring the health status of a subsystem/component in the vehicle and storing this data in the component history database as well as all the previous diagnosis results and other component level details.

Actors:

- Mechanics at D level
- Commander of brigade

Goal:
To allow viewing history of a component or subsystem or a vehicle including past diagnosis results, component specifications and other details. The use case allows the actor to move from a vehicle perspective to a component perspective and vice versa.

Flow of events:
1 The actor logs into the history database to view history/diagnosis results.
2. System asks for the vehicle id.
3. The actor may browse vehicle id numbers displayed by the system.
4. Actor provides the vehicle id to the system either by entering the id or by clicking on one of the displayed id's.
5. System displays the list of components/subsystems along with basic information within the vehicle selected.
6. Actor selects a component/subsystem by clicking the desired component/subsystem.
7 System computes basic statistical measures (e.g. averages) based on information contained in the database, as necessary.
8. System displays history, including diagnoses, inspection performed, vehicle mileage, and maintenance performed, of that component/subsystem along with any basic statistical features computed in the previous step.

Related Use-Cases:
View health summary of vehicle at D level

Frequency and Levels

Frequency of usage:
Five times a day for each vehicle

Level of operation: ~~Vehicle C1 M1~~
~~C2 M2~~
C3 M3

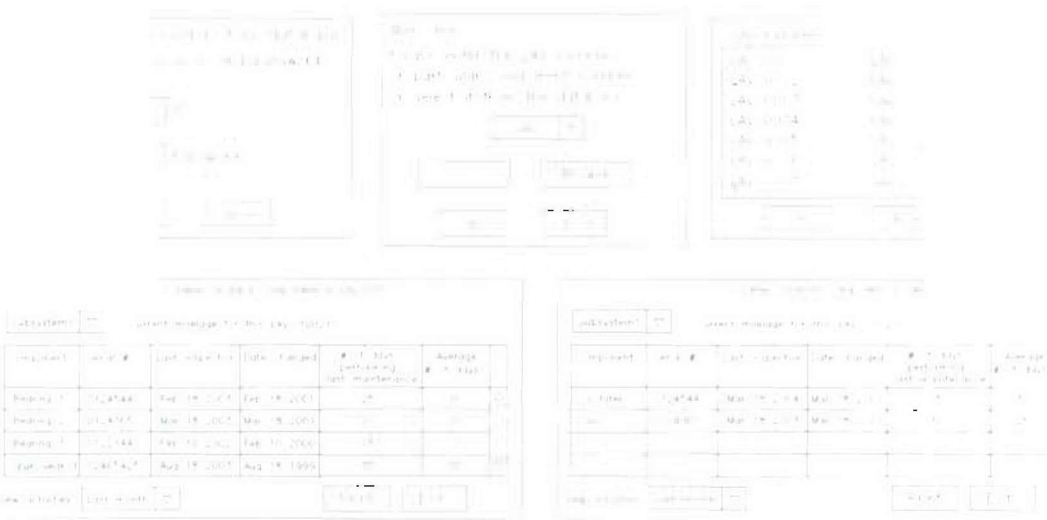
Data Implications

C3 → M3: 20k (diagnosis result from database, avg. mean time between failure of vehicle. etc)/1 vehicle
M3 → C3: 0.5k (ID, password, etc.)/1 vehicle

Algorithms and Decision Support Tools

Algorithms used:
Database search and retrieval of vehicle component details

Decision support tools:
Display of results (Front end)



Use Case 28: View Health Summary of Vehicle at O-Level

Precondition:

The IDGE system (at various levels) is monitoring the health status of a subsystem/component in the vehicle and storing this data in the component history database as well as all the previous diagnosis results and other component level details.

Actors:

- Maintenance analyst at O-level
- Commander of platoon/company/battalion in field

Goal:

To allow viewing history of a component or subsystem or a vehicle including past diagnosis results, component specifications and other details. The use case allows the actor to move from a vehicle perspective to a component perspective and vice versa.

Flow of events:

1 The actor logs into the history database to view history/diagnosis results.
2. System asks for the <u>component/subsystem id</u>.
3. The actor may browse component/subsystem id numbers and descriptions displayed by the system.
4. Actor provides the component/subsystem id to the system either by entering the id or by clicking on one of the displayed id's.
5. System displays summary information about all instances of that component/subsystem that are currently installed.
6. If additional history is needed, the system prompts the Actor to enter a period (e.g. last month, last quarter, last year etc.)
7. System computes basic statistical measures based on information contained in the database, as necessary.
8. System displays summary information (history, including diagnoses, inspection performed, and maintenance performed) including basic statistical measures about all instances of that component/subsystem over the period selected by the actor.

Related Use-Cases:

View health of a vehicle at O-level

Frequency and Levels

Frequency of usage:
Five times a day for each vehicle

Level of operation: ~~Vehicle~~ C1 M1
~~C2 M2~~
~~C3 M3~~

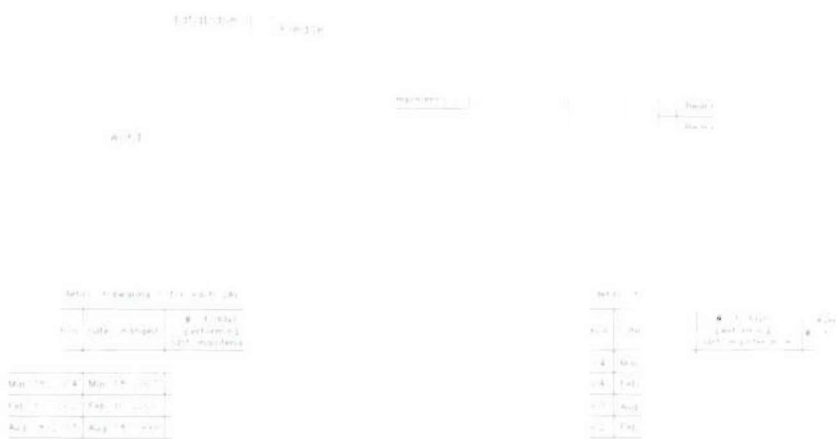
Data Implications

C1 → M1: 20k (diagnosis result from database, avg. days of maintenance performance etc.)/1 vehicle
M1 → C1 0.5k (ID, password, etc.)/1 vehicle

Algorithms and Decision Support Tools

Algorithms used:
Database search and retrieval of vehicle component details

Decision support tools:
Display of results (Front end)



Use Case 29: View Health Summary of Vehicle at I-Level

Precondition:

The IDGE system (at various levels) is monitoring the health status of a subsystem/component in the vehicle and storing this data in the component history database as well as all the previous diagnosis results and other component level details.

Actors:

- Maintenance analyst at I level
- Commander of division/FSSG in field

Goal:
To allow viewing history of a component or subsystem or a vehicle including past diagnosis results, component specifications and other details. The use case allows the actor to move from a vehicle perspective to a component perspective and vice versa.

Flow of events:
1. The actor logs into the history database to view history/diagnosis results.
2. System asks for the component/subsystem id.
3. The actor may browse component/subsystem id numbers and descriptions displayed by the system.
4. Actor provides the component/subsystem id to the system either by entering the id or by clicking on one of the displayed ids.
5. System displays summary information about all instances of that component/subsystem that are currently installed.
6. If additional history is needed, the system prompts the Actor to enter a period (e.g. last month, last quarter, last year etc.)
7. System computes basic statistical measures based on information contained in the database, as necessary.
8. System displays summary information (history, including diagnoses, inspection performed, and maintenance performed) including basic statistical measures about all instances of that component/subsystem over the period selected by the actor.

Related Use-Cases:
View health of a vehicle at I level

Frequency and Levels

Frequency of usage:
Once a day for each vehicle

Level of operation: ~~Vehicle C1 M1~~
C2 M2
~~C3 M3~~

Data Implications

C2 → M2: 20k (diagnosis result from database, avg. days of maintenance performance etc.)/1 vehicle
M2 → C2: 0.5k (ID, password, etc.)/1 vehicle

Algorithms and Decision Support Tools

Algorithms used:
Database search and retrieval of vehicle component details

Decision support tools:
Display of results (Front end)

Use Case 30: View Health Summary of Vehicle at D-Level

Precondition:
The IDGE system (at various levels) is monitoring the health status of a subsystem/component in the vehicle and storing this data in the component history database as well as all the previous diagnosis results and other component level details.

Actors:
- Mechanics at D level
- Commander of brigade

Goal:
To allow viewing history of a component or subsystem or a vehicle including past diagnosis results, component specifications and other details. The use case allows the actor to move from an vehicle perspective to a component perspective and vice versa.

Flow of events:
1. The actor logs into the history database to view history/diagnosis results.
2. System asks for the component/subsystem id.
3. The actor may browse component/subsystem id numbers and descriptions displayed by the system.
4. Actor provides the component/subsystem id to the system either by entering the id or by clicking on one of the displayed ids.
5. System displays summary information about all instances of that component/subsystem that are currently installed.
6. If additional history is needed, the system prompts the Actor to enter a period (e.g. last month, last quarter, last year etc.)
7. System computes basic statistical measures based on information contained in the database, as necessary.

8. System displays summary information (history, including diagnoses, inspection performed, and maintenance performed) including basic statistical measures about all instances of that component/subsystem over the period selected by the actor.

Related Use-Cases:
View health of a vehicle at D level

Frequency and Levels

Frequency of usage:
Five times a day for each vehicle

Level of operation: ~~Vehicle~~ ~~C1~~ ~~M1~~
~~C2~~ ~~M2~~
C3 M3

Data Implications

C3 → M3: 20k (diagnosis result from database, avg. days of maintenance performance etc.)/1 vehicle
M3 → C3: 0.5k (ID, password, etc.)/1 vehicle

Algorithms and Decision Support Tools

Algorithms used:
Database search and retrieval of LAV component details

Decision support tools:
Display of results (Front end)

Use Case 31: Trigger Request Management

Precondition:
The mechanics at particular maintenance level checks the availability of the component that needs to be repaired or changed.

Actors:
- Maintenance person at O level
- Maintenance person at I level
- Maintenance person at D level
- Request Management Manager

Goal: To support the needs of components by the mechanics at a particular level of maintenance.

Flow of events

1. The mechanic in particular maintenance level check the availability of the component in the warehouse or through the component availability database
2. If (component = available) the mechanic takes the component from the warehouse and update the remaining number of components into the inventory database.

Alternative Flows:

2. If (component = unavailable) the mechanic requests for the component online to the Request Management Manager.
3. The Request Management Manager updates the order activity into the inventory database.

Related Use Cases:
Perform maintenance actions at O, I, and D level

Frequency and Levels

Frequency of usage: (to be determined based on how the futuristic scenario are implemented. Therefore, this is not part of the data implication analysis)

Level of operation: ~~Vehicle~~	~~C1~~	M1
	~~C2~~	M2
	~~C3~~	M3

Data Implications

M1, M2, M3: (to be determined based on how the futuristic scenario are implemented. Therefore, this is not part of the data implication analysis)

Algorithms and Decision Support Tools

Algorithm Used: request for the availability of the component, upload the remain number of the component into the inventory database

Decision Support Tools: display the availability of the particular component at particular level.

8.4.2 Aggregate Data Transmission Implications

The following represents the aggregate data transmission implications if the use cases are implemented as envisioned and are used with frequencies suggested by the interviewees. The data implications below represent aggregates for each day. The notation used in the table below mirrors the levels we have identified in each use case: C1 through C3, M1 through M3 and the vehicle level. These in turn capture the three echelons of maintenance and are further described in Section 4.1.5 of this final report.

From	To	Total (kb)
Vehicle	C1	20040
C1	Vehicle	2
C1	M1	140
M1	C1	101
C1	C2	50
C2	C1	0
C2	M2	120
M2	C2	81
C2	C3	50
C3	C2	0
C3	M3	100
M3	C3	61

The intermediate products that lead to the above aggregated data requirements are shown below as a spreadsheet. The spreadsheet with the computation formulae is available as an attachment to this final report as file name: computing-data-aggregates.xls

Use case #	Use case name	From	To	Size of data (kb)	Frequency/day	size of fleet
1	Record from sensor and store in black box	Vehicle	Vehicle	21600	1	100
						100
2	Query a sensor	Vehicle	C1	20	0.1	100
		C1	Vehicle	1		100
3	Periodically upload sensor data from black box in each vehicle	Vehicle	C1	20000	1	100
		C1	Vehicle	0.5		100
4	Report a breakdown	Vehicle	C1	20	0.14	100
		C1	Vehicle	0		100
5	Process a breakdown report at O-level	C1	C1		0.14	100
						100
6	Perform diagnosis of a subsystem at the O-level	C1	M1	20	0.14	100
		M1	C1	20		100
7	Escalate diagnosis from O-level to I-level	C1	C2	50	0.014	100
		C2	C1	0		100
8	Perform diagnosis of a subsystem at the I-level	C2	M2	20	0.014	100
		M2	C2	20		100
9	Escalate diagnosis from I-level to D-level	C2	C3	50	0.0014	100
		C3	C2	0		100
10	Perform diagnosis of a subsystem at the D-level	C2	C2	0	0.0014	100
						100
11	Perform prognosis of subsystem at O-level	C1	C1	0	1	100
						100
12	Initiate CBM by filling the ERO at O-level	C1	M1	20	0.1	100
		M1	C1	20		100
13	Perform prognosis of subsystem at I-level	C2	C2	0	1	100
						100
14	Initiate CBM by filling the ERO at I-level	C2	M2	20	0.1	100
		M2	C2	20		100
15	Perform prognosis of subsystem at D-level	C3			1	100
						100
16	Initiate CBM by filling the ERO at D-level	C3	M3	20	0.1	100
		M3	C3	20		100
17	Direct vehicle	Vehicle	C1	0	0.1	100

Use case #	Use case name	From	To	Size of data (kb)	Frequency/day	size of fleet
	movement	C1	Vehicle	0.5		100
		C1	M1	0		100
		M1	C1	20		100
18	Dispatch maintenance crew and resources for preventive repair and maintenance	C1	M1	20	0.1	100
		M1	C1	0		100
19	Initiate repair of vehicle at O-level	C1	M1	20	0.13	100
		M1	C1	20		100
20	Perform maintenance action at O-level	C1	M1	20	0.13	100
		M1	C1	20		100
21	Initiate repair of vehicle at I-level	C2	M2	20	0.0129	100
		M2	C2	20		100
22	Perform maintenance action at I-level	C2	M2	20	0.0129	100
		M2	C2	20		100
23	Initiate repair of vehicle at D-level	C3	M3	20	0.0014	100
		M3	C3	20		100
24	Perform maintenance action at D-level	C3	M3	20	0.0014	100
		M3	C3	20		100
25	View health of vehicle at O-level	C1	M1	20	5	100
		M1	C1	0.5		100
26	View health of vehicle at I-level	C2	M2	20	5	100
		M2	C2	0.5		100
27	View health of vehicle at D-level	C3	M3	20	5	100
		M3	C3	0.5		100
28	View health summary of vehicle at O-level	C1	M1	20	5	100
		M1	C1	0.5		100
29	View health summary of vehicle at I-level	C2	M2	20	5	100
		M2	C2	0.5		100
30	View health summary of vehicle at D-level	C3	M3	20	5	100
		M3	C3	0.5		100
31	Trigger request management	See futuristic scenarios elsewhere				100
						100

8.5 Review of Prognostics and Health Management Systems

Robust diagnostic systems for complex mechanical systems have been the focus of an enormous amount of research over the past 30 years. Turbo-shaft engines, transmissions, and lubrication systems are simply a few examples of targeted applications of CBM technology. A review of current health monitoring and diagnostic systems has shown that military applications are the driving force behind the majority of current research and development in this area.

In 1997 the US Army's General Officer Steering Committee, anchored by a three-star general, directed the establishment of a strategy now known as the Army Diagnostic Improvement Plan (ADIP) that supports a variety of Army-wide initiatives, including Army After Next, Force XXI, Joint Vision 2010 and Global Combat Support System – Army [1]. The improvement plan consists of three basic thrusts, outlined below.

1. (Near-term) Target legacy platforms with existing monitoring capabilities for the incorporation of diagnostic systems,
2. (Mid-term) Transition to anticipatory maintenance system via enhanced maintenance/logistics automation technologies, and
3. (Long-term) Full prognostic maintenance capability designed into future combat systems.

The ADIP vision involves wireless sensor technology that provides real-time connectivity of critical combat systems to the logistical framework of the Army, providing an anticipatory maintenance and logistic capability. While this plan advocates portable diagnostic equipment for maintainers, such as the Soldier's Portable On-system Repair Tool (SPORT) and the Aviation Turbine Engine Diagnostic System (ATEDS), it is more focused on the development of embedded diagnostic systems. These systems incorporate technical manuals and other maintenance tools in an interactive electronic format, Systems that have already been targeted include the AH-64D Apache, the UH-60A/L Blackhawk, the CH-47F Chinook, the M1A2 Abrams, the M2A3 Bradley Fighting Vehicle and the HET (Heavy Equipment Transporter). A prototype embedded prognostic system (Real-time Engine Diagnostics-Prognostics, REDI-PRO) using artificial neural networks has been developed for the AGT-1500 gas turbine engine that drives the M1A2 main battle tank. Future combat systems such as the Comanche scout helicopter and the Crusader self-propelled howitzer were also being developed with built in diagnostic systems, prior to the termination of their programs in May of 2004 and 2002, respectively.

The Army Aviation and Applied Technology Directorate (AATD) have been involved in several research programs that include diagnostics among their main thrusts. These include the following [2]:

- Future Transport Rotorcraft (FTR)
- Joint Turbine Advanced Gas Generator (JTAGG)
- Advanced Rotorcraft Transmission II (ART II)

- Rotorcraft Drive System for the 21st Century (RDS-21)
- Common Engine Program (CEP)
- Digital Aviation Logistics – Prototype (DAL - P)

Associated with CEP, FTR and JTAGG is the Integrated High Performance Turbine Engine Technology (IHPTET) program, which is a DOD sponsored program with involvement from numerous industry and government agencies [3]. A similar program with much more emphasis on prognostic capabilities is the Versatile Affordable Advanced Turbine Engine (VAATE) program, which has two seven-year phases that run through 2010 and 2017, respectively. The ambitious research under this program includes damage avoidance control, life-extending control, data-fusion techniques for proactive maintenance, turbine blade crack detection and virtual component performance tracking [4]. NASA's Ultra-Efficient Engine Technology (UEET) research is in collaboration with the DOD IHPTET and VAATE programs and is making contributions in the area of wireless relay of health monitoring data to ground stations and advanced sensing technologies [5].

The high-profile F-35 Joint Strike Fighter (JSF) is being designed with comprehensive prognostics and health management (PHM) systems. The importance of designing the entire PHM (both on-board and off-board) in cooperation with the initial design and development was realized through past failures (in regards to the lack of consideration for diagnostics during the initial system design) with numerous military aircraft. While aircraft such as the AV-8B, F/A-18, T-45, E2 and F-14 had some diagnostics designed during development, the lack of a suitable off-board data management infrastructure meant that data analysis and the development of robust diagnostic techniques became practically unachievable. Due to inadequate comparisons of limited archived data, little confidence was placed in such systems [6]. Unlike its predecessors, the JSF development process includes a comprehensive PHM-integrated ground station and logistical supply system known as the Autonomic Logistics System [7]. Such a system will allow for component usage and maintenance action tracking and comparisons across the squadron and fleet levels. The JSF program is the most recent application of PHM technology, and will be the most advanced system of its kind. Every component that warrants prognostics, based on safety requirements and cost benefit analyses, will be covered by the system. The goals of the JSF PHM, as specified by the Navy, is the reduction of life cycle costs and maintenance man hours per flight [6], but also includes the streamlined integration of maintenance logistics to the operational environment [8].

The V-22 Osprey program is another high profile platform that is being designed with diagnostics and prognostics in mind. The V-22 Vibration Structural Life and Engine Diagnostics (VSLED) system has already demonstrated the ability to consistently identify hanger bearing faults and aided in the troubleshooting of excessive nacelle vibration. An engine diagnostic system is currently in development with plans to monitor the entire transmission system [9].

The application of diagnostics to rotorcraft systems is not a recent development. The first rotorcraft Health and Usage Monitoring Systems (HUMS) were developed to improve safety and reliability of rotorcraft operating in the North Sea, transporting offshore oil rig workers to and from station. The typical implementations of these systems include drive-train vibration diagnostics, oil particulate monitoring and main rotor track and balancing. The first HUMS, manufactured by Stewart Hughes (now owned by Smiths Industries), was flown in 1991, and the Civil Aviation Authority developed the first helicopter health monitoring certification standards in May 1999 (CAP 693, CAA AAD 001-05-99). In the United States, the FAA has also published Advisory Circulars on HUMS (27-1 and 29-2). HUMS data analyzed by the United Kingdom Civil Aviation Authority in 1999 revealed that approximately 70% of then-recent airworthiness related incidents that resulted in significant maintenance actions (of which there were 63) were detected. The results of the study indicated that 1 or possibly 2 of the successfully detected incidents would likely have resulted in an in-flight accident that would have endangered the lives of the crew and passengers. In its final report, the CAA commented [10]:

> It is considered that the first generation HUMS, which added comprehensive vibration monitoring to existing health monitoring techniques, has already demonstrated the ability to identify potentially hazardous and catastrophic failure modes, and has already reduced fatal accident statistics.

The benefits of HUMS go far beyond the safety concerns that predicated its development. The reductions in operator insurance costs, increased availability due to less unscheduled maintenance, and increased consumer confidence as a reliable mode of transportation are some of the potential secondary benefits of HUMS [10].

There are currently three HUMS manufacturers, Smiths Industries (Teledyne Controls), BF Goodrich, and the Intelligent Automation Corporation. Smiths Industries has the longest experience, with several fielded models: EuroHUMS, North Sea HUMS, AHUMS and GenHUMS. The capabilities of the Smiths HUMS include vibration monitoring of the transmission and engines, rotor track and balancing, oil particulate monitoring, and integration with the flight data recorder. The use of these systems have resulted in 26 detections of transmission related problems to date, including bearing faults (brinelled raceways, damaged rolling elements and raceways), shaft faults (misalignment, unbalance, couplings), and gear faults (wear, fatigue, and misalignment). Their signal processing methods include time-synchronous averaging, amplitude demodulation and feature-based techniques for vibration-based gear diagnostics; oil monitoring (chip detection, pressure, temperature); and shock pulse methods and pattern recognition techniques for vibration-based bearing diagnostics. Smiths HUMS are installed in over 250 aircraft worldwide, and include Eurocopter, Augusta-Westland and Bell Helicopter systems. Fielded systems include the following rotorcraft models: S61N, AS332 (Mk1,2), AS 532 (Mk1,2), S76, Bell 412, BA 609, EH101, UK Mod Chinooks, Apaches, Sea King, Puma and Lynx [11].

In the United States, the BF Goodrich Corporation won a 1997 DARPA sponsored contract to develop an Integrated Mechanical Diagnostic Health and Usage Monitoring System (IMD-HUMS) for the US Navy. Goodrich has HUMS systems installed on US Navy and Marine Corps V-22, CH-53E, MH-53E, SH-60B, MH-60S/R, AH-1Z and UH-1Y aircraft. In addition, 30 systems are in delivery to the US Army Aviation Applied Technology Directorate to be deployed on 101st Airborne UH-60L Black Hawks. Sikorsky (United Technologies) also has a contract with BF Goodrich to provide HUMS for their S-92, S-76, S-70 and S-80 aircraft [9].

The US Navy has been active in PHM technology development and insertion for several years. The Navy's SH-60 Helicopter Integrated Diagnostic System (HIDS) was their initial program that drove subsequent efforts, including the DoD sponsored Joint Advanced Health and Usage Monitoring System Advanced Concept Technology Demonstration (JAHUMS-ACTD). The JAHUMS program served to demonstrate the HUMS capabilities within an operational environment. Most of the flight testing (which began in early 1995), technology development, and data collection were conducted at the Naval Air Warfare Center Aircraft Division (NAWCAD), Patuxent River. As part of the HIDS program, seeded fault testing of helicopter transmission components was conducted on a ground test rig to target flight critical components. The seeded fault testing allows data to be collected over the transition to failure. The collected data can then be used to develop diagnostic and prognostic algorithms.

At the same time that the Navy was conducting its JAHUMS program, the Army and NASA were involved in HUMS research for the UH-60A using the Rotorcraft Aircrew Systems Concept Airborne Laboratory (RSCAL) This testing was accomplished in 2001 [12],[13]. More recently, the Intelligent Automation Corporation (IAC) has developed a HUMS solution for the Army that involves pilot-driven data acquisition of in-flight vibration that is collected and processed on a ground station database. The IAC system was accepted by the US Army for the Vibration Monitoring Enhancement Program (VMEP). The VMEP system is fielded on 115 units, including the AH-64A/D, UH-60A/L, MH-60K and CH-47D. As many as 24 accelerometer channels (6 simultaneous) and 8 tachometer channels (2 simultaneous) can be connected to the VMEP system, which is based on a PC-104 platform and a 233MHz processor. The AH-64 Apache and UH-60 Blackhawk are outfitted with 18 accelerometers, 2/3 tachometers and a blade tracking sensor. The on-board data acquisition device is shown in Figure 8.3.

Figure 8.3 VMEP Vibration Monitoring Unit – Data Acquisition Device

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8.6 Interim Report 1

8.7 Interim Report 2/3