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A functional architecture for a logistics expert system in a sea based environment

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THESIS

A FUNCTIONAL ARCHITECTURE FOR A LOGISTICS EXPERT SYSTEM IN A SEA BASED ENVIRONMENT

by

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December 2005

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The Armed Forces of the United States are becoming more expeditionary in nature, in that more forces will be home-ported or home-stationed in the Continental U.S. One of the major characteristics associated with future military concepts is that they employ Joint and Coalition Forces from a sea base conducting a full range of operations in the littoral regions of the world. A key aspect of conducting operations is the sustainment of forces in a sea based environment. Future logistical architectures associated with providing that sustainment will be joint and integrated to provide seamless support to all forces operating in and around the sea base. The ordering system associated with that future logistical architecture must be robust, redundant, and not have a single point of failure. The ordering and tracking of all sustainment supplies through the supply chain distribution system will be important in ensuring that supplies are delivered to the right place and time to guarantee success.

This thesis proposes to emphasize a functional architecture for an Expert Ordering System in a Sea Based environment that will reduce the overall logistical manpower requirements of the Joint/Combined Force. Use cases of different realistic scenarios will be produced to show justification of the system.

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A FUNCTIONAL ARCHITECTURE FOR A LOGISTICS EXPERT SYSTEM IN A SEA BASED ENVIRONMENT

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LIST OF ACRONYMS AND ABBREVIATIONS

AAR	After Action Review
APA	Army Preposition Afloat
APOD	Air Port of Debarkation
APS	Army Preposition Stock
ASL	Authorized Stockage List
CAF	C4ISR Architecture Framework
CENTCOM	Central Command
CLF	Combat Logistics Force
COCOM	Combat Commander
CONOPS	Concept of Operations
CONUS	Continental United States
CS	Combat Support
CSA	Corps Support Area
CSG	Carrier Strike Group
CSS	Combat Service Support
DoDAAC	Department of Defense Activity Address Code
DODAF	Department of Defense Architecture Framework
EDI	Electronic Data Interchange
EEDS	Early Entry Deployment Support
ESG	Expeditionary Strike Group
GPS	Global Positioning System
HSV	High Speed Vessels

ICD	Initial Capabilities Document
ITV	In-transit Visibility
JFC	Joint Force Commander
JOA	Joint Operations Area
JTA	Joint Technical Architecture
MAGTF	Marine Air Ground Task Force
MEB	Marine Expeditionary Brigade
MFG	Manufacturer
MLDT	Mean Logistics Delay Time
MNS	Mission Needs Statement
MOOTW	Military Operations Other Than War
MPF	Maritime Preposition Force
MPSRON	Maritime Preposition Force Squadron
NCA	National Command Authority
NEO	Non-combatant Evacuation Operations
NSN	National Stock Number
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OMFTS	Operational Maneuver From The Sea
OV	Operational View
POL	Petroleum, Oils, and Lubricants
POS	Point of Sale
RFID	Radio Frequency Identification
RIC	Routing Identifier Code

RSO&I	Reception, Staging, Onward movement and Integration
S&RL	Sense and Respond Logistics
SATCOM	Satellite Communications
SPOD	Sea Port of Debarkation
STOM	Ship to Objective Maneuver
SV	System View
TSV	Theater Support Vessel
TV	Technical View
UML	Unified Modeling Language
UPS	United Parcel Service
VMI	Vendor Managed Inventory

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I. INTRODUCTION

The research will take an intensive look into the doctrine of current Service Centric logistics practices and develop an operational view of an expert system's architecture that supports Joint/Combined Logistics management, in a Sea Based as well as a Land Based environment. The research will address concerns associated with the ordering and reordering process for forces operating in a sea based environment. The objective of the research will be to analyze the concept of the use of an expert system to increase efficiency in the logistics supply chain, and thereby offer the opportunity to reduce the manpower ratio associated with this process.

A. BACKGROUND

"Amateurs study tactics, Professionals study logistics."-Old Soldiers Proverb (Stephens, 2002)

"Throughout the struggle, it was in his logistic inability to maintain his armies in the field that the enemy's fatal weakness lay." -Dwight D. Eisenhower (Department of the Navy, 1997)

Logistics is a complicated multifunctional task, which must be mastered to win battles in conflict as well as in business. The only difference is that the military focuses on life and death, while business measures profit. (Pagonis, 1992, p.210) Throughout history, military conflicts have been decided on and off the battlefield. The winner was not always the best tactician. The leader with the most staying power and who could afford to expend the most men and material usually prevailed. For instance, in the War Between the States, the Confederacy was noted for having the best military leaders but the Union had superior logistics and could afford to take losses while still moving forward. In today's environment, logistics is the careful integration of transportation, supply, warehousing, maintenance, procurement, contracting, and automation, organized into a coherent functional area. (Pagonis, 1992, p.2)

The information age is having a significant impact on all aspects of warfare, and logistics is no exception. (Department of the Navy, 1997) The results of these information age innovations are reducing the percentage of force required to deliver the increasing logistic support needed for an expeditionary force. Better management of information leads to greater responsiveness and efficiency in the provision of logistical support. (Department of the Navy, 1997) It has been proposed that the use of expert systems in the naval concept of "Sea Basing" will be a force multiplier (create synergy) and could benefit the armed forces of the United States as a whole.

1. History of Logistics

"Logistics is the 'practical art of moving armies.'" − General Antonie Henri Jomini (Cox, 2002)

Logistics is an integral part of business and warfare. It has been so since time immemorial. (Department of the Navy, 1997) It ensures the effective use of limited resources. (Department of the Navy, 1997) In business, logistics is the management of the supply chain and all of the human and mechanical aspects associated with the supply chain, from the manufacturer, to the purchaser of the finished goods, through the disposal of the goods. In warfare, logistics is the sustainment of a military force in the field of combat. Logistics is both an art and a science. It is a science because it is rooted in known facts, relationships and rules. (Department of the Navy, 1997) It is the science of planning and carrying out movement and maintenance of forces. (Department of the Navy, 1997) Logistics is an art in the sense that it is creative in its application of scientific knowledge. (Department of the Navy, 1997)

Supplying an army in the field has changed drastically since the advent of modern warfare. In the earliest recorded warfare, every man had to look out for himself. Troops were expected to feed themselves and live off of the land. (Department of the Navy, 1997) The Industrial Age and the advent of mass production along with greatly improved transportation systems allowed armies to stockpile goods and create a proverbial logistics mountain, commonly referred to as the "Iron Mountain." That mountain of supplies and material would then be pushed forward to troops on the front lines.

Support from the sea was used extensively during the Second World War. Amphibious operations such as those conducted in North Africa, Normandy and the

Philippines were major assault and sustainment operations. Ships carried troops and supplies over long distances and deposited them on hostile shores. They unloaded their cargo at ports or on a secure beach. All of the material was unloaded and stacked on the beachhead. Supplies and personnel replacements were pushed forward to replenish the losses sustained in an attrition style and later a maneuver style of warfare. Up to 700 tons per day of supplies were required to sustain a fighting division in contact with the enemy. During defensive operations most of the tonnage requirement was dedicated to ammunition. In offensive maneuver operations, petroleum, oils, and lubricants (POL) were the majority of the supplies consumed. (Eisenhower, 1950, p.290) The logistical doctrine observed at that time required that amphibious assault forces had an initial basic load of supplies with subsequent re-supply of critical expendable supplies such as water, fuel, ammunition and food. (Parsons, 1999, p.1174) All assault divisions were required to carry 3 days or 2100 tons of supplies with them into battle. The logistical support needed to replace those expended supplies was then pushed forward from ships to the beachhead. From the beachhead, the supplies were funneled to the combat units that needed them the most.

Since the Persian Gulf War of the early 1990's, logisticians have studied and improved their logistics systems. This has primarily been accomplished through the use of personal computers along with improved transportation and communication systems. The military logistic systems of today are more agile and anticipatory than their predecessors. A "Just-In-Time" logistics system is envisioned, where supplies and services are pushed, by anticipation, or pulled, by user request, through the supply chain. All in all, just-in-time logistics is still a concept that is being studied and modified in a peacetime environment, in an effort to reduce the "logistics mountain" required for an overwhelming victory against an unknown threat. Logisticians work with the intelligence community to identify unknowns in warfare. They then attempt to mitigate the risks associated with these unknowns. (Pagonis, 1992, p.2)

2. Sea Power 21

Sea Power 21 is an overarching conceptual framework in which a force at sea can prosecute the national goals of the United States and ensure dominance over any adversary. It takes into account three dynamic components: Sea Shield, Sea Strike, and Sea Basing. (Clark, 2002, pp. 32-41) The fourth component, ForceNet, integrates these three components. See Figure 1.

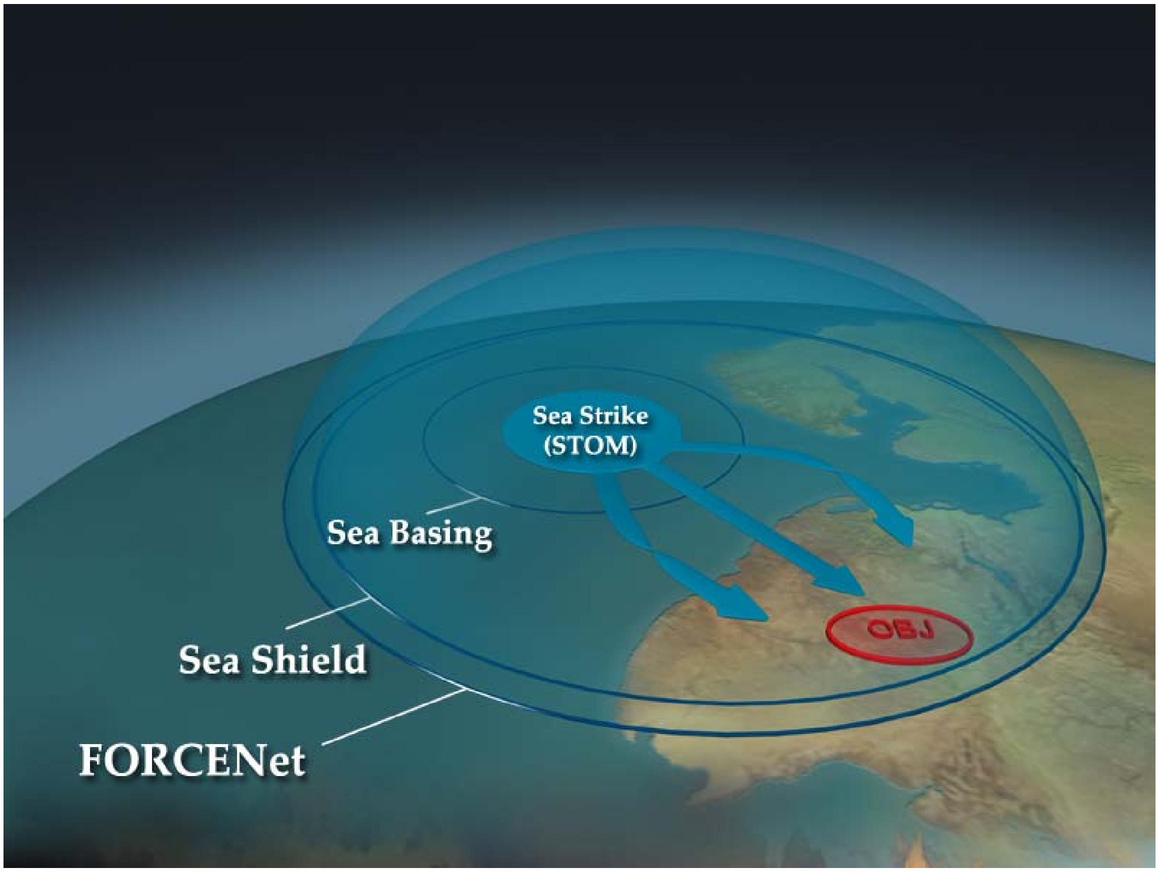

Figure 1. Sea Power 21 from (Marine Corps Combat Development Command [MCCDC], 2004)

a. Sea Shield

Sea Shield is the ability to protect a force at sea from surface, subsurface, air and ballistic missiles as well as "projecting global defensive assurance". (Clark, 2002, pp. 32-41) The concept is based on the use of specific vessels for defensive missions combined with other vessels used primarily for offense. The mission critical logistical ships will utilize little, if any, defensive armament, and so will require the full protection provided by Sea Shield.

b. Sea Strike

Sea Strike is the ability to project power in the form of manpower, munitions and information in an offensive manner. (Clark, 2002, pp. 32-41) That power must be precise and persistent in nature. Sea Strike is the hammer which provides the threat to an adversary to ensure his acquiescence to our national interest or capitulation if desired. Sea Strike also acts as a deterrent to potentially hostile nations who are considering attacks on our countries or our allies.

c. Sea Basing

Sea Basing is the ability to operate at sea for an undetermined amount of time and provide "joint operational independence". (Clark, 2002, pp. 32-41) It provides freedom of maneuver in an unconstrained environment free of limitation imposed by land based logistical sites located in Host Nations. The United States Navy and other naval forces have accomplished Sea Basing on numerous occasions in the past but in a limited fashion.

d. Force Net

Force Net is the informational and architectural network which binds all three of the components into the viable concept of Sea Power. (Clark, 2002, pp. 32-41) It will provide the ability to align the system of systems and increase the potency of a force at sea without an unnecessary increase in size. It will assist in optimizing solutions and integrate them into the overall situation awareness required by a commander at sea or in the field.

B. PURPOSE

The United States Armed Forces are always preparing for the next conflict. One of the concepts of operations (CONOPS) to prepare for that next conflict is Sea Basing, which is one of the pillars of the US Navy's Sea Power 21. Sea based logistics is the process of supporting operations ashore and at sea from at-sea platforms. It reduces or eliminates the logistical support footprint on land and enhances the speed and flexibility of maneuver forces. The ultimate goal is to put the maximum amount of warfighters (combat troops) on the ground using the minimum amount of logistical support required to achieve the mission goals. Sea based logistics must be able to support all of the naval ships as well as the forces conducting the amphibious operation. The goal is to accomplish the logistical support with the least amount of resources. Future sea basing must be efficient, flexible and reduce the need to build up a logistics stockpile on the beach. (Secretary of the Navy, 2003) To accomplish the goals of future conflicts the Armed Forces are trying to bring more combat force to bear on the threat located in the littoral regions of the world while reducing the logistics forces currently required to maintain that combat force. A possible partial solution to reducing logistical manpower requirements and speeding up the throughput of supplies to the combat forces is the use of an expert system that tracks, maintains, orders and reorders all classes of supply.

C. RESEARCH QUESTIONS

Through this paper, we will analyze and answer the following questions:

1. What are the some of the problems/challenges in the current Service Centric Logistics system?

2. What are some of the lessons learned/ heuristics in Logistics since World War II and how can they be implemented into an expert ordering system?

3. Starting with the initial problem of ordering and reordering supplies, will a functional decomposition lead to the concept of an expert system?

4. Could an Expert System be used to order and reorder all classes of supply?

5. Is an expert system a logical solution to reducing the manning effort for ordering and reordering supplies?

D. BENEFITS OF STUDY

By answering these questions, we hope to bring a better understanding of where the armed forces are today with supply ordering, and give a positive direction for where we can go from here. The concept of using Expert Systems to order supplies is certainly not new, but as the reader reads this thesis, we hope he or she will gain a better understanding of what challenges have been faced in the past, and how those challenges might be overcome.

E. SCOPE AND METHODOLOGY

This thesis will emphasize a functional architecture for an Expert Ordering System in a Sea Based environment that could potentially reduce the overall logistical manpower requirements of the Joint/Combined Force. The emphasis is not on writing code or producing a program. It will be on analyzing the potential benefits of an expert system for ordering and reordering all classes of supply. Operational Models along with activity diagrams of realistic operations will be produced to show one possible solution to the problem.

1. Expert Systems in General

"Expert System: A class of computer programs that can advise, analyze, categorize, communicate, consult, design, diagnose, explain, explore, forecast, form concepts, identify, intercept, justify, learn, manage, monitor, plan, present, retrieve, schedule, test, and tutor. They address problems normally thought to require human specialists for their solutions." (Firebaugh, 1988, p.335)

Essentially, an expert system is an automated computer system that acts as a replacement for a "real person". The computer system has a database to draw on with a set of logical and heuristic business processes, imbedded in it. When a specific situation arises, such as the inventory level of a specific item gets below a certain level, the system puts in a requisition for the item, but there is more to it than that. This expert system can also review the ordering rate, and based on the ordering rate, or the defense condition level, or on location, may adjust the level at which supplies are ordered. The ability to adapt to the changing environments as a real person would is the key to a successful expert system.

2. Architectures Views in General

The problem or challenge must first be defined before a solution can be found. Part of defining the problem, is bounding the problem. The Systems Architecture does exactly this. One of the primary purposes of the systems architecture is to define exactly where the problem is bounded, and how the solution will address each part of the problem. This architecture can take several different views. Each is of the same system, but shows different information.

a. Operational

"Operational View: This view describes the tasks and activities, organizational and operational elements, and information flows required to accomplish or to support military or consultation function." (Moxley, 2001)

The operational architectural view represents the tasks and processes required to accomplish the goal. These process diagrams a specific process such as "ordering supplies" and systemically walks through the steps. At each step, the activity is identified and the person or system performing that activity is identified.

b. System

"System View: This view is generated from the Operational View by the responsible host nation or design authority. It describes and identifies the system(s), both internal and external, and interconnections required to accomplish or to support the military or consultation function. This view maps information flows, hardware, and applications to user locations and specifies the connectivity, performance, and other constraints." (Moxley, 2001)

The system architectural view focuses on the specific steps and processes performed by the system. The system view shows interaction between various pieces of software, and helps to define the interfaces between the software applications. One key output generated from the operational view activity diagrams and depicted in the systems architectural view, are interfaces. Interfaces are important because the interaction between the system and the human are the primary focuses for Human Systems Engineering. The systems view also helps to define the separation and interfaces between the solution and the outside environment. The systems view will describe the internal operation of the expert ordering system and provide the location of interaction between system to system and system to human.

c. Technical

"Technical View: This view, generated by the host nation or equivalent authority, describes the arrangement, interaction, and interdependence of the elements of the system and takes into account the technical constraints imposed by the Systems View. It provides the minimal set of rules governing the selection of the appropriate standards and products from the implementation domain." (Moxley, 2001)

The technical architectural view utilizes information from the operational and systems view to set limits and technical constraints. This helps to keep the architecture based in reality and not to excessive in scope. The technical view will set the rules and guidelines for ordering supplies with an expert system in a sea based environment.

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II. REVIEW OF CURRENT JOINT/COMBINED LOGISTICS

A. INTRODUCTION

"Behind every great leader there was an even greater logistician." − Michael Cox. (Cox, 2002)

Many of the logistical systems used in modern day combat operations, at sea, on land and in the air, are incremental improvements of legacy systems dating back to World War II. The Iron Mountain associated with military logistics still exists but is of somewhat smaller form and logistics remains a "slow and cumbersome" process. (Keeter, 2004) This was painfully evident during the logistical buildup for Operation Iraqi Freedom. It was the largest since the preparation for the Normandy invasion in 1944. (Keeter, 2004) Once maneuver operations commenced, the Marine logistics information systems, which in some cases are 30 years old, were unable to meet the needs of the widespread and rapidly moving combat units. (Barnard, 2004)

One of the more significant improvements to military logistics systems came with the incorporation of the personal computer and the internet. The modern logistician uses many innovative and technical tools not envisioned in the days of World War II, Korea, and Vietnam. The throughput of logistics from the manufacturer to the end-user has improved along with improvements of the distribution systems. Technical innovations have improved the speed and efficiency associated with requesting supplies but not necessarily quality of logistical support provided. For example, if a National Stock Number (NSN) is submitted incorrectly or a shipping label is misprinted or put in the wrong place, the wrong item could be shipped to the wrong place at a very respectable speed. Another issue is that units relocate but fail to complete all of the paperwork associated with changing the units' Department of Defense Activity Address Code (DoDAAC) or Routing Identifier Code (RIC). The requested supplies are acquired and shipped but to the wrong place or to the wrong supporting unit. This increase in throughput has resulted in an increase in overall number of errors, requiring additional resources to correct.

Tracking systems have been established such as Radio Frequency Identification (RFID), where a conscientious logistician can mind the progress of requested supplies through the supply chain distribution system. This can accomplished with web-based applications that are relatively user friendly. Tracking is also accomplished with the use of legacy information systems that require a trained operator to constantly query a data base for updated status.

All of the current logistical systems work within a framework associated with the Joint Logistical Functions and the Classes of Supply. This framework has been established so that like items and services can be more efficiently managed by a group or section that can concentrate on those particular commodities.

B. JOINT LOGISTICAL FUNCTIONAL AREAS AND THE CLASSES OF SUPPLY

A basic, top-level frame work has been established that encompasses the logistical functional areas as well as the Classes of Supply associated with those functional areas. These frameworks are used to organize and manage all of the supply requirements associated with a military force. These functional areas and classes of supply allow military logisticians to focus on like or similar commodities. The logistician tracks those supplies from their initial request or order by the user to the acquisition or allocation and then through the supply chain distribution system to the final delivery of the requisitioned item to the initial requester.

1. Logistical Functional Areas

There are six logistics functions defined in United States Armed Forces joint doctrine. They are Supply, Maintenance, Health Service, Transportation, Services, and General Engineering (see Table 1). (Department of Army and Navy, 1996) These logistical functions are used to focus the logisticians tasked to provide the fighting force with supplies to that are required to fight and win against an ever-changing threat.

FUNCTION	DESCRIPTION
Supply	Acquire, manage, receive, store and issue material to operating forces
Maintenance	Inspect, test, service, classify, repair, replace, reclaim, modify, convert, calibrate, rebuild and overhaul equipment for operating forces
Health Services	Evacuate, hospitalize, medical logistics, casualty collection, health maintenance, casualty treatment, medical laboratory service, blood management, vector control, preventative medicine service, veterinary service, and dental service to personnel in the operating force
Transportation	Move units, personnel, equipment and supplies for the operating forces
Services	Aerial delivery, laundry, clothing exchange and bath, and graves registration for operating forces
General Engineering	Construction, damage repair, and operation and maintenance of facilities for operating forces

Table 1. Joint Logistics Functions (Department of Army and Navy, 1996. p. IX-2)

The functional areas break down logistics to a more finite and manageable level and correspond to the Classes of Supply that they manage or consume. Each functional area has one or more classes of supply linked with it, which are required to accomplish its associated mission.

2. Classes of Supply

There are ten Classes of Supply (see Table 2). Military material is broken down into these well-defined areas or classes to aid in maintaining the responsibility of procurement and management of items in the supply chain. The classes of supply provide an additional framework for collectively managing all of the supplies required to maintain a fighting force in the field, in garrison or at sea. They assist logisticians in focusing their efforts and providing the right supplies to the right unit. The efforts associated with maintaining the flow are most evident in bulk commodities such as Class I, III, and V. A fighting force on the offensive must maintain a sufficient flow of these classes of supply to sustain its momentum and accomplish its objectives. (See Appendix A, for a more in-depth view of the classes and sub-classes of supply.)

CLASS	SUPPLIES
I	Subsistence and comfort items
II	Clothing, individual equipment, and administrative supplies and equipment
III	Petroleum fuels and lubricants
IV	Construction and barrier materials
V	Ammunition
VI	Personal demand items
VII	Major end items
VIII	Medical material
IX	Repair parts
X	Material to support nonmilitary programs
Misc.	Water Salvage, and captured material

Table 2. Classes of Supply (Department of Army, 2003, p. 6-3)

Supplies are throughput from the source of supply/port of debarkation/sea base to the end user as much as possible. (Department of Army, 2003, p. 6-2) This reduces handling costs as well as shortens the time line associated with distributing the supplies to the unit most in need. Most bulk commodities are "pushed" as far forward as possible before they are distributed to the end user. Pushed items are more anticipatory in nature. The logistician relies on the common battlefield operating systems to see what operations will require the most supplies and anticipate the request and delivery of the supplies to ensure that there is not break in the operations tempo associated with that operation. They work closely with supported units to ensure that the required supplies are available when and where the end user needs them.

More specific or special supply items are "pulled" forward by the end user. They satisfy a specific need or a specific purpose and are not shipped or acquired until the end user has a valid requirement for that supply item. It is difficult to anticipate exactly when something will break. Often, a repair part can only be identified after the system is broken. Once that requirement is realized, the end user requests the item and it is shipped through the distribution system.

3. How Logistical Architectures Support Warfighting

"Combat Service Support" (CSS) is the activity that provides services and supplies to operating forces. (Department of Navy, 1997, p. 5) CSS is an indispensable part of any operation. Without CSS the tanks and trucks could not and would not move. Without mobility, a maneuver force becomes a target. CSS provides all of the logistical functions at the tactical level, where the troops in the trenches need it the most. CSS, as part of logistics, keeps the operating forces manned, armed, fueled, fixed, sustained and moved in a combat environment. (Department of Army and Navy, 1996) Table 3 integrates the Logistical Functional areas with the Classes of Supply to provide linkage of which supplies support each function.

FUNCTION	DESCRIPTION
Supply	I, II, III, IV, V, VI, VII, VIII, IX, and X
Maintenance	Consume VII, and IX in support of the warfighter
Health Services	Consume and manage VIII in support of the warfighter
Transportation	Move all Classes of Supply around the battlefield as well as consume copious amounts of II, III and IX
Services	Consume all Classes of supply in support of the warfighter
General Engineering	Consume and manage IV, VII, and IX in support of mobility and counter mobility

Table 3. Joint Logistics Functions and the Classes of Supply Associated with Them

The existing logistical architectures, in the form of the Joint Logistics Functions and Classes of Supply, attempt to keep material flowing to the end user without any self-imposed restrictions or constraints as well as anticipate and react to those imposed by an operational threat. A functioning logistical architecture must incorporate or represent the fundamental characteristics of effective and efficient CSS, which are: (Department of Army, 2003, p. 1-4)

- Responsiveness – provide the right support to the right place at the right time
- Simplicity – avoid unnecessary complexity
- Flexibility – the ability to adapt existing structures and procedures to changing situations, missions and concepts of operations
- Attainability – generating the minimum essential supplies and services necessary to begin operations

- Sustainability – the ability to maintain continuous support during all phases of campaigns and operations
- Survivability – the ability to protect support functions from destruction or degradation
- Economy – providing the most efficient support to accomplish the mission
- Integration – synchronizing all aspect of CSS operations with joint operations in a seamless manner

C. CHAPTER SUMMARY

It is the ultimate goal of logistic planners at all levels to translate the art of logistics into CSS at the tactical level. This is accomplished by tracking and reordering supplies in a timely manner and maintaining accountability and visibility of those supplies in the supply chain distribution system. This ensures that the warfighter will have what they need when they need it.

III. LITERATURE REVIEW

A. INTRODUCTION

"A Sea base is a system of systems enabling personnel, material, fires, and command and control to come together rapidly, integrate, and be projected as a flexible force capable of undertaking a broad spectrum of over-the-shore operations" (DSB, 2003)

Logistics in a Sea Based environment is the cornerstone for success in future naval and expeditionary operations in the littorals of the world. The indefinite sustainment of those naval and joint forces will be the key to success in providing military options against our future threats. These military options will cause a future threat to think twice and provide a level of deterrence that enhances the options available to the National Command Authority when and if diplomacy fails.

The sustainment of the Sea Base and all of the joint forces working in, through and around it will take the logistical coordination of many dynamic variables. The logistical coordination will be required to be accomplished with an ever decreasing/constrained pool of available personnel. The use of a system that senses and responds to the logistical needs of the warfighter will be necessary to accomplish the task of sustaining the sea base as well as conserve personnel strength while ensuring the accomplishment of any mission that is assigned to operational forces in a Sea Base.

B. SEA BASING CONCEPTS OF OPERATIONS

"Sea basing is defined as the rapid deployment, assembly, command, projection, reconstitution, and re-employment of joint combat power from the sea, while providing continuous support, sustainment, and force protection to select expeditionary joint force without reliance on land bases within the Joint Operations Area (JOA). These capabilities expand operational maneuver options, and facilitate assured access and entry from the sea." (DoD, 2005)

Sea basing augments joint force capabilities associated with using the sea as a maneuver and staging site. It works in conjunction with Sea Shield and Sea Strike to provide a complementing capability that provides an advantage to our armed forces. (see

Figure 2) It ensures joint forces will maintain access to the littoral regions of the world. It is comprised of several defining principles. These principles are based on the advantages garnered from using the sea as a sovereign maneuver space that can be used with impunity and without the need of fixed ports or airfields. (DoD, 2005)

- Use the sea as a maneuver space.
- Protect joint force operations.
- Provide scalable, responsive joint power projection.
- Sustain joint force operations from the sea.
- Leverage forward presence and join interdependence.
- Expand access options and reduce dependence on land bases.
- Create uncertainty for our adversaries

Sea basing assists in the executing of Ship To Objective Maneuver (STOM), a supporting piece of Operational Maneuver From The Sea (OMFTS) the centerpiece of the United States Marine Corps' vision for the 21st century. (*Maritime Prepositioning Force 2010 and Beyond*, 1997) It provides a stable, easily protected site to stage and execute operations in a Joint Operations Area (JOA).

The maintenance, repair, medical treatment, and supply operations of the Joint Force will be conducted from sea based platforms. Joint and naval distribution systems will replenish the logistical infrastructure afloat. The ships or vessels that make up the sea base will reinforce the Combat Logistics Force (CLF) and sustain the surface combatants of the Expeditionary Strike Groups (ESGs) and Carrier Strike Groups (CSGs). In essence, the sea base will become floating warehouses for the forces deployed and operating afloat and ashore. (Kang & Gue, 1997) An Expert System that functions within the concept of Sense and Respond Logistics (S&RL) can be developed to increase the efficiency with which these floating warehouses are operated.

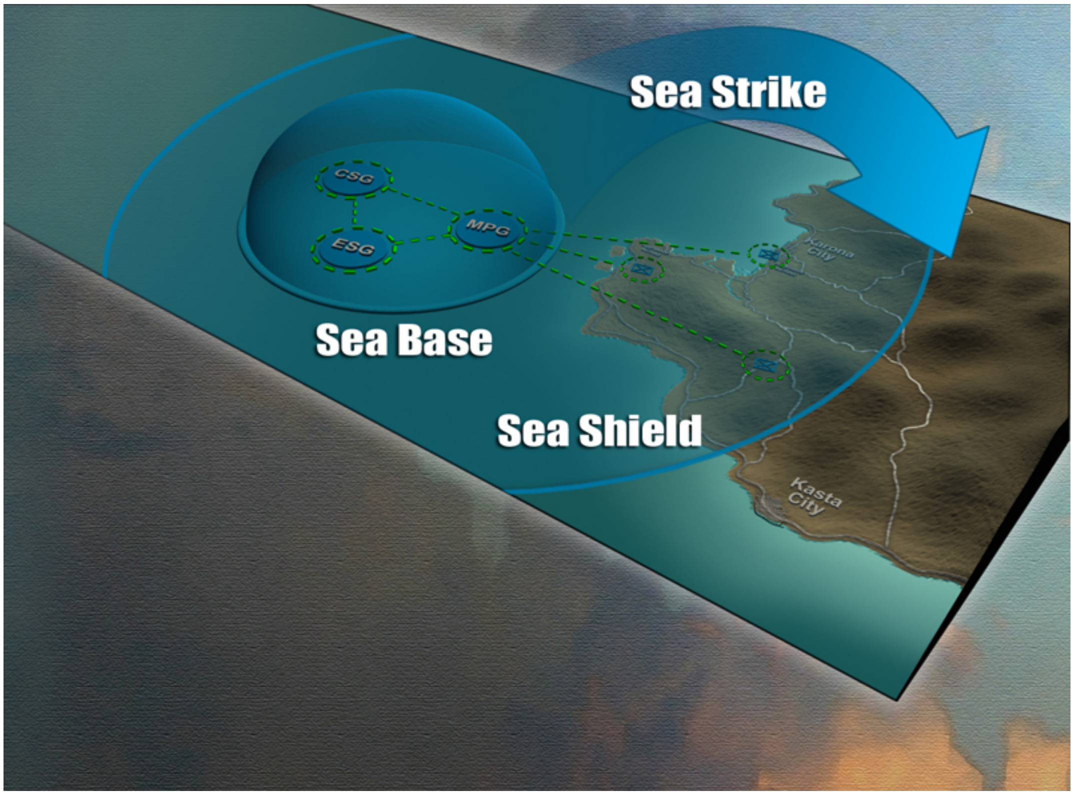

Figure 2. Integration of the Sea Base with Sea Shield and Sea Strike from (MCCDC, 2004)

The Sea Base, located off the coast of an adversary, in a JOA, will employ the combat forces and equipment located onboard to engage a threat. The combat forces in the Sea Base will be the one-two punch that keeps a threat guessing with the capabilities associated with Sea Strike. Specific assets located in the Sea Base will provide force protection for the Sea Base and the combat forces ashore with the capabilities associated with Sea Shield.

1. Close Phase

"Rapid closure of joint force capability to an area in crisis." (DoD, 2005)

The assets that are closest to the JOA, such as a CSG or ESG, will displace from their original operating area or areas and sail to the area of interest designated by the National Command Authority (NCA). The NCA consists of the President of the United States and the Secretary of Defense or their alternates who are the ultimate lawful source of military orders. (National Command Authority, 2005) The NCA's representative in the geographical area is the Combat Commander (COCOM), who is responsible for all operations in an area or theater. This allows the closing forces to take advantage of the sovereignty of the sea and provide an initial response that may provide a show of force that accomplishes the NCA's will without actually engaging combat forces. (DSB, 2003) It also provides an initial force that can be used to secure limited objectives or conduct Military Operations Other Than War (MOOTW) such as Non-combatant Evacuation Operations (NEO), Nation Building exercises or emergency relief after natural disasters. A Joint Force Commander (JFC), appointed by the COCOM will provide the command and control required to make a concerted effort of the forces in the JOA. See Figure 3.

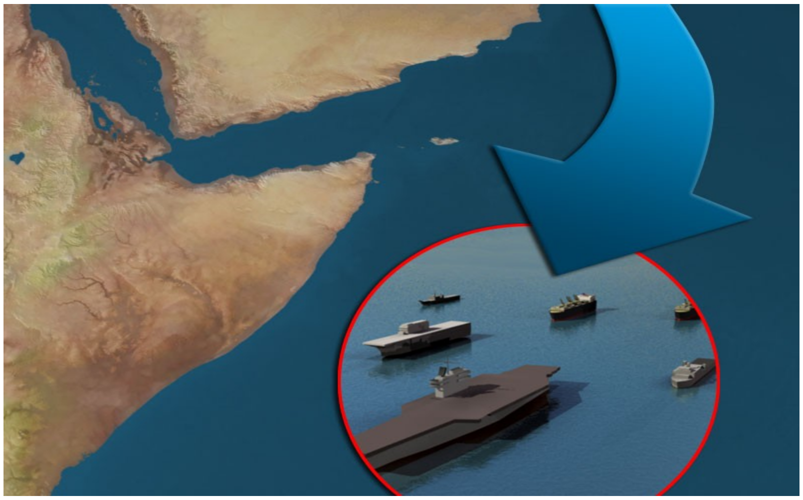

Figure 3. Rapid Force Closure in the JOA

2. Assemble Phase

"Seamless integration of scalable joint force capabilities on and around secure sea based assets." (DoD, 2005)

Once the available forces in the area arrive at the JOA, additional forces start flowing into the area from CONUS and OCONUS. These joint forces will assemble to create the operational and support assets required to execute the tasks assigned by the JFC. The reception and staging of the forces will commence in the Sea Base in anticipation of onward movement and integration into operations. Assembling the joint force in the JOA will be accomplished by air and sea with the use of inter-theater and intra-theater lift resources, such as the Air Force C-17s and C-130s as well as Navy High Speed Vessels (HSV) and Army Theater Support Vessels (TSV). See Figure 4.

Figure 4. Assemble the Joint Forces projected from CONUS to the JOA at Sea from (MCCDC, 2004)

3. Employ Phase

"Flexible employment of joint force capabilities to meet mission objectives supported from the sea base." (DoD, 2005)

The joint forces assembled in the sea base will be employed to conduct OMFTS and STOM operations in the JOA. These operations will be complimentary and use economy of force to meet the COCOM's requirements and accomplish the overarching vision requested by the NCA for the JOA. The joint force will employ sea, air and ground assets to shape the battlefield and make the opposing force submit to the JFC's will with the optimum required force. The joint force can also be used for MOOTW operations that will depend less on combat forces and more on Combat Support (CS) and Combat Service Support (CSS) forces which are in higher demand during nation building and disaster relief operations. See Figure 5.

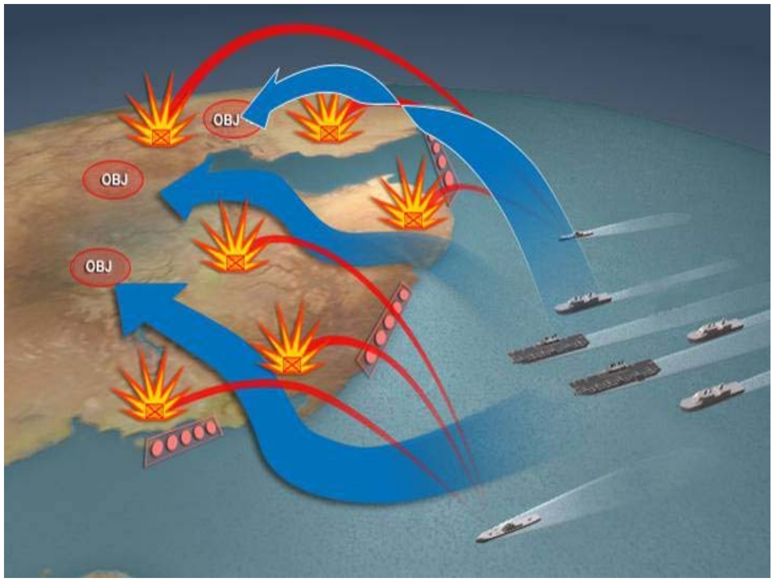

Figure 5. Employ the Joint Forces to accomplish a full spectrum of operations after (MCCDC, 2004)

4. Sustain Phase

"Persistent sustainment of selected joint forces afloat and ashore through transition to decisive combat operations ashore." (DoD, 2005)

The sustainment of the sea base will be accomplished by the CLF as well as Air Force strategic airlift and Navy strategic sealift. Sustainment supplies will be shipped from CONUS and OCONUS sites to the JOA. These sustainment supplies will be used to maintain the sea base as well as the forces ashore conducting STOM.

The forces ashore will be sustained by air and over-the-shore by legacy and future multipurpose platforms such as the CH-53, CH-60, MV-22, LCAC, LCAC(X), LCU-1600s and LCU-2000s. These air and sea connectors will be required to carry supplies to forward deployed units and internally within the sea base. See Figure 6.

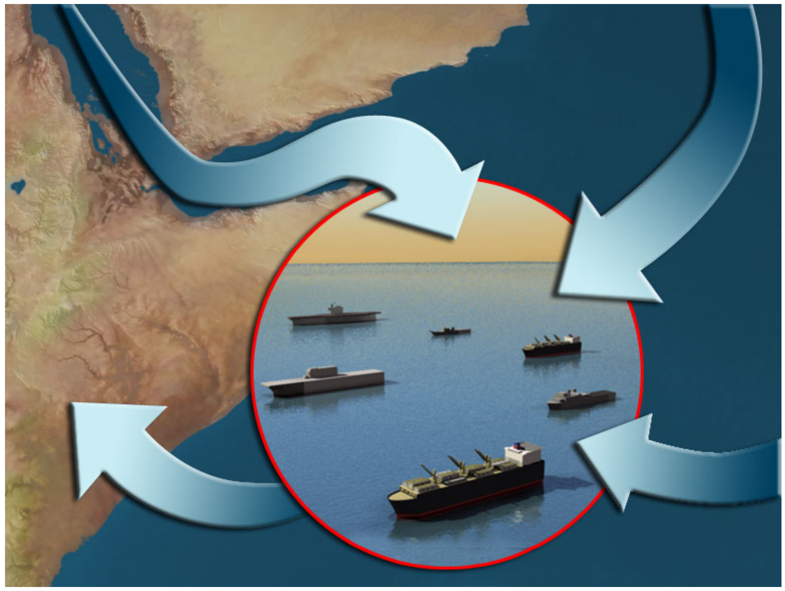

Figure 6. Assemble Sustainment Forces in the Joint Operations Area from (MCCDC, 2004)

Sustainment of a joint force without an advance base will be dependent on the ability of the joint force to project supplies into the JOA. (DSB, 2003) This sustainment of the sea base will be critical in determining the operations tempo and staying power of the joint force in the JOA. The sea base will need dependable sea and air connectors to allow the joint force to stay on station for an indefinite time period. If an opponent perceives a logistical shortfall they could wait out the joint force until it is no longer economical for it to remain in the JOA and thereby reducing the effectiveness of the sea base as a threat. See Figure 7.

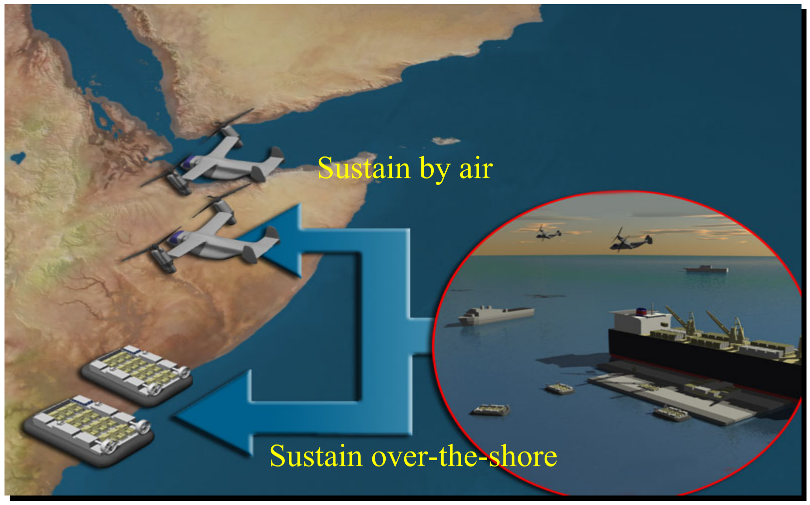

Figure 7. Sustain Joint Forces ashore by Air and Sea after (MCCDC, 2004)

5. Reconstitute Phase

"The capability to rapidly recover, reconstitute and redeploy joint combat capabilities within and around the maneuverable sea base for subsequent operations" (DoD, 2005)

The joint force must be able to extract itself from one location and reconstitute itself. The sea base will reconstitute itself by repairing its equipment and replenishing its supplies as well as human resources. The sea base will then have the ability to move to another location and set up a new JOA. The joint forces in the sea base will then be utilized to accomplish follow-on missions. The sea base must be able to transition from one style of operations to another in a very short time. The threat force will have to keep guessing when and where the joint force will strike next. The ability to make an opponent indecisive and the ability of the joint force to present multiple threats will create an additional facet to the NCA's ability to use diplomacy and military threat to accomplish the desired effect without actually using the force. A true diplomat, like a carpenter, must have a hammer and know how to use it. The sea base is a part of the hammer that will be used to shape and determine the outcome of diplomatic efforts in the future. See Figure 8.

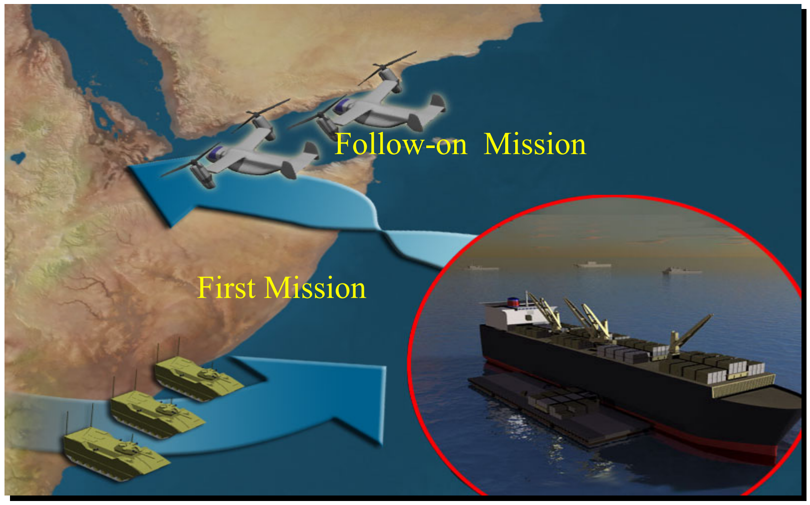

Figure 8. Reconstitution and Redeployment of Forces and Equipment for follow-on mission after (MCCDC, 2004)

C. SENSE AND RESPONSE LOGISTICS CONCEPT OF OPERATIONS

"Sense and Respond Logistics is a transformational network-centric concept that enables Joint effects-based operations and provides precise, agile support. Sense and Respond Logistics relies upon highly adaptive, self synchronizing, and dynamic physical and functional processes." (OFT, 2003)

The DoD is developing a plan that incorporates S&RL into its existing logistical architectures. (Barnard, 2004) S&RL is a "network-centric concept which enables Joint effects-based operations and provides precise, agile support." (Office of Force Transformation [OFT], 2003) It will provide a cross-service, cross-organizational logistical capability, linking many different entities together so that they can mutually support each other to accomplish their given tasks without creating any undue stress on the supply chain distribution system. S&RL systems will support the requirements of the warfighter and assist them in receiving their specific supply needs in a timely and efficient manner that will compliment the existing supply chain distribution system

S&RL is a concept in which the end user or "demand node" chooses a desired effect and the location of that effect which is called an "effect node". (OFT, 2003) The effect could be engaging a threat so that the threat is manipulated into making a decision that is desired by the JFC or it could be to repair equipment and maintain a desired level of supply in preparation for an operation. The "point-of-effect" is the key to determine the capabilities necessary to accomplish the task as well as the time line required to make a request a reality. Figure 9 depicts the concept of S&RL as it pertains to the entire spectrum of possible operations. A robust command and control system will be required to capture the demands and process them throughout the system so that the right capabilities will be assigned to achieve the desired effect.

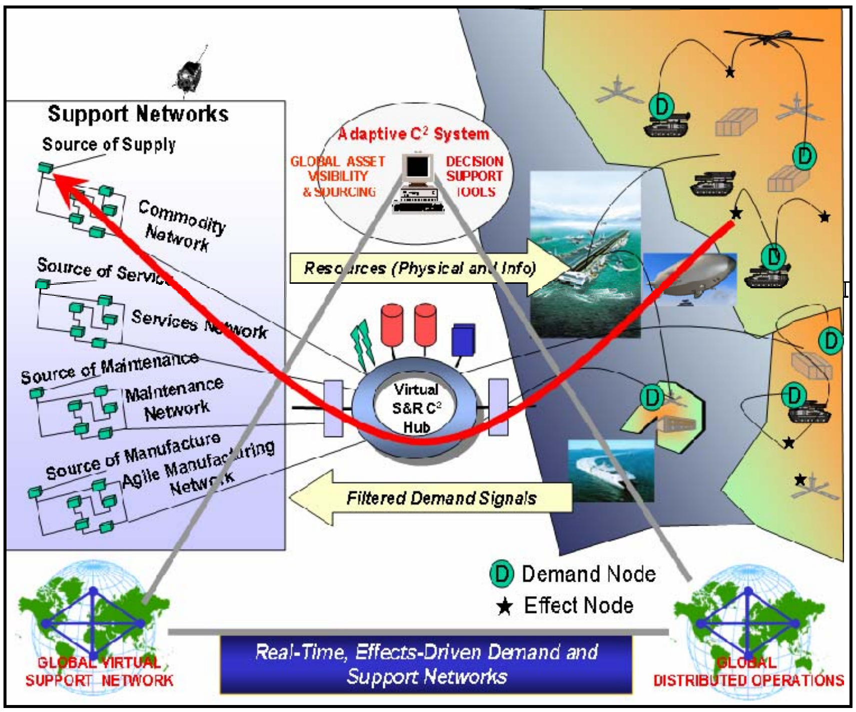

Figure 9. End-to-End Sense and Response, from Point-of-Effect to Source of Support (OFT, 2003)

The key concern and challenge associated with the S&RL concept are the areas between the demand nodes and effect nodes. They are currently portrayed as a "logistics no-man's land" where little is currently understood or determined. (OFT, 2003) Linking the demand and effect nodes by a coherent method or methods will be required to make S&RL a fully functional concept. S&RL tackles several support issues such as: adaptability and speed; flexibility; modularity; integration. The use of an expert system in accomplishing S&RL will be invaluable in implementing the concept as well as making it a reality. An expert system will not address all of the issues associated with the distribution system required to deliver the effects based logistic but it will assist in determining the user needs and establishing distribution priorities associated with S&RL.

1. Adaptability and Speed

S&RL must adapt to ever changing logistics requirements. Many of those requirements are unpredictable in nature. (OFT, 2003) They must be synchronized with the overall operations plan to ensure that resources are requested, obtained and delivered to the end user with the highest priority in a timely fashion. S&RL must be coordinated with the concept of operations for a specific mission as well as the overall concept of logistics for daily operations. The goal is to achieve the operational requirements of the JFC at the point-of-effect when it is most needed to create a positive effect for the end user and a negative effect for the threat at which the requirements are focused. This focus on speed and adaptability will create a cumulative effect that allows the JFC to use economy of force as well as mass to create a desired outcome.

2. Flexibility

S&RL must be a flexible supply chain that can be modified to meet specific mission needs as well as the sustainment needs associated with keeping a force in the field or at sea. (OFT, 2003) It must sacrifice some efficiency to accomplish this goal and can not be compared to an optimized supply chain similar to those visible at retail distribution supply chains in CONUS. S&RL will require a constant negotiation of logistical priorities to ensure the right capability is provided for the right effect. To remain flexible in nature, the supply chain distribution system should be independent from geographical constraints. (OFT, 2003) In other words it should function in any environment and be effective in all possible JOA, including the sea base.

3. Modularity

S&RL must be modular in nature. (OFT, 2003) It will need to be able to provide logistical support to many different entities working in a JOA, i.e. Department of Defense, Department of State, Department of Homeland Security, etc. The logistical support provided will be required to aid everyone and does not lend itself to the service centric approach currently in use in the full gamut of operations possible. The logistical support modules associated with S&RL will have full visibility of the logistical needs of the end user as well as the supplies in the distribution system be transported to the end user.

4. Integration

S&RL must be integrated into all aspects of the joint environment. It must be adaptive to ever changing requirements and responsive to the needs of the end user as well as the JFC. There is little room for error or seams in the logistical system. This will require an information technology/command and control system that can accommodate logistical visibility and provide a common access picture of the battle space, so that all elements of the joint force will be working in concert and not in tandem. (OFT, 2003) Nothing great can be accomplished without risk. The risks associated with any logistical endeavor must be identified and mitigated to ensure a successful outcome. (OFT, 2003) The integration of S&RL into all levels of command and execution will be paramount.

D. REVIEW EXAMPLES OF SUCCESSFUL IMPLEMENTATION OF AUTOMATED SYSTEMS FOR COMMERCIAL LOGISTICS SYSTEMS

Automated systems are currently being used in commercial applications by retail chains such as Seven-Eleven and Wal-Mart. They have been successful in the implementation of the systems and have gained significant improvements in efficiency and reduced personnel costs. These systems have assisted the chains in optimizing their respective supply chain and therefore solidifying their market position.

1. Point of Sale Automatic Ordering

Seven-Eleven has one of the most innovative inventory management systems of any retail chain. The chain uses an Electronic Data Interchange (EDI) network which links the electronic ordering system with the Point of Sale (POS) system to track sales at each retail store and transmit the data to the head office, distribution centers, dedicated manufacturers and wholesalers and independent manufacturers and wholesalers.

The Electronic Point of Sale system was introduced between September 1982 and February 1983 in approximately 1,750 stores. The data stored in the network could be accessed in the stores for local management. By 1988, with the introduction of personal computers to the stores, the store manager could create graphs showing an analysis of sales by food category, actual sales time by slot and customer, daily totals, weekly averages, best to worst analysis of goods sold and even an analysis of discarded merchandise as a ratio to goods sold.

These analyses were available at the regional office or head office in terms of the items purchased, time of purchase and information about the type of customer. The customer information was captured on a separate keypad to indicate age within three age bands and whether the customer was male or female.

The EPoS and online ordering system used the analysis data to allow the store managers to ensure that fast moving items were kept in stock, slow moving items were replaced, new merchandise was evaluated early and effectively, inventories were reduced and inventory turnover rates increased, and probably most importantly, the proper inventories were available on the shelf based on differing conditions at different times.

Distribution to the stores created its own challenge. In Japan, the Seven-eleven stores were able to place an order by 10:00am and be able to expect the delivery of the items by 3:00pm the same afternoon. This level of delivery guarantee helped to reduce required inventories and helped to reduce the likelihood of sellouts of high volume items. (Sutherland, 1995)

Another key to the success of Seven-Eleven is that each store caters to the local neighborhood. For example, in San Francisco on Fisherman’s Warf, the store is filled with ready-to-go snack foods from sandwiches to pastries. Not found in the store are the basic groceries associated with most stores in residential neighborhoods. (Sutherland, 1995)

2. Radio Frequency Identification in Supply Chain Management

Wal-Mart is one of only a few major retailers who use a unique approach to inventory management. This method is called Vendor Managed Inventory (VMI). VMI is a method of transferring the ownership of the inventory from the retailer to the supplier. By doing this, the inventory as an asset comes off the balance sheet, and less working capital is needed to run the business. VMI is enabled using information technology through the use of Electronic Data Interchange (EDI). Each day, the suppliers pull down the inventory usage of each retailer, and identify the daily demand for their products. They can then determine what the inventory levels should be based on current demand, and determine delivery requirements to the retailer. Wal-Mart automated this process in the late 1980's. Prior to that, the vendor representatives would tour each retail store and perform manual inventories. The use of VMI has resulted in the reduction of time between order and delivery of goods from as much as 25-30 days to around 14-17 days in some cases. (Emigh, 1999)

The first use of Radio Frequency Identification (RFID) in a retail store was by the European Retail Giant Metro. The store, called "Future Store" was opened in Rheinberg, Germany in order to showcase the benefits of radio frequency identification technology to consumers, suppliers, and to Metro. The goal was to use RFID to improve inventory control, supply chain execution, and product availability.

RFID tags can be attached to nearly anything, including people, and tracked by proximity readers. The idea was for Metro to ship and scan all products at their distribution center which would allow the Rheinberg store to track what was in the shipments, and when the shipments were scheduled to arrive, in real time. Upon arrival, the Future Store could do an arrival scan to determine that all cases were received, and know within minutes without checking and rechecking individual pallets and doing a manual recount. (Barlas, 2003, April 28)

Wal-Mart was not to be left behind in the RFID department. They directed in June 2003 that their top 100 suppliers must use RFID by 1 January 2005. The directive was to affix RFID tags down to the case and pallet level. Each supplier is responsible for ensuring the tags are added to the cases and crates, and that the data associated with the tag is uploaded into the inventory system. It was estimated that with this mandate, the demand for RFID tags would be around 8 billion per year just for the top 100 suppliers.

Wal-Mart is pushing the RFID revolution in the same fashion that they did with the implementation of scanning bar codes. (Barlas, 2003, June 4)

The use of the RFID technology will result in a great cost savings over inventory management, order control, inventory delivery time, and eventually will result in less time spent at the checkout counter. RFID will also reduce reorder and delivery times by providing a near-real-time view of what items are being sold and what items are in the supply chain replacing them. This translates into a more efficient supply distribution chain with less inventory costs passed on to the customer.

E. CHAPTER SUMMARY

The basing of large forces at sea and the use of automated systems to sustain them are important aspects of future operations in the littorals of the world. Several commercial firms have made incremental steps toward achieving an optimized supply distribution chain but the observations have not been fully incorporated into a joint logistic architecture. In many cases the commercial observations will not be completely implemented because of their optimized nature which will reduce the ability of the joint force to be flexible and adaptable when executing operations. The reduction of manpower as well as the emphasis on economy of force and culminating effects based operations will require the assistance of automated and expert systems to accomplish the ever changing aspects of logistics.

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IV. RESEARCH ANALYSIS OF LESSONS LEARNED

A. INTRODUCTION

> Know the enemy and <u>know yourself</u>; in a hundred battles you will never be in peril. When you are ignorant of the enemy but <u>know yourself</u>, your chances of winning or losing are equal. If arrogant both of your enemy and <u>yourself</u>, you are certain in every battle to be in peril. – Sun Tzu (Griffith, 1963)

> Those who do not learn from their mistakes are doomed to repeat them – Age Old Adage

> It's like deja-vu, all over again. – Yogi Berra (Berra, 1998)

Through every conflict imaginable there have been lessons, lessons learned and lessons not learned. It is incumbent upon a fighting force to learn from its mistakes. Mistakes made more than once are waste and totally unacceptable in a military operation. Surfacing challenges have to be managed in a timely manner, and their solutions have to be annotated, to ensure that follow-on forces do not waste valuable time by facing the challenge and "reinventing the wheel". A new solution to the same problem may not be as effective as the previous solution and could be much worse.

Heuristic – "Involving or serving as an aid to learning, discovery, or problem-solving by experimental and especially trial-and-error methods" (Mish et al, 1996)

Lessons learned are essentially heuristics that should be used to ensure that the same mistakes are not made again. They should be simple and to the point. The simpler they are, the more they will be remembered, used and reused. Heuristics are usually not optimal solutions, but they are sufficient enough to ensure that a quick and easy acceptable solution is achieved. The following are some heuristic lessons learned concerning logistics and the ordering and reordering of supplies from modern conflicts in which the United States has been involved.

B. WORLD WAR II LOGISTIC LESSONS LEARNED

World War II challenged the United States logistically like no other war in history. The US and its Allies fought three separate enemies on 5 different fronts: (Eastern Europe, Western Europe, North Africa/Southern Europe, China-Burma-India and the Southern Pacific). Supply operations during World War II were characterized by a push style of logistical planning and ordering. Millions of tons of food, weapons and equipment were transported across the globe. Supplies were gathered at ports of embarkation to await loading and transportation across the oceans to the war zones. Once the supplies reached their respective theater of operations, they were pushed forward to the units on the front lines. Large supply dumps were created as far forward as possible so that they would be close to units that needed supplies, when the need was recognized. (Taylor, 1983) This system worked, but it was very inefficient and incurred unnecessary wastage.

Many new and unique practices were created or used during World War II. They were the resulted from the optimization of various parts of an existing and inefficient supply system. The US Armed Forces did the best they could with what they had. Ultimately, the Allies overwhelmed their foes by producing war material faster than the enemy could destroy it and replace their own losses. Logistical supply operations ensured a US and Allied victory over the Axis powers and some of the heuristics derived from the sub-optimized supply system are as valid today as they were during that conflict. The bottom line is that "large stockpiles of supplies on the battlefield are a thing of the past" (Bourgeois, 1999).

- The packaging of supplies should be strong enough to contain the items but not bulky as to present problems in shipping and storage. (Note: Heuristic was derived from Leighton & Coakley, 1955)

During Operation Torch, the invasion of North Africa, it was noted that packages of supplies should not be too large or heavy. The packaging should be light and durable enough so that it can be manhandled and/or lifted by available cargo gear. (Leighton & Coakley, 1955) In combat operations, logisticians try to increase throughput or supply chain velocity, so that the needed supplies are sent to forward units as quickly as possible. That throughput is bottlenecked at the port of debarkation or anywhere along the supply chain, when cargo handling gear is not available to move it between modes of transportation. If material handling equipment is not available, the lowest common denominator is raw manpower. Supplies and their accompanying packaging should be kept at a manageable, individual weight so that they can still be moved forward when material handling equipment is not available.

- Soldiers should not be over equipped. This adds hardship to the soldier and reduces the mobility of the force. (Note: Heuristic was derived from Huston, 1966)

Figure 10. Unloading barracks bags on Rendova Island (Bohrod, 1943)

The combat soldier and Marine of World War II were grossly overloaded with personal equipment. "This not only added to the burden the individual had to carry, but it taxed transportation and moreover, put unnecessarily heavy demands on the whole supply system." (Huston, 1966) It was noted during Operation Torch that the burden on individual soldiers crossing an assault beach should be reduced to a bare minimum. (Ross & Romanus, 1991) Additional weight slows the overall advance of forces and fatigues those forces. A lighter combat force has a higher probability of achieving its objective on or ahead of time.

It was also noted in World War II that wear and tear on equipment was much higher for units that were in contact with the enemy and on the move. Units that were directly engaged with opposition tended to lose or discard large amounts of individual equipment. (Ruppenthal Vol. II, 1959) Soldiers optimized their individual load so that they carried only what was most important to them into combat. They kept what they absolutely needed and left the rest with a supply sergeant in the rear, or on the battlefield where it could be scrounged by a fellow soldier or by an enemy. This abandonment of supplies was very wasteful and not an efficient manner of supply conservation.

- Pipeline and Supply usage factors are no more than reasonable assumptions. (Note: Heuristic was derived from Leighton & Coakley, 1955)

Figure 11. Pipeline Construction, Linas, France (Dix, 1944)

Planning factors and expenditure factors oversimplify the requirements of a theater of operation. It is almost impossible to account for all of the variables associated with an operation before hand. In 1943 the usage factors did not take into account such variables as climate, terrain, and intensity of action. (Leighton & Coakley, 1955) An additional concern was that commanders and their logisticians overemphasized comparative data based on short periods of intense combat when expenditures where higher. (Leighton & Coakley, 1955) This over emphasis on combat derived data provided a much higher consumption rate for supplies during the periods of relative inactivity.

The procurement of supplies to meet these real and perceived requirements was exacerbated by the theater's absence of prompt planning for current and future operations. (Ruppenthal Vol. II, 1959) This lack of appreciation did not take into account the transportation time required to transit the long distances between the Continental United States (CONUS) and the theater of operations. It was noted that most field commands over-requisitioned supplies, over and above the standard usage factors. This was an attempt to build up an unauthorized reserve in their area of operation. It was perceived to be a cushion to take into account unpredictable delivery of supplies. (Ruppenthal Vol. II, 1959) Those abusing units lacked supply discipline and did not have faith in the existing supply chain to deliver what they needed, when they needed it. A future supply ordering system must take into account the wants and needs of the end-user and not rely solely on predetermined factors that might or might not be realistic for the environment and scenario present in a JOA.

C. KOREAN WAR LOGISTIC LESSONS LEARNED

The Korean War occurred less than five years after the unconditional surrender of Japan and the conclusion of World War II. (Huston, 1966) Logistical supply operations during the Korean War were based on the doctrine and experience developed during World War II. Due to the unique conditions present on the Korean peninsula and limited aspect of war associated with the conflict, additional challenges and solutions were observed in reference to ordering and requisitioning supplies for combat and sustainment operations.

Korea is over 5,000 miles from CONUS. One of the biggest challenges associated with this war occurred in the transportation of supplies. (Huston, 1966) Due to this huge distance, it took an average of 120 days from the order to the delivery of requested supplies, for a unit in combat. (Huston, 1966) The twin tyrannies of time and distance created unique challenges and required careful logistical planning to ensure that the minimum amount of supplies would be present in theater to conduct operations.

- Automatic supply is only as good as the data used to derive the supply requirement. (Note: Heuristic was derived from Huston, 1966)

Automatic resupply shipments are predetermined packages of supplies based on a table of organization (type of unit) and generic consumption rates. It is a PUSH type of system where supplies and material are shipped from CONUS to the theater so that supplies will be present, just-in-case. This provided additional stress to the overall transportation and storage requirements for the theater. (Huston, 1966) It is inefficient in nature and incurs excessive wastage. The data used to determine automatic resupply shipments are heuristic in nature and the actual amount of supplies delivered may not be appropriate for the particular operation that is being planned and executed. It was also noted that the planning, ordering and shipping time-lines were too elongated. This was a liability, considering the ever shifting tactical and operational situations associated with the conflict. (Huston, 1966)

- The hoarding of supplies hurts the entire force. (Note: Heuristic was derived from Westover, 1955)

It was noted that some combat units hoarded supplies while other units desperately needed the same supplies. The frivolous demands encountered by hoarding extra supplies took its toll on the entire system, by requiring a need for extra transportation assets while simultaneously decreasing the supply of vehicles because of increased operating distances. (Westover, 1955) The addition of superfluous items caused the overall force to lose mobility and decrease the efficiency of soldiers by overloading them. (Westover, 1955) In several cases, Class II and IV items were abundant in Pusan but very rarely made it to the front lines. This was due to fact that a greater effort was made to provide Class I, III and V items to combat units. (Westover, 1955) Many of the supplies at the forward units could have been redistributed to adjacent units that needed some of the items. A lack of visibility in the forward units did not allow the operational logisticians to play the part of the honest broker.

The goal of any supply system is to provide all classes of supply to the end-user and ensure that the combat commander has what he needs to provide a decisive effect at a decisive point in time. It is a logistician's job to ensure that the combat commander has the material needed to maintain combat strength. The hoarding of supplies presents a distorted image that affects the overall ability of the force to sustain itself. An expert logistical ordering system will prevent any one unit from hoarding supplies and ensure that supplies are redistributed to units as far forward in the battle space as possible.

D. VIETNAM LOGISTIC LESSONS LEARNED

The United States conducted operations in Vietnam for over ten years. During this time, there was a logistic build up, a sustainment and a retrograde phase of operations. Supplies were in such abundance that many items unknowingly fell into the hands of our antagonists. (Heiser, 1974) This cannot be tolerated in the future, and supply discipline must be maintained. The forces that are set ashore in a JOA should be provided with the equipment and supplies needed to accomplish the desired effect.

Excessive supplies are translated into wastage and will inevitably lead to a slower distribution system and therefore encourage the JOA's forces to circumvent the supply system.

- Large stockpiles make easy targets. (Note: Heuristic was derived from Heiser, 1974)

Figure 12. Field Depot through Duc Storage Area, 5 Miles North of Saigon (Heiser, 1974)

Large stockpiles should be kept to a minimum. They make hard-to-defend, high value, targets for our enemies. (Heiser, 1974) Excessive concentration on troop standard of living (PX, i.e. Class VI) items will cause a corresponding effect on the supply chain distribution system. This also affects the real estate associated with storing, delivering, maintaining and protecting those personal supplies. (Heiser, 1974) A set standard of Class VI requirements should be established at the beginning of an operation and adhered to by all operating forces. If not, the consequences of degrading the distribution system will cause delays in the delivery of items necessary to create a true effects-based impact on the operation. A given standard-of-living could be programmed into an expert system that would sense the stature and longevity of the operation (based on size and timeline) and thereby determine the Class VI requirement. The shipment of nonessential supplies from CONUS should be avoided. (Heiser, 1974)

- Separate supply systems cause confusion and should be avoided. (Note: Heuristic was derived from Heiser, 1974)

Separate distribution systems for Medical, Signal, Aviation and Special Forces were functional in the circumstances associated with Vietnam, but they did not build upon each others strengths and weaknesses. In future operations, more than one distribution pipeline will be severely uneconomical. If the pipeline is too long and cumbersome, both in physical length and time, it will be susceptible to enemy attack and manipulation. (Heiser, 1974) In future operations, a common supply-chain distribution system should be used to support all forces operating in the JOA. This reduces redundancy and increases efficiency. A common supply system would increase the visibility of duplicate supply requirements by adjacent units, thereby maximizing the efficient transport of these common needs. An expert system will be able to track and assist in the management of the future distribution systems.

E. OPERATION DESERT SHIELD /DESERT STORM LOGISTIC LESSONS LEARNED

Saddam Hussein's act of aggressively annexing the sovereign nation of Kuwait, in 1990, elicited a counter response by the United States along with the support of the United Nations and coalition forces. The US prepared to defend Saudi Arabia and retake the Emirate of Kuwait by first pumping in a deterring force and logistical support named Desert Shield. The eventual transition from defensive to offensive operations was dubbed Desert Storm. The most influential part of Desert Shield and Desert Storm was the logistical build up required to support and sustain the coalition forces in the deserts of Saudi Arabia.

The forces participating in Operation Desert Shield/Desert Storm faced a difficult time adapting to the adverse and harsh atmosphere associated with desert warfare. Pushed to its limits, the equipment used during this campaign created an insatiable requirement for (Class IX) repair parts. By developing an expert ordering system, America's future fighting forces will be able to sense the environmental conditions in a given JOA and be prepared for the requests that emanate from it.

- Prepositioned stocks can be quite helpful in fulfilling early requirements, if you know what is available. (Note: Heuristic was derived from Pagonis & Cruikshank, 1992)

Figure 13. SS GREEN HARBOUR of the Maritime Prepositioning Squadron 2 at Diego Garcia (The Motor Transport Corps, 2005)

Maritime Prepositioning Force (MPF) is a collection of ships strategically located around the world. They are broken up into MPF Squadrons (MPSRON). Before Operation Desert Shield, each squadron contained the equipment and basic supplies for a Marine Expeditionary Brigade (MEB) sized Marine Air Ground Task Force (MAGTF). These MPF assets were the first cargo ships containing sustainment provisions to enter the ports of Saudi Arabia. They were a primary source of material and supplies during the early phases of Desert Shield. The bare minimum of every imaginable item needed was provided to sustain the early entry forces. (Pagonis & Cruikshank, 1992) Without that initial infusion of supplies, the arriving combat forces would have had to survive on what they brought with them. The SS GREEN HARBOUR of the MPSFRON 2 was the first ship to arrive in Saudi Arabia carrying pre-stocked ammunition and equipment. (Figure 13)

These prepositioned stocks were essential for the initial survival of the first responding units. One of the main challenges observed was that no one meeting the MPF vessels knew what supplies were loaded in what container. (Vergun, 2002) Each arriving container had to be opened and unstuffed to establish the contents inside. An automated expert ordering system will have visibility of all supplies on the MPF located in the sea base and will be able to cross level supplies to the end user needing them most.

- Supplies that are over ordered and not consumed must be removed or destroyed so that the enemy will not have use of them. (Note: Heuristic was derived from Pagonis & Cruikshank, 1992)

Figure 14. Equipment in Sterile Yard awaiting shipment to CONUS (The Motor Transport Corps, 2005)

The surge personnel and supplies associated with Desert Shield as well as the significant planning associated with Desert Storm built up massive piles of supplies in and around the ports of Saudi Arabia. The swiftness of the ground advance and the effect of the air war on the Iraqi Army were not anticipated and many of the supplies sent to theater were not needed. (Pagonis & Cruikshank, 1992) The accumulation of excess supplies was due in part to poor or non-existent visibility of assets in theater and in the supply chain, which stretched half way around the world. These excess supplies had to be repackaged and placed back on ships headed to CONUS or be destroyed so that the enemy would not have use of them. This was an inefficient use of manpower and material that could have been prevented if properly managed. In future JOAs, an overabundance of supplies may not be available. An automated expert system will allow the logisticians in the sea base to maintain visibility and not reorder, or over order, supplies that are in the supply chain.

- “Automation can help offset the difficulty of providing logistics to supported units.” (Note: Heuristic was derived from Robinson & Walley, 1994)

During Desert Shield and Desert Storm, in-theater processing of containers presented a major challenge. In many cases the documentation in the form of the ship’s manifest did not match what was in the containers. (Pagonis & Cruikshank, 1992) Multiple consignee containers had to be unpacked at the port and repacked so that they could be transported to the correct unit in a specific area. In some cases containers were sent forward, and 90% of the contents had to be returned to the correct receiving unit in the rear. (Pagonis & Cruikshank, 1992) A tremendous number of these containers with unidentified contents where delivered to theater. This caused many containers to be frustrated (become non-deliverable without extensive research) at the port and not allowed to flow forward. (Pagonis & Cruikshank, 1992) An automated form of cargo identification would have assisted logisticians in identifying the contents of containers and ensure that the right supplies went to the right place. This would have dramatically increased throughput and assisted in providing a means to achieve requisition status information more rapidly.” (Robinson & Walley, 1994) An automated expert ordering system will access a ship’s manifest and container data, giving visibility of the containers’ contents, for seamless visibility of the sea base and supply distribution chain. This will assist in the throughput of supplies forward to the units that need them ashore and at sea.

F. OPERATION IRAQI FREEDOM

In 2003, the United States and coalition forces massed in the Emirate of Kuwait, located on the Arabian Peninsula, in preparation for the invasion of Iraq. The gathering of logistical support equipment and supplies went much smoother than that experienced during Operation Desert Shield and Desert Storm. During OIF, logistical planners amassed “small hills” of supplies compared with the large mountains accumulated during the previous war. (Science Applications International Corporation [SAIC], 2003) Even still, these small hills are larger than what is envisioned to support future operations from a sea base. Operation Iraqi Freedom (OIF) is currently in its third phase and will not be ending in the near future. The following are several heuristics that have been derived in logistical operations observed during OIF1.

- Success from anticipatory estimates is more from luck than by design. (Note: Heuristic was derived from SAIC, 2003)

Figure 15. Convoy of tanker trucks carrying bulk Class III, preparing to cross the "berm" from Kuwait into Iraq (Courtesy of MAJ Lawrence Bittner, USAR)

During the initial ground campaign of OIF1, CENTCOM logisticians tried to anticipate what the needs of combat maneuver units would be and queue the items in the supply chain for future use. Pushing supplies forward before a need exists does not necessarily mean that combat troops will be getting what they need, when they need it. This system was primarily used to fill the gaps and limitations associated with inadequate logistical communication and information systems. Essentially, the push system was blind. (SAIC, 2003) The pushing of supplies through the Corps Support Area (CSA) may have also contributed to clogging the distribution system and providing combat units with excessive provisions. (SAIC, 2003) It was noted by the 3rd Infantry Division that supplies coming from the CSA where not visible to its logisticians, and there was little or no idea of what was being pushed until it was received. (Third Infantry Division, 2003) Many additional items were reordered to replace items moving forward, once this initial surge of supplies left the staging areas of Kuwait with the leading maneuver units. Over

3,000 containers of sustainment supplies, containing all classes of supply, were offloaded from cargo ships within weeks of the commencement of the ground offensive. "The theater supply-and-distribution system became overwhelmed." (Solis, 2004) An expert ordering system, sensing the needs of the end user, will provide a consistent and steady flow of supplies from CONUS through a future sea base to operating forces, providing what it is needed when it is needed.

- Effective communication equipment and supply architecture are necessary for all aspects of a fighting force and especially for logisticians. (Note: Heuristic was derived from Broadmeadow, 2003)

Figure 16. A Container Management Team in Kuwait training with an Early Entry Deployment Support (EEDS) Kit (Courtesy of Henry Cook)

The logisticians supporting OIF1 were handicapped, in some respects, by lack of a fully integrated and joint supply architecture that could support all components of the coalition forces in a timely and flawless manner. This communication deficiency impeded the throughput and reliability of the request-pull system. (SAIC, 2003) "The supply system architecture planned for use during OIF was a 'workaround' combination of systems and methods….that never permitted visibility at the battalion or division level of a requisition from inception to receipt." (Broadmeadow, 2003) The lack of a dedicated logistics communication architecture was noted in both the 3rd Infantry Division and 1st Marine Division After Action Reviews (AARs). (Third Infantry Division, 2003) and

(Brief on 1 MARDIV Observations, 2003) "The only consistently reliable form of communication was satellite communications (SATCOM) radios, but they were mostly distributed to combat units and not logistic units." (SAIC, 2003) Combat Service Support units should have had a dedicated system that allowed them the ability to track ordered items from the time they were initially requisitioned until the time of delivery to the end user.

The effectiveness of an automated ordering system will revolve around the hub of a robust logistical communications system. The system should be modular in nature and integrated into the communications architectures used in future conflicts. A joint communication system needs to be fully developed and in place to ensure that all aspects of the behind the scenes logistics battle does not slow down or diminish the striking power of a future sea based combat force.

- Prepositioned stocks are great but they do not have everything that is needed (Note: Heuristic was derived from Solis, 2004)

The Maritime Prepositioning Force (MPF), the Army Prepositioned Afloat (AFA) and the Army Prepositioned Stocks (APS) located in Kuwait were a key factor in the overwhelming success of ground combat associated with Operation Iraqi Freedom. (Solis, 2004) They allowed a rapid Reception, Staging, Onward movement and Integration (RSO&I) of Army and Marine Corps forces with their equipment. This increased the combat power available to the Joint Force Commander (JFC) in theater.

One of the drawbacks to the availability of this prepositioned equipment existed in the fact that the deploying forces had very limited visibility of exactly what were in those stocks. The personnel affiliated with each source of supply knew what they had, but the maneuver unit staffs did not know exactly what was available unless they made liaison with that entity. (Solis, 2004) The logisticians associated with maneuver units ordered and reordered supplies, when in fact those supplies were already available in theater. This lack of prepositioned stock visibility "worsened an overwhelmed theater supply and distribution system." (Solis, 2004) The initial lack of visibility, compounded by the determination of the combat logistician supporting the first responding maneuver forces, caused the supply chain to lose velocity. The supply distribution system will be more efficient if the supplies located in theater are cross-leveled as far forward as possible and used more wisely. Future logistical systems that operate in a sea based environment will have full visibility of prepositioned stocks so that they will be used first. Those supply items not available in the sea base will be shipped from CONUS once requested.

- Knowing where your supplies are located is half the battle. Getting them to the right place at the right time is the other half. (Note: Heuristic was derived from SAIC, 2003)

Figure 17. RFID Tag used during OIF3 to track containerized cargo (Courtesy of Henry Cook)

The logisticians participating in OIF, as well as Operation Enduring Freedom (OEF), used various aspects of commercial enterprise to keep track of the items ordered and evolving through the supply distribution chain. They maintained In Transit Visibility (ITV) with the use of Radio Frequency Identification Tags (RFID) in conjunction with a number of web based applications to monitor the progress of orders. Over 70% of the material entering theater could be identified and located rapidly during OIF1, which was an improvement over Desert Storm. SAIC, 2003) The ITV of the supplies was exceptional from CONUS to theater but much of the visibility was lost once the shipping containers or air cargo pallets left their respective Sea Port of Debarkation (SPOD) or Airport of Debarkation (APOD). (SAIC, 2003) This was due in part to the lack "of consistently dependable communications systems". (Third Infantry Division, 2003) This gap in ITV prohibited the logistical systems in use from facilitating the onward movement of material from SPOD or APOD to the order's initiator. (SAIC, 2003) The dramatic decline of ITV in theater may in part be due "to the emphasis on pushing material forward." (SAIC, 2003)

ITV of supplies in Kuwait and Iraq may be related to the RFID tags themselves. The batteries in many of these tags fail prematurely, due to the excessive desert heat. The tags are also sometimes removed, accidentally or on purpose, during the transportation process. The human factor associated with ITV is excessive. An additional concern is the lack of an interface with the ITV system by the end user. "The work-around combination of systems never permitted visibility at the battalion level of a requisition from inception to receipt." (Brief on 1 MARDIV observations, 2003) The lack of an integrated systems architecture resulted in a less than optimal solution with respect to ITV. Consequently, this resulted in very little assurance that the right supplies terminated in the hands of the right people, at the right time, and in the right place.

An automated and integrated expert ordering system will provide the end user with a clear and concise status of the supplies ordered. An estimated arrival date will be provided to prevent the reorder of supplies. This will assist in alleviating the negative consequences associated with over ordering supplies, in a human effort to hedge bets and over acquire scarce resources. The ability of the end user to see exactly where supplies are in relation to the unit's location will add a bit of surety to what has been called the management of organized chaos.

G. CHAPTER SUMMARY

Many different heuristics have been noted throughout past wars in reference to what can be done differently or improved in the way of logistics on the battlefield. Many of them have been common sense in nature and others have been hard learned over and over again. In addition to the heuristics noted above, future logistic architectures and systems should address the following items:

- Limit the length and links associated with the supply chain distribution system
- Cross level supplies as far forward as possible
- Improve logistics communication which will maintain and improve ITV

- Beware of inefficient push type logistic systems; do not create logistical mountains or hills
- Do not overload combat troops with more than what is absolutely necessary, keep them as light and maneuverable as possible

These heuristics assist in defining the requirements of future logistical architectures by ensuring that the obvious is not forgotten or confused in the clutter associated with the modern day acquisition process.

Military logistical concepts of operation have improved over time, but some of the lessons learned are appropriate in today's conflicts as well as future JOAs. Lessons learned must be incorporated into any future logistical system as a heuristic manner of coping with past imperfections. The proposed architecture for an expert ordering system will not be perfect, but it will incorporate some of the heuristics that have evolved over the last 60 years of joint and semi-joint warfare. The architecture will be a building block that can be used in future generations of automated logistics systems. The efficiency and robustness of future logistical architectures will determine the ultimate staying power of a combat force and will determine the outcome of future conflicts. The armed forces of the United States must learn from past experiences and ensure that our enemies do not exploit our lessons not learned.

Today's military forces are very mobile. The large stockpiles of logistical supplies, present in World War II, Korea, Vietnam, Desert Storm and Operation Iraqi Freedom will be too burdensome to support. This will make logistics the linchpin to success in any future operation. Future logistical systems must maximize the use of automated distribution and tracking systems that allow for the continuous visibility of supplies from their points of origin to their final destinations. (Bourgeois, 1999) The automation must be developed into an architecture that can accommodate any envisioned situation, while still allowing for streamlined modification relative to those challenges not yet envisioned.

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V. EXPERT ORDERING SYSTEM ARCHITECTURE

A. ARCHITECTURE FRAMEWORK

"Architecture is the art and science of designing and building systems." (Webster's II, 1984) A systems architecture is the framework used to tie all of the subsystems together and accomplish the ultimate requirements of that system. This helps the designer to break the system into smaller systems, which can be decomposed to the solution level and optimized. These solutions can then be tested, and re-integrated into a complex system which answers the initial complex problem. The Systems Architecture is the roadmap for this process.

The most common form the architectural decomposition takes is the Functional Decomposition. In a Functional Decomposition, the System is broken down into its parts by function. The problem is then decomposed until a solution is derived for that part. In this case, the problem of ordering supplies is the start point, and decomposing from that point forward.

There are six major functions required to perform the process of Ordering Supplies. They are Identify Need, Acquire Supplies, Package, Transport, Store, and Track Status. These divisions are created based on who is responsible for each function. Five of them have to do with the ordering process, and the sixth is for tracking the supplies while in transit. The Expert System discussed here would be used to address the problems associated with the major functions of identifying the need, acquiring the supplies, and tracking the status. The packaging, transporting and storing of the supplies are beyond the scope of this thesis. Figure 18 shows the Functional breakdown on the ordering system analyzed.

The Identify Need function is primarily performed by the logistician in the JOA. The logistician is responsible for ensuring the order is entered into the system to include all critical data. He or she is responsible for identifying the class of the item, the item description and National Stock Number (NSN), the Quantity required for this order, and identifying the priority of the order. The logistician must assemble these components and enter them into the ordering system.

The second function, Acquire Supplies, is assisted by the Expert Ordering system. In this functional segment, the Expert Ordering system checks the inventories of the local supply, any adjacent supply availabilities, and the sea base. If the item is still not located in sufficient quantities, the system continues to check the CONUS depots before placing an order with the manufacturer. When the system locates the required item, it will determine the best location to draw from based on priority, availability, delivery time, and cost of transportation. It then would flag the item(s) for transport. The system is then responsible for reordering supplies to back fill the item(s) from where it was (they were) taken. It does this by preparing the order for the manufacturer and submitting the order for approval.

The third function is the Track Status. This is the section which makes the Expert System unique. The track status division contains the updated supply data, the status of the track history, and provides trend data. This trend data is used by the Expert Ordering system to adjust required supply levels based on typical usage data. It will be capable of increasing and decreasing these supply levels based on usage rates, mission requirements, and incorporates weather conditions into the analysis.

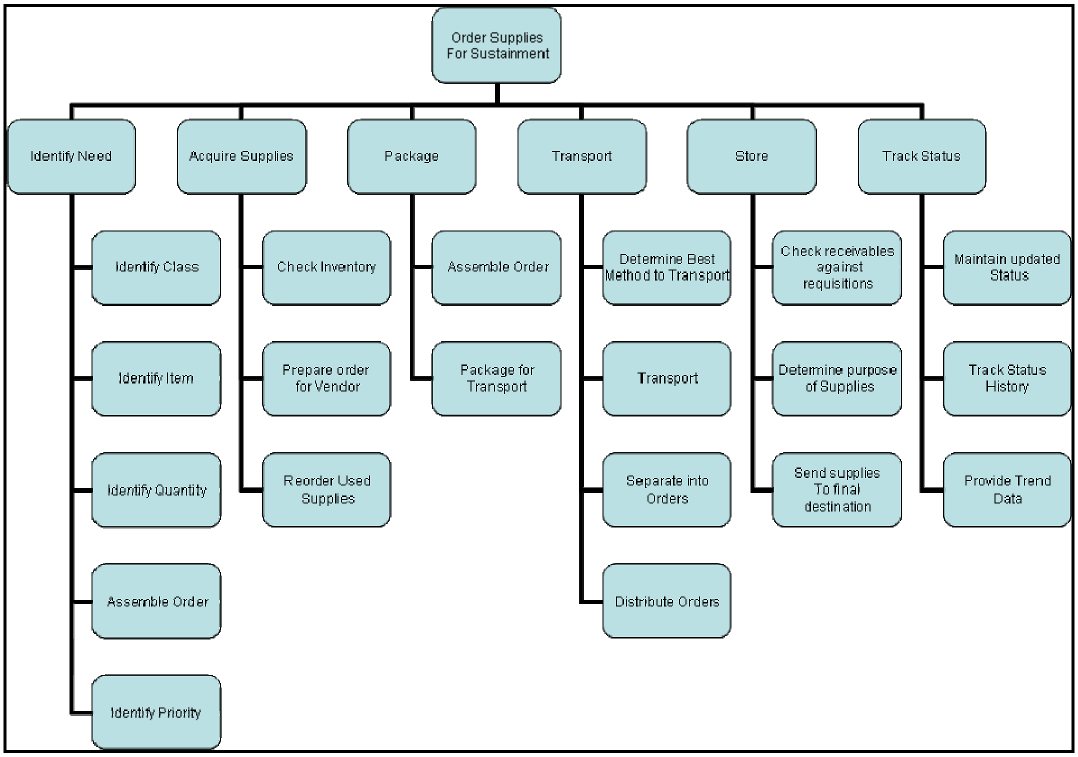

Figure 18. Functional Decomposition of an Ordering Ssytem

B. ARCHITECTURE VIEWS

1. Operational View

"The operational view shows how military operations are carried out through the exchange of information. It is defined as a description of tasks and activities, operation elements, and information flows integrated to accomplish support military operations" (Maier & Rechtin, 2002, p. 224). Three of these elements are required for most systems engineering projects. They are the Operational View (OV) 1, the OV-2, and the OV-3.

"High-Level Operational Concept Graphic (OV-1): A relatively unstructured graphical description of all aspects of the systems operation, including organizations, missions, geographic configuration, and connectivity. The rules for composing this are loose with no real requirements" (Maier & Rechtin, 2002, p. 225).

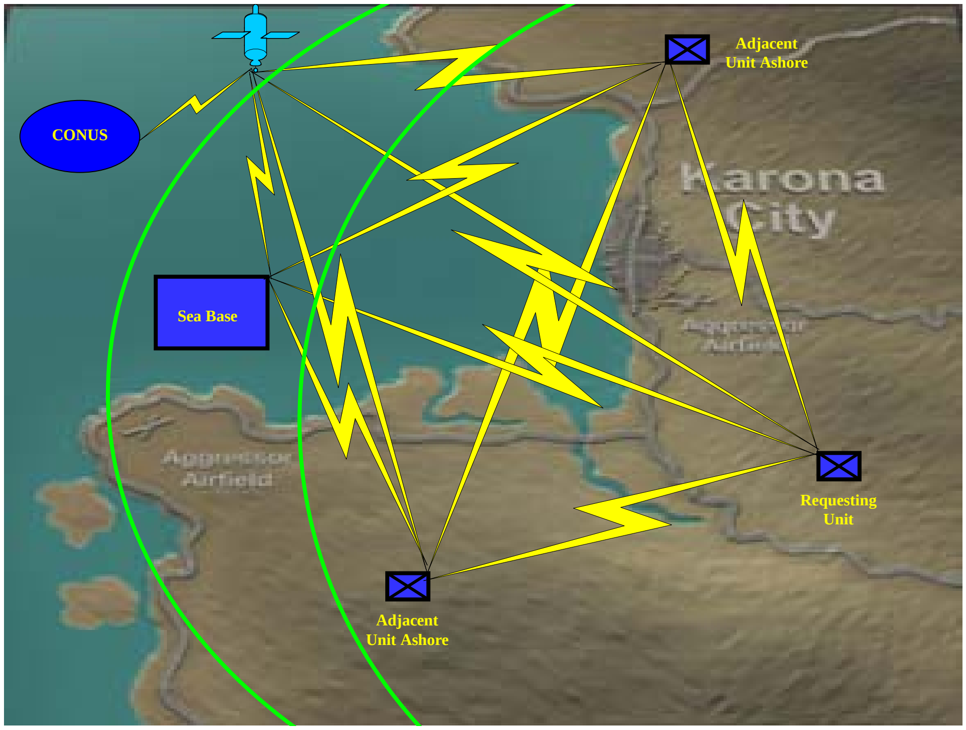

Figure 19. Expert System OV-1 In-theater with reach-back to CONUS

Figure 19 provides a graphic depiction of the high level conceptual view of the Order and Reorder system, showing the communication from the Sea Base and forces ashore conducting operations to CONUS through a satellite communications system. The system is fully integrated into the Sea Base. The System first searches adjacent units ashore for the required supply items, then at the Sea Base, then at the Depot, then at the Manufacturer (Noted by Green Lines). The Expert System locates the available supply item or items, and determines the best source of that item based on availability and priority. The system then requisitions the item from that source, and places a back order to replace the spent item directly from the manufacturer (MFG).

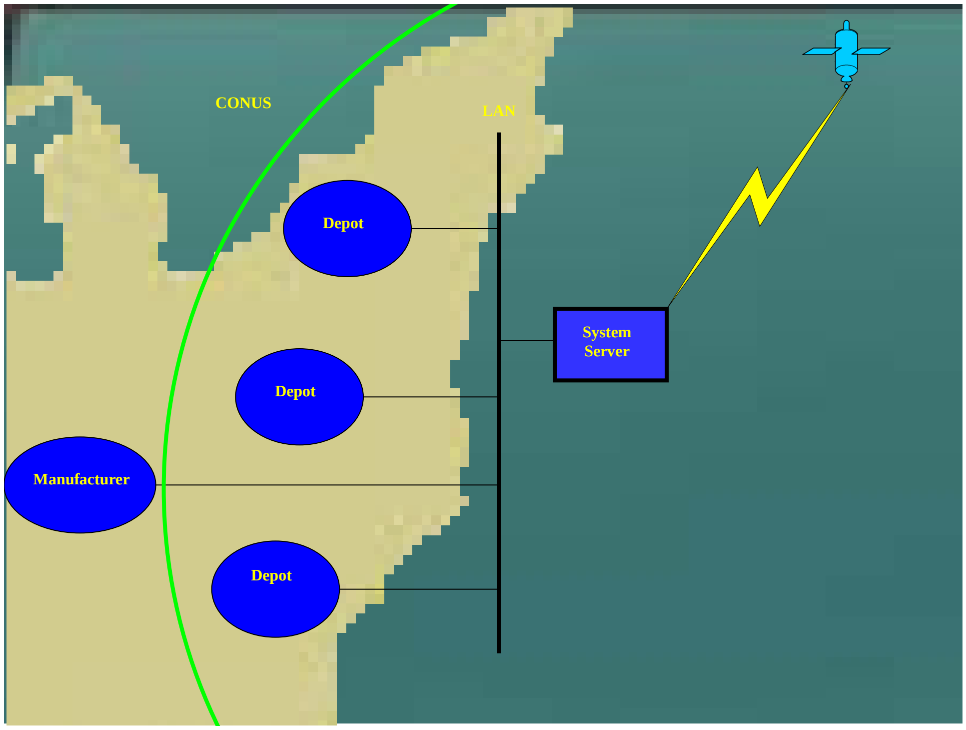

Figure 20. Expert System OV-1 from the satellite to the supply system in CONUS

The OV-1 diagram continues in Figure 20 by showing the communication from the Satellite communications system to the System Server in CONUS. Should the expert system not locate the required supply item from the in-theater sources, it reaches back to CONUS supply depots. If the item is still not located, the item is requested directly from the manufacturer. The system notifies the logistician of the expected delivery of the item. The expert system also prepares requisitions to re-supply expended items from units and the sea base. Based on demand and other environmental factors, the expert system may increase or decrease the item count in the unit Authorized Stockage List (ASL) for that item and orders more or fewer of that item than is required to replace the used stock.

"Operational Node Connectivity Description (OV-2): Defines the operational nodes, and activities at each node, and the information flows between nodes. The rules for composing this are more structured than for OV-1, but still loose" (Maier & Rechtin, 2002).

The Expert System OV-2 is shown in Figure 21. This diagram shows the major actors and systems used in the order and reorder of supplies. It takes into account the actual flow of supplies from node to node. The information that passes between the nodes is as follows:

A) The End User identifies a need and sends the request for supplies to the Logistician. The Logistician replies to the End User stating that they received the order and provide a status of when the order was placed.

B) The Logistician validates the inputs and sends the request to the Expert System and the Expert System responds with a notice that it received the request.

C) The Expert System checks each of the potential Sources of Supply in an expanding search starting with the closest in-theater units.

D) The Expert System searches the Sea-base for the needed supply. If the Sea-base has the supply item, it is sent to the distribution system along path "G" and a status is sent back to the Expert System along path "H". If the required item is found in multiple locations, the Expert System makes a determination of where to pull the item from based on availability and priority.

E) If the supply is not located in-theater, the Expert System searches the CONUS Depots for the needed supply. If the Depot has the supply item, it is sent to the distribution system along path "G" and a status is sent back to the Expert System along path "H".

F) If the supply item is not located at the Depot, the Expert System prepares a requisition and submits it to the Manufacturer.

G) At whichever point the supplies are located, the supplies are sent to the distribution system.

H) The Distribution System sends the status of the order to the Expert System for tracking purposes.

I) The Distribution System sends the supplies to the Logistician and back fills the used supplies to the Depot, Sea base, and other in-theater units as required..

J) The Logistician forwards the supplies to the End User, completing the Order loop.

Not shown in Figure 21, is the track and status and the decision-making loop for adjusting the ASL levels at the sea base and at the operational units. The Track and Status activity is triggered by the Logistician sending a request for status to the Expert System.

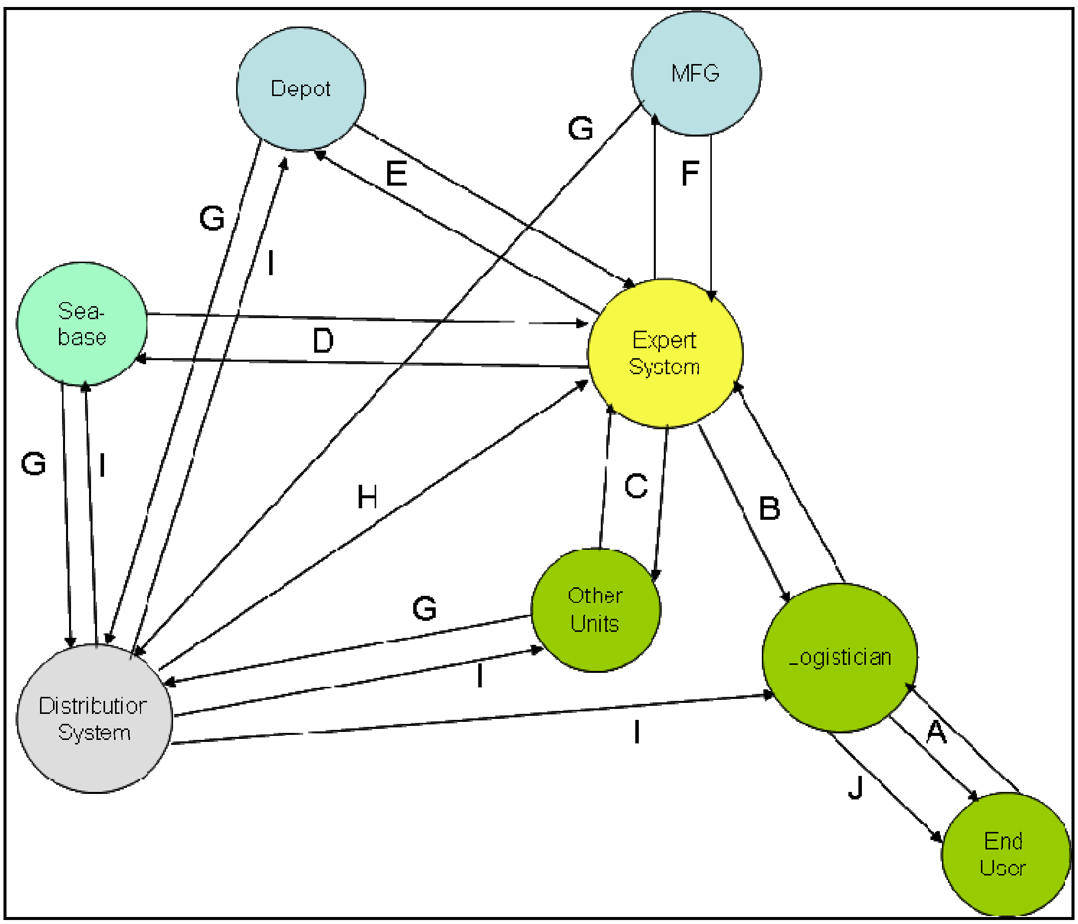

Figure 21. Expert System OV-2 Diagram

The third operational view that is typically created is the Operational Information Exchange Matrix. The Operational Information Exchange Matrix (OV-3) is a matrix description of the information flows among nodes. This is normally done as an augmented form of data dictionary table. (Maier & Rechtin, 2002) The OV-3 diagram depicts logical interfaces between the nodes. These logical interfaces are also shown in sequence diagrams. Sequence diagrams show the data transfer through a standard verb/noun relationship. For example, the data passing between the end user and the Logistician could be stated as provide order data. The term "order data" is a specific set of information. The actual information items making up "order data" would be detailed out in the system dictionary. The OV-3 is not provided as the definition of the data items included in these logical interfaces requires a greater detail than what exists in this high level architecture.

The remaining operational diagrams are used only as needed to add clarity or assist in the design. They are not shown because the information contained requires more detail than is available at this level of decomposition. The Organizational Relationships Model (OV-4) is a moderately structured model of command relationships. (DoD Architecture Framework Working Group [DODAF], 2004) It shows the role or organizational relationship between the organizations. The Activity Model (OV-5) is very similar to a data flow diagram for operational activities. (Maier & Rechtin, 2002) Activity diagrams depicting the order and reorder activity are shown later. Activity diagrams used in the Order and Reorder process are depicted in Figure 24 to Figure 30. The Operational Rules Model (OV-6a) identifies the business rules that constrain the system operation. (DODAF, 2004) The Expert System would use these business rules to analyze the input data. The Operational State Transition Description (OV-6b) defines the business process responses to events. (DODAF, 2004) This is usually a formal diagram. As decomposition continues, the Operational Event-Trace Description (OV-6c) diagrams are developed. These are trace activities in a scenario or Use Case in a sequence-of-events-format. (DODAF, 2004) These diagrams are typically developed from the OV-5 and are commonly referred to as Sequence Diagrams. The last operational view diagram is the Logical Data Model (OV-7). This is usually a class-object model or some other type of relational data model. It defines the data requirements and relationships. (Maier & Rechtin, 2002)

2. System View

"The System View is defined as a description, including graphics, of a system and interconnections providing for, and supporting, warfighting functions. The system view is described with one essential product and twelve optional products." (Maier & Rechtin, 2002, p. 225) The one required element is the System Interface Description, also known as the System View (SV) 1,

The System Interface Description model identifies the system's physical nodes and their interconnections. (Maier & Rechtin, 2002, p. 225) It is similar to the operational node connectivity description (OV-2), but without the human interface. The SV-1 for this Expert System will show the communication between the expert system, and the inventory data stored at each unit, sea base, and depot.

The Expert System SV-1 is shown in Figure 22.

- Connection A: The diagram shows the interaction between the expert system and other in-theater units as well as the sea base inventory as it searches each potential source for the needed item.
- Connection B: This shows the communication between the expert system and the Depot level inventory data.
- Connection C: The expert system interacts with the manufacturer when the needed supply item is not located as well as to back fill cross-leveled or forwarded supplies.
- Connection D: This shows the interconnection between the expert system and the distribution system for tracking purposes. This feedback is then sent back to the expert system along connection D.

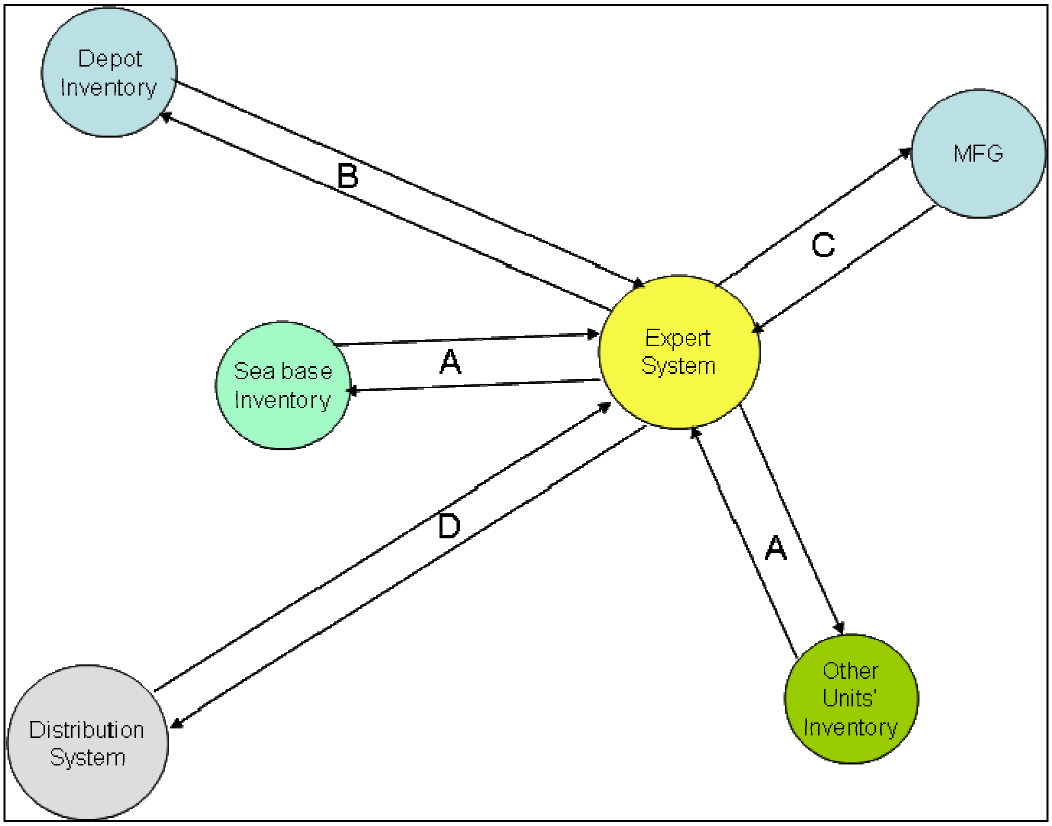

Figure 22. Expert System SV-1 Diagram

3. Technical View

"The technical view is defined as a minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements, whose purpose is to ensure that a conformant system satisfies a specified set of requirements. It has two elements, one required and one optional or supporting" (Maier & Rechtin, 2002, p. 226). The required element is the Technical Architecture Profile View (TV-1). The Technical Architecture Profile is a listing of the standards mandatory for the system being described. In most applications of the C4ISR Architecture Framework (CAF) the technical architecture comes from the Joint Technical Architecture (JTA). (Maier & Rechtin, 2002) The supporting element is the Standards Technology Forecast or TV-2 diagram. This is a projection of what standards and products will emerge during the time the system is developed and operated. (Maier & Rechtin, 2002)

These are the architectural views that are normally used in a complete decomposition. This thesis will not decompose below a high level description and TVs will not be presented. The specific requirements associated with completing the TVs are complex and will require enormous input from all of the present and future stakeholders which are not currently defined or known.

C. USE CASES

"A Use Case represents a series of interactions between an outside entity and the system, which ends by providing business value." (Kulak & Guiney, 2004, p. 35)

Use Cases are a verbal and pictorial method of expressing how a specific process functions. It includes a description of the process, who the actors are in the process, what the triggers are in the process, what preconditions existed before the process began, a basic course of events, any exceptions to the basic flow, what the post conditions will be, any business rules associated with the process, and any technical requirements for the process to function properly. Actors are users, other systems, or external events that interact in a process. (Kulak & Guiney, 2004)

Here, the Use Cases are used to examine what aspects of the legacy ordering system need to be addressed, what areas can be automated, and how they might be able to be automated. The Use Cases are used to validate the functionality of the architecture.

Ordering Supplies Use Case

The first process examined is the process of ordering supplies. This process follows the steps required from the identification of the need, through developing the requisition, to submitting the requisition, through the search for the needed items, and finally ends with the item received by the end user.

The primary actors in this process are the supply system, the logistician or requestor, and the end user. In the improved ordering system, the expert system would replace the ordering system actor.

The trigger for this process is that a need is identified, and the end user reports to the logistician to request the item.

The basic course of events is as follows:

1. Identify the item and class of supply needed

    a. Identify the item and class of supply needed

    b. Identify the quantity of the item required

    c. Check local inventories for the item

    d. If the item is in inventory, issue the item to the end user and place an order for the used inventory item

    e. Assemble the order for the needed supplies

    f. Identify the priority for the supplies

2. Acquire the needed supply item(s).

    a. The order is received by the sea base.

    b. The logistician in the sea base checks onboard inventories for the needed supplies.

    c. If the item is onboard, the logistician issues the item to be sent ashore for the requesting unit with the method determined by the priority of the item.

    d. If the item is not aboard, or if the item has been issues from inventory, the logistician prepares an order to reach back to the CONUS depots.

    e. The order is received by the depot logistician who checks on-hand inventories and issues the item, or back orders the needed items from the manufacturers as required.

3. Package and transport the supply item(s).

    a. The needed item(s) are packaged and assembled based on the intended destination (i.e. depot, sea base, in-theater units). Ideally, the packages should be prepared so that there is no need to open and repackage the items before the end user receives the order. This improves the throughput efficiency.

    b. Assemble the shipments and determine the best method of transport.

c. Transport the supply items as far down the distribution chain as possible

d. Break the shipments into orders and distribute them to the logistician

4. Store and distribute the supply item(s) to the end user.

   a. The logistician receives the supplies and checks what is received against the unit's orders

   b. The logistician determines whether the items are needed immediately or are to replace used stock

   c. The logistician distributes the supplies as needed and stores the restock items

This flow shows how the system would function without the expert system in place of the supply system. In the first step of identifying the needed supply item(s), the expert system would replace the need for the logistician to check the local inventory. If the item is in the inventory, it would notify the logistician and the logistician could issue the item(s) to the end user. The expert system would then re-order the expended inventory item. If the item is not in stock, the expert system would assemble an order and seek the supplies at adjacent units, and at the sea base. The expert system has the ability to search nearby inventories as well as the sea base inventory. There is no need for additional personnel until the item is located or has to be ordered from the manufacturer.

The expert system would have the ability to check all in-theater inventories in the time that the local logistician is able to check just the unit's local stock. This accelerates the locating of the item, and shortens the Mean Logistics Delay Time (MLDT). MLDT is the total time between the identifying of a needed item to the time the needed item is in the end user's possession. Additionally, the expert system has the ability to increase accuracy of the item by first ensuring all required information is entered by the logistician before the order is submitted, and then by reducing the number of human hands involved in the inventory search.

The expert system can assist the logistician in the store and distribute process by immediately identifying the purpose of the supplies received. The expert system can also provide a level of visibility to the logistician. When the needed supply item(s) is found, the expert system can estimate the transit time, and notify the logistician of approximately when the unit can expect the supply item(s).The logistician can also initiate an order status request. The expert system will query the distribution system to determine where the supply was last and give an estimated time of arrival. For this part of the system to function properly, there would need to be advances in the fidelity of in-transit visibility (ITV) presently available in the distribution system.

The final key to the expert system is the ability to improve the local supply stock levels. The expert system will take trend data to determine usage rates. This usage rate will take into account environmental factors such as temperature and location (desert versus jungle), mission (peacekeeping versus assault), and many other factors as yet to be determined. The expert system will then recommend changes to the ASL based on these analyses.

D. USE CASE DIAGRAMS AND ACTIVITY DIAGRAMS

Use Case diagrams and activity diagrams are an effective way to graphically represent the Use Case. A Use Case diagram shows the high level process and what the activities are that support that process, and what actors interact with the process. (Kulak & Guiney, 2004) Both Use Case diagrams and activity diagrams make up the OV-5 views.

Figure 23 shows the over-arching Use Case of ordering and re-ordering supplies. The Order and Reorder activity is the highest level being considered in the asset management world. In this diagram, it is clear who is involved in the overall process, from the actor involved in ordering the supplies, to the actors involved in moving the supplies, to the actors involved in receiving the supplies. The expert system would be the software system which would answer this process.

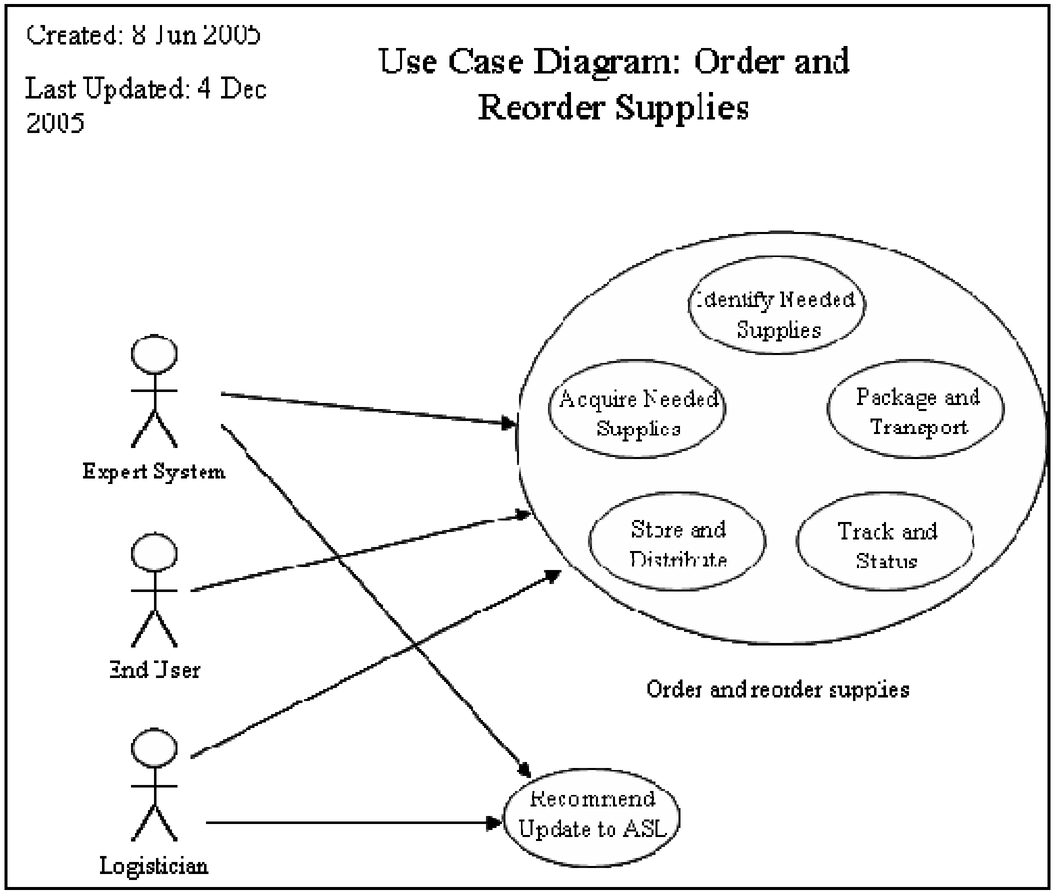

Figure 23. Expert System Order and Reorder Supplies Use Case

Each major step in the ordering process is in itself a process (or activity). These activities are shown on the diagram as separate Use Cases as per the Unified Modeling Language (UML) coding. (Kulak & Guiney, 2004) In UML, an oval represents a Use Case. The bubbles located inside the larger bubble indicate that these Use Cases are an extension of the higher-level Use Case. The actors have a Generalization relationship with the Order and Reorder Supplies activity, since they play a part and interact at different points during the activity. The steps required to perform the Order and Reorder Supplies process are Identify Needed Supplies, Acquire Needed Supplies, Package and Transport, and Store and Distribute. See Figure 24.

The Track and Status Use Case is also a part of the Order and Reorder Use Case.. The Order and Reorder Use Case does not require the Track and Status use case, however the Track and Status Use Case still adds value to the order and reorder process.

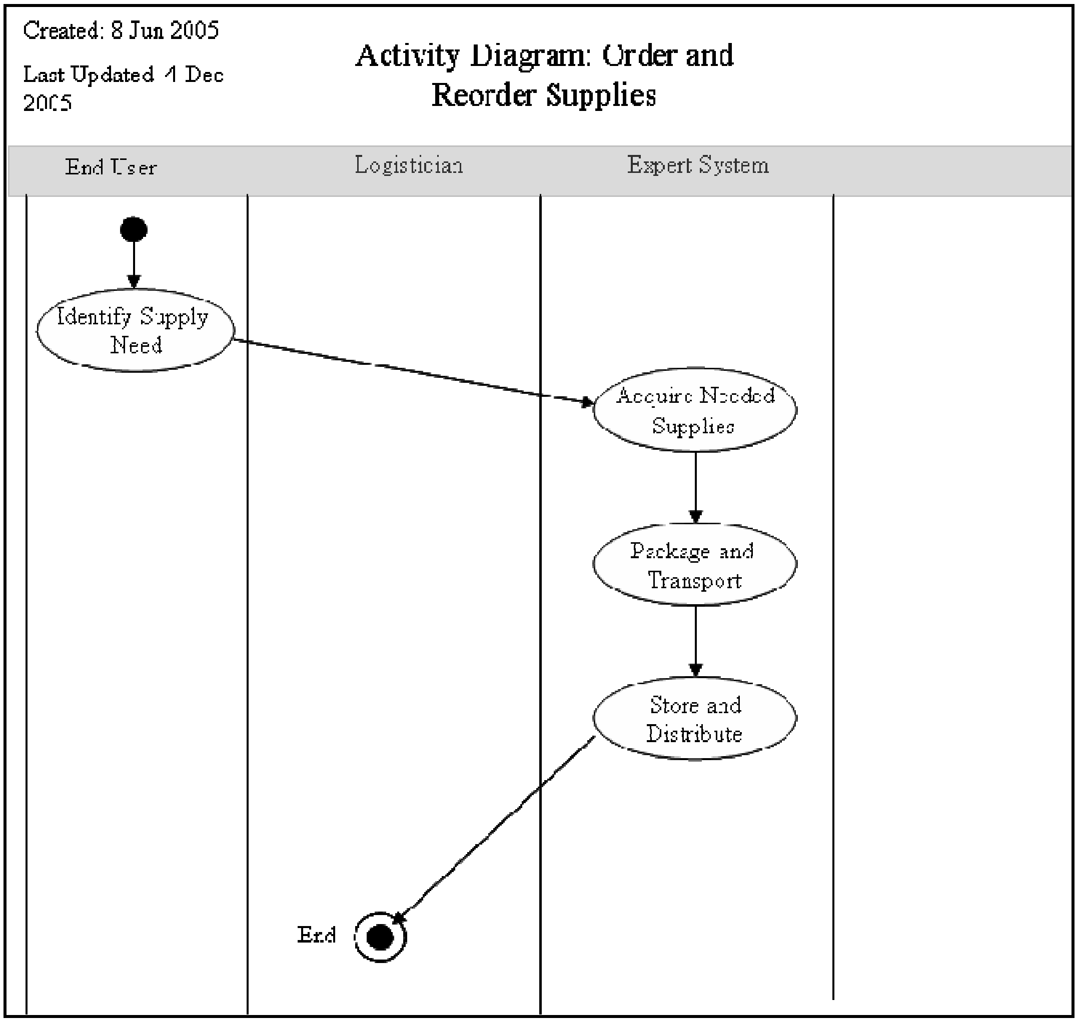

Figure 24. Order and Reorder Supplies Activity Diagram

Each of next level Use Cases is its own separate process. Each process can be broken into the steps required to perform that process. These steps are shown on an Activity Diagram. Activity diagrams focus on the changes from one state to another. (Kulak & Guiney, 2004) Figure 24 shows the steps contained in the System level activity of Order and Reorder Supplies. The activities in this diagram correspond to the use cases shown on the Use Case diagram (Figure 23).

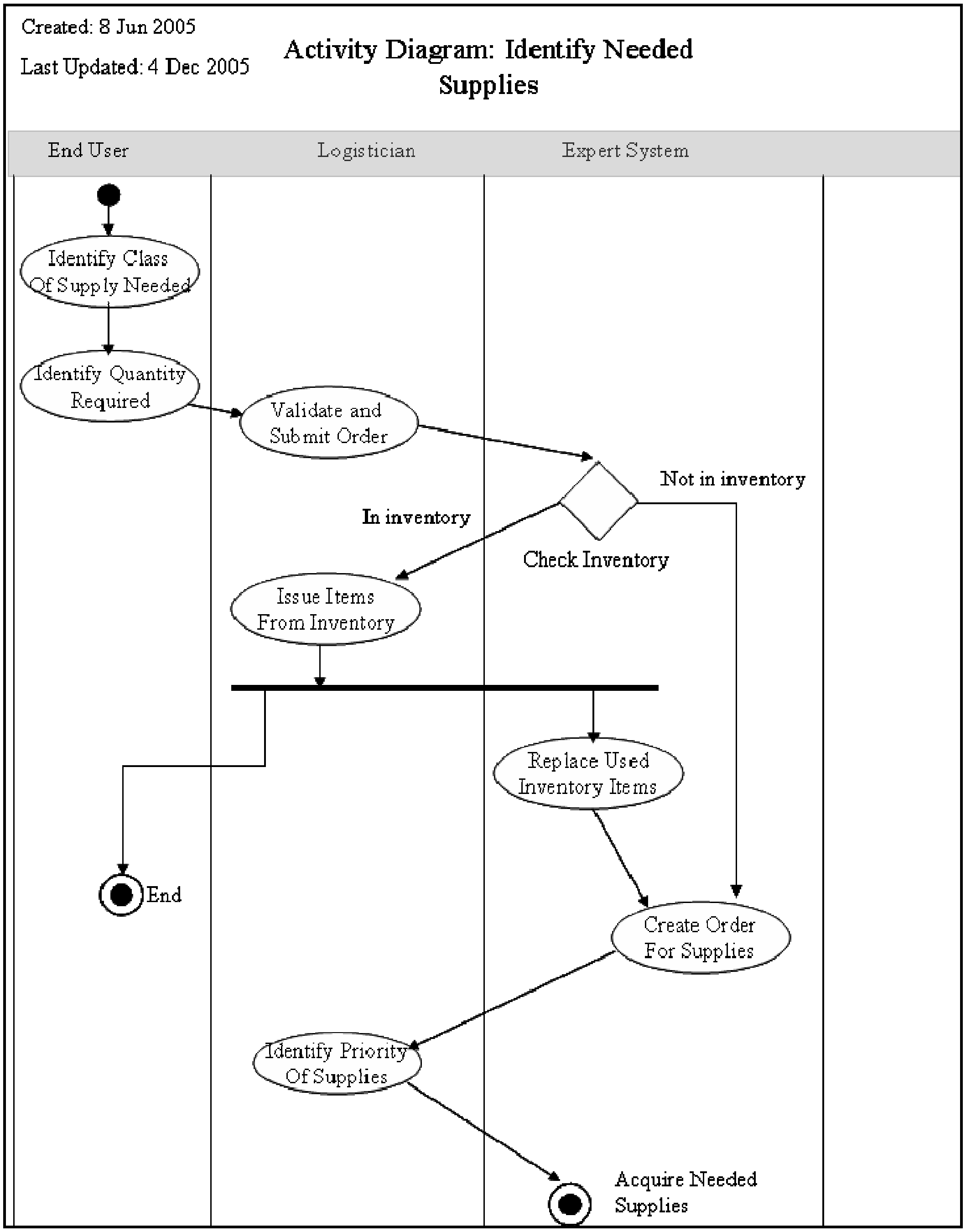

Figure 25. Identify Needed Supplies Activity Diagram

Each of these activities can be broken down at the next level into the steps required to perform the activity. The steps required to identify needed supply are detailed in Figure 25. The steps required to acquire needed supplies are detailed in Figure 26. Figure 27 depicts the steps in packaging and transporting the supplies, and Figure 28 indicates the steps to store and distribute the supplies to the end user. The distribution network falls outside the scope of this paper and will only be discussed as necessary to support the expert system discussion. It does not specify a mode such as road, rail, air or sea.

Figure 29 is one of the key reasons for the expert system. By using an interface defined between the Logistician and the expert system, the Logistician can find out where in the supply chain their required supplies are located. The system envisioned here is similar to that used by United Parcel Service (UPS). The method for transporting the supplies to the Logistician will be based on the priority given to the order at the time of the order. Tracking and statusing will also recommend the modifications to the approving authority for a unit's ASL. The unit's ASL should be modified and tracked for the environmental and operations expected. This will provide valuable data and information for future units conducting similar missions in similar environments. They will be better prepared.

The tracking and reporting that provides the visibility of the supply chain can be accomplished by many different methods, such as active or passive RFID or Global Positioning System (GPS) tracking. The implementer of the expert system must determine what legacy or future systems to incorporate into the tracking module.

The final activity diagram shown here is the primary key to the expert system. This diagram (Figure 30) shows the process where the expert system analyzes the ordering of each unit and updates the unit's recommended stockage lists with an optimized set of stores. The expert system can use a set of known business rules to examine the usage by that unit, and either increase or decrease a specific item as necessary to minimize the weight and volume of stores transported by the unit, and at the same time ensuring the highest level of availability of the unit.

The expert system will combine a number of factors including environmental, usage, and mission factors. The environmental factors include inputs for weather such as hot, cold, dry, or rainy. The system would allow for climate inputs such as artic, temperate, tropical, or arid. The system should also analyze terrain data such as flat, mountain, hills, woods, swamp, jungle, and of course urban.

The usage factors would be based on trend data stored within the expert system. If the expert system determines there is an increased need for a particular supply item, the system will increase the recommended stockage list to compensate. The actual changes to the stockage list should still be approved by the unit's Logistician. If he or she approves the changes, the expert ordering system can assemble and submit a requisition for supplies to update the existing supplies to meet the minimums in the updated recommended stockage list.

The unit mission will affect the recommended stockage list as the various missions have differing requirements. For example, MOOTW would likely require less ammunition supply than an assault force would require. The type of ammunition would be different as well.

The expert system could go another step forward by analyzing the stockage lists at the sea basing level and even at depot level. The expert system can analyze the trend data for previous missions of like type, and recommend changes to the sea base or to the depot levels based on this trend analysis data. This can be used to optimize inventory stockage at all levels of supply.

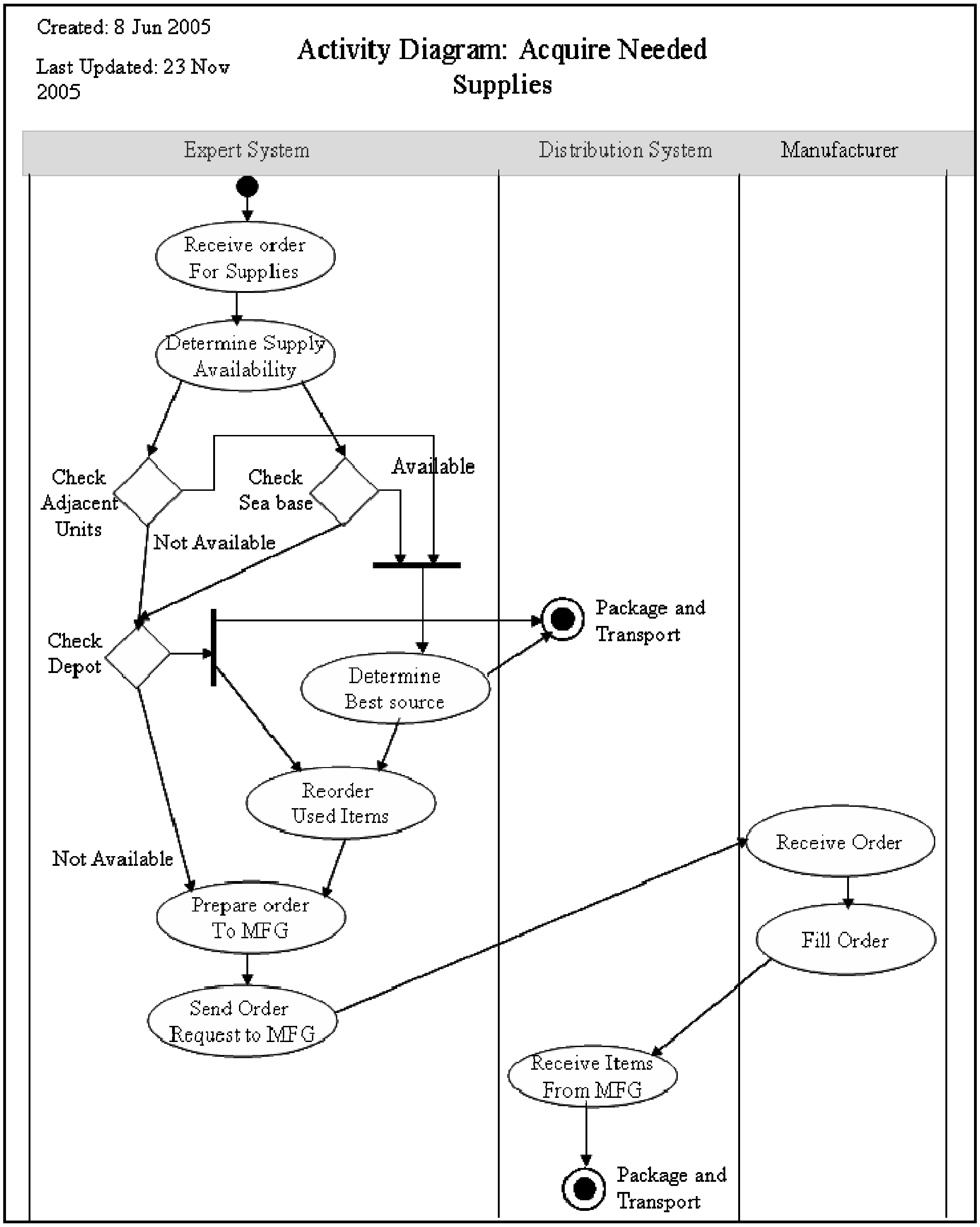

Figure 26. Acquire Needed Supplies Activity Diagram

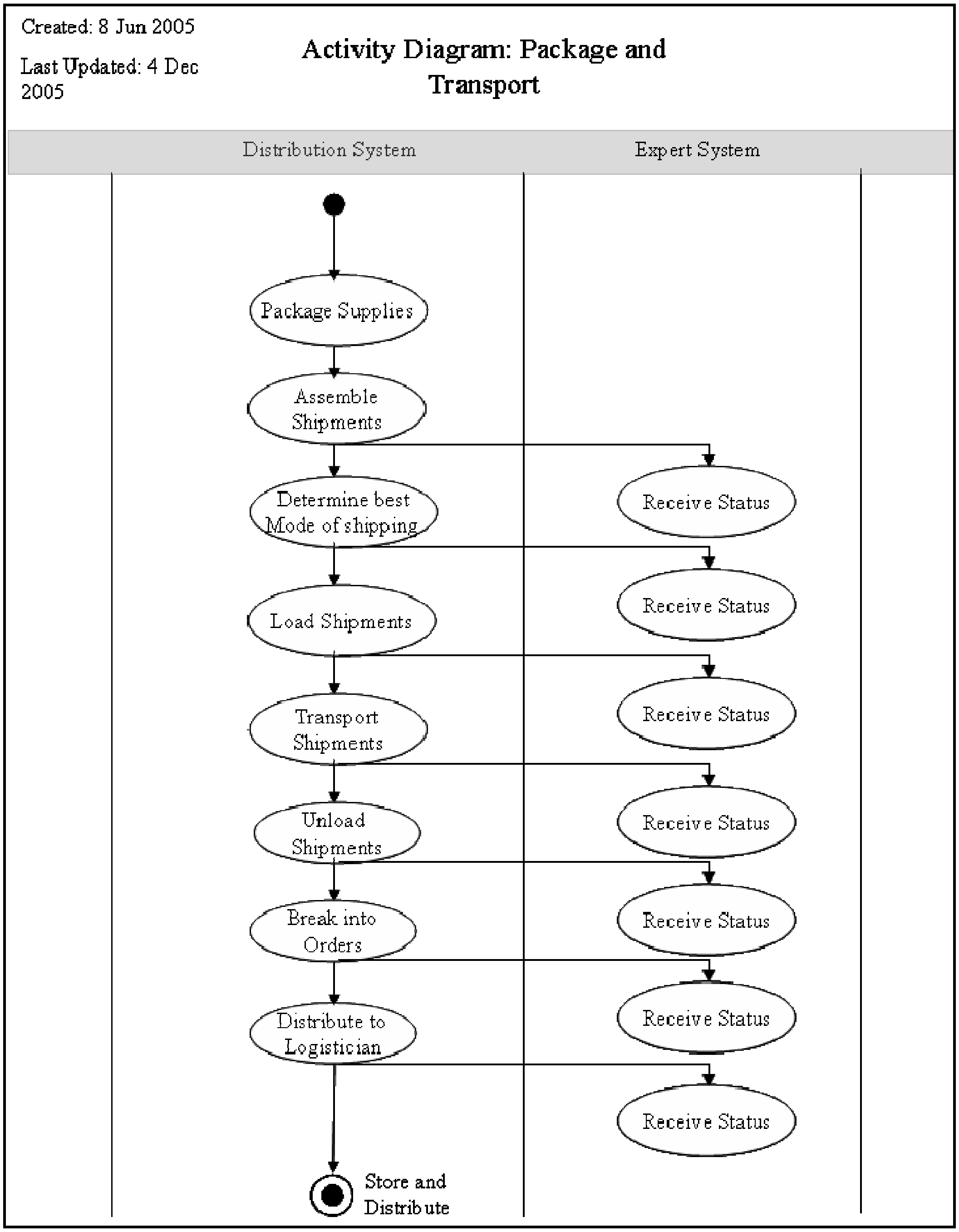

Figure 27. Package and Transport Activity Diagram

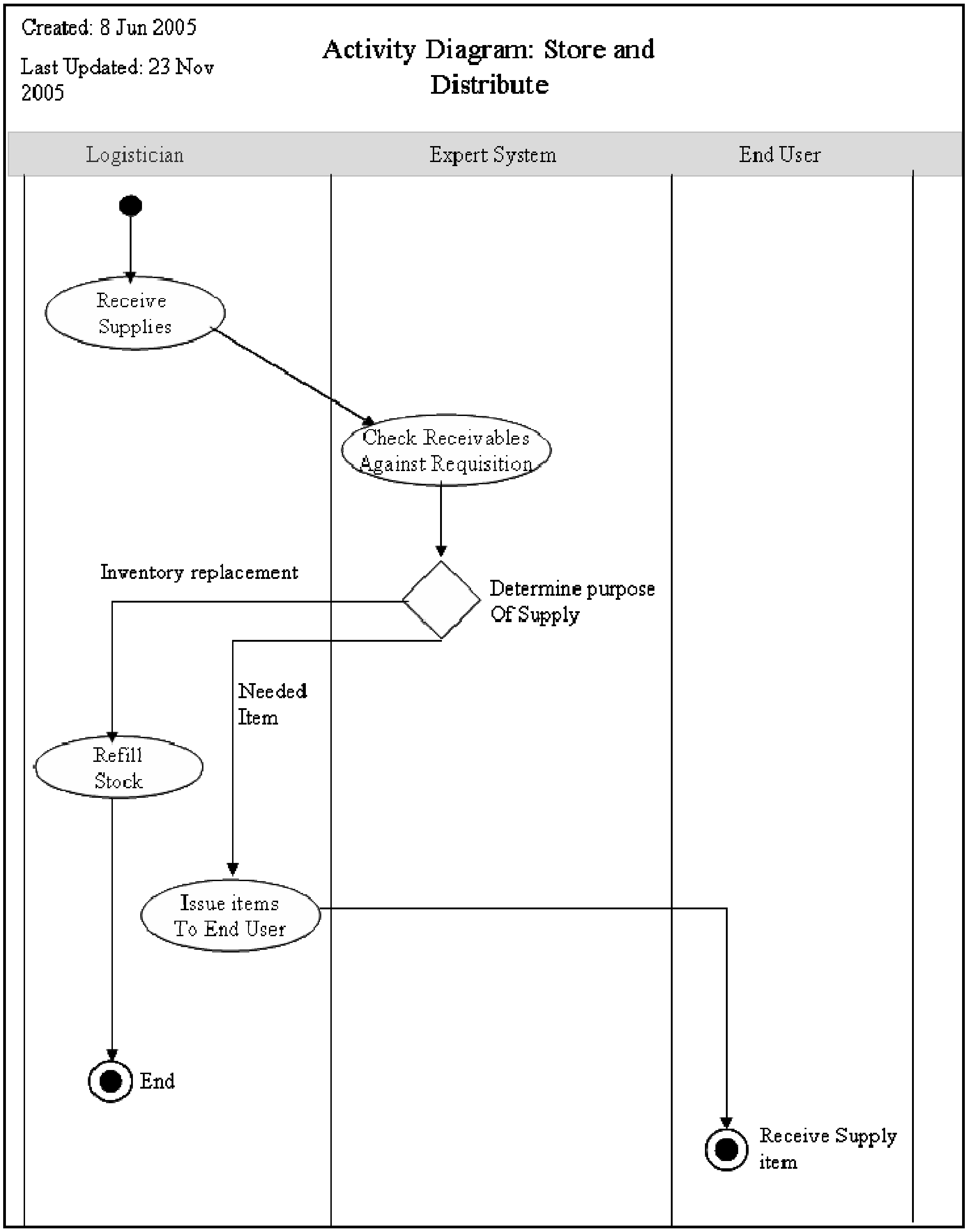

Figure 28. Store and Distribute Activity Diagram

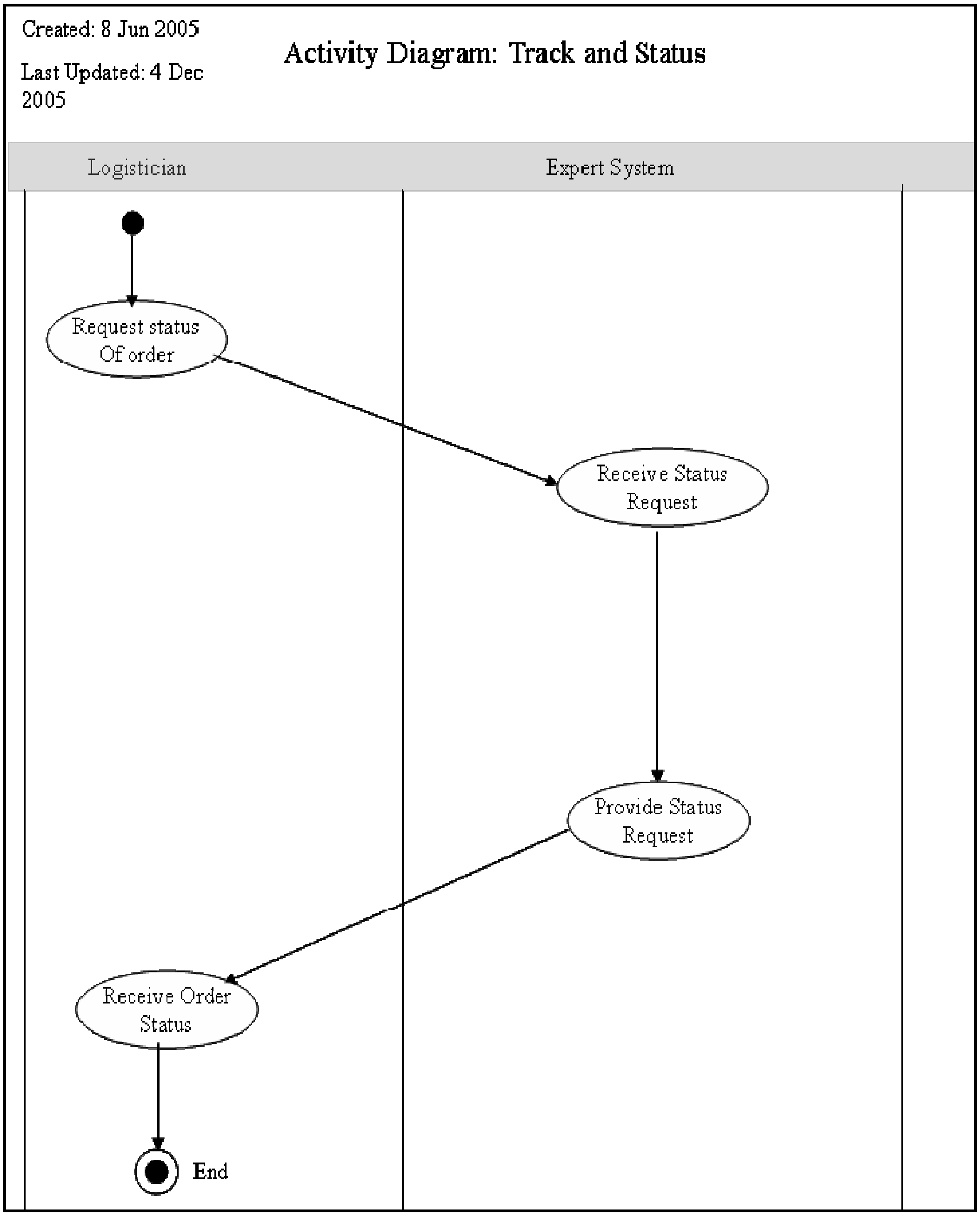

Figure 29. Track and Status Activity Diagram

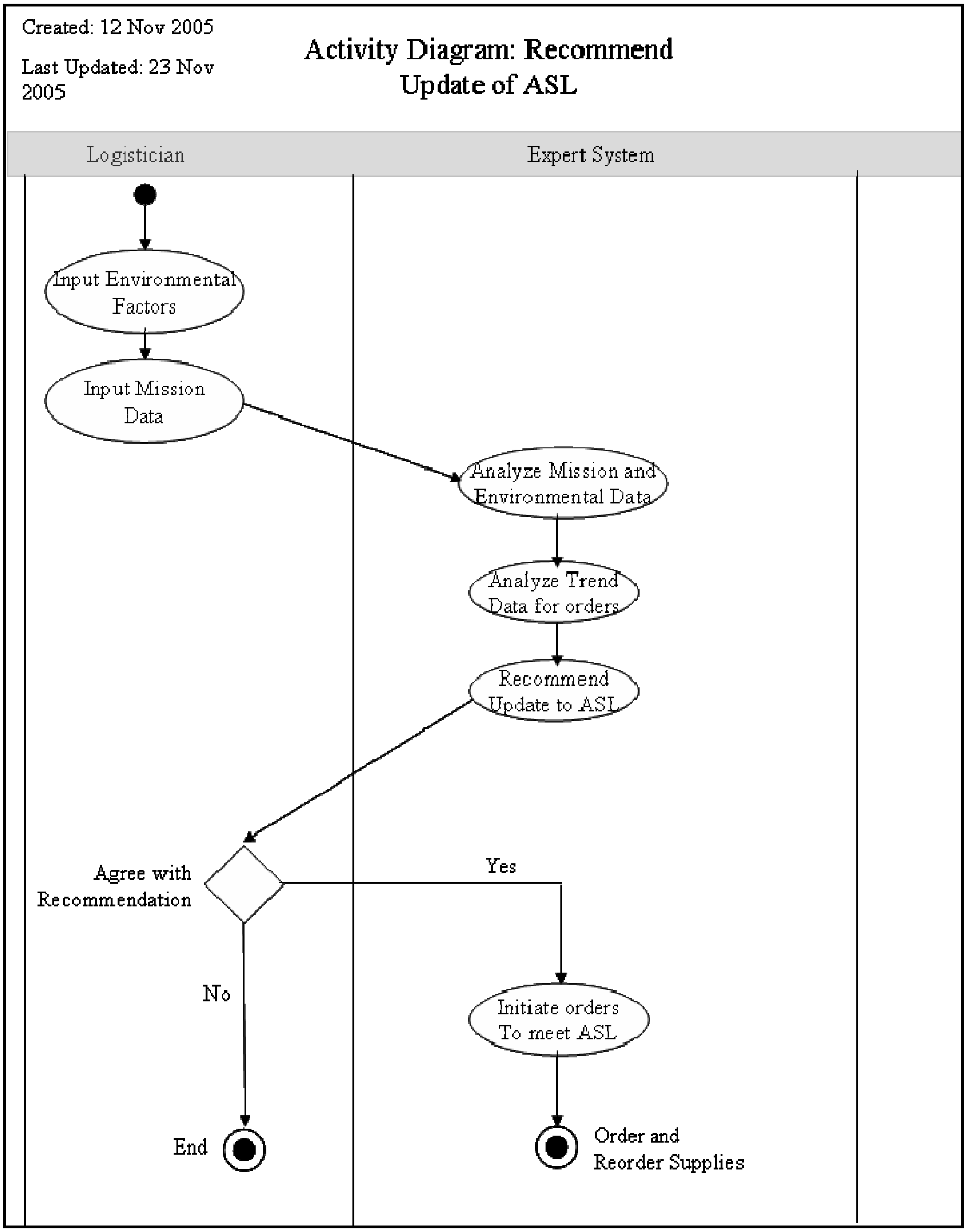

Figure 30. Recommend Update of ASL Activity Diagram

E. CHAPTER SUMMARY

The architectural views provide a top level solution for ordering and reordering supplies in a sea based environment. The Use Cases validate the architecture and provide insight that can be used to write and construct business rules that will assist in the implementation and optimization of the expert ordering system.

These Use Case diagrams can be decomposed to lower levels which provide a greater level of fidelity to produce code in future iterations. In each of these Use Case diagrams, the activity occurs in a specific column, or swimlane. The swimlane is used to help identify who performs the activity or step in that column.

The distribution system is solely used as the glue which ties the nodes together in the supply chain. No existing or legacy systems have been mentioned at this time. Some of the systems may fully meet the modular needs of the architecture, but the architectural views and Use Cases concentrate on the high level needs of the system. It will be the decision of the implementing agency to pick or create the systems that plug into the expert system modules.

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VI. CONCLUSIONS

A. INTRODUCTION

This thesis has addressed the concerns associated with the ordering and reordering process for forces operating in a sea based environment as well as other contingencies. Over the years, the Armed Services have improved their efficiency in delivering supplies to forward forces. The idea of an expert system to reduce the manpower associated with the logistics system is simply the next logical step in streamlining the logistics process.

B. KEY POINTS AND RECOMMENDATIONS

A number of benefits have become apparent in the development of this thesis. At present, the order and reorder system is somewhat labor-intensive. An expert system will reduce manpower by eliminating the need for separate Logisticians to check inventories for the same item. In place of the additional Logisticians, the expert system will check adjacent units and the sea base for the needed supply. Should the item not be located with adjacent units, sea base or depots, the expert system will assemble an order and submit the order directly to the manufacturer. In this way, an expert ordering system will simplify the ordering and reordering of all classes of supplies by only requiring the Logistician to enter the needed supply data a single time. Then, as items are used from the on-hand stocks, the expert system will place the orders necessary to maintain the ASL. The Logistician is presently required to keep up with each item ordered, to ensure that any used stockage is replaced in a timely manner. The expert system will do this for the Logistician automatically.

The expert order system is expected to provide several improvements in the efficiency of the ordering system. Since the data is entered by a single Logistician, there is less opportunity for error to enter the system, resulting in increased accuracy and velocity. Since the expert system is doing the inventory assessment and order packaging planning, it will result in an increase in efficiency and throughput.

An important advantage to the expert system will be the ITV of the supplies. The end users will be able to get an estimate of when the needed items will arrive, and so will be less likely to over-order. This increases end user's surety or trust in the system and will likely result in a decrease in hording. This has an added effect of reducing the quantity of supplies required to be transported, thereby reducing the possibilities of slowing the throughput of the overall distribution system.

Finally, the expert system will provide statistical tracking for ASL adjustments. These statistical adjustments will be reviewed against the vital environmental and mission data and recommend updates to the ASL. Providing these updates would require much time and energy from the Logistician, as well as a level of visibility that may not be available to the unit logistician. The end result is that the expert system will analyze this data and will recommend changes to right-size the ASL at the unit level, the sea base level, and potentially even at the depot level.

C. POTENTIAL AREAS FOR FURTHER RESEARCH

This thesis presents a high level look at the concept of using an expert system to improve the efficiency of Logisticians supporting units conducting a full spectrum of operations. By incorporating an expert system to make adjustments to the unit and depot level ASL, the logistician is given the opportunity to focus more on providing exceptional service to the end user. The architecture presented in this thesis can be used as a basis to continue decomposition in accordance with the DODAF standards, to the code level to create a functioning prototype of the expert system. This prototype can then be tested and implemented into the order and reorder process.

An additional area of future study would be to conduct a stakeholder analysis for the Joint logistical system as a whole with a focus on addressing the needs concerns and challenges associated with incorporating an expert ordering system. The stakeholder analysis would identify any individuals or organizations having an interest or interface with the expert system. This document would help in capturing requirements as well as identify interfaces and standards that must be incorporated to complete the architectural views.

There is also a need to produce a mission needs statement (MNS), an initial capabilities document (ICD) and a CONOPS. These documents are used to solidify system requirements and gain Congress funding. They can also be used as a basis for an initial request for proposal packages, if the system is to be designed and built by non-DoD contractors.

For the expert system to be effective for tracking there needs to be a successful system using some form of ITV. Depending on the priority or needed fidelity, the best form of ITV may be either some form of passive or active RFID, or some technology such as GPS or some future technology that can be used to track items in the distribution system. A trade study weighing the value of each of these technologies would be helpful to the success of the expert system.

Probably one of the biggest improvements to this architecture for an expert system would be to incorporate a form of S&RL for some of the more predictable supply items. Some of these could be monitored in near-real time and fed back into the system such that the Logistician is not required for more than monitoring the rate consumption. An example of this would be fuel. Other things such as food or preventive maintenance parts are predictable within known usage rates. For the preventive maintenance parts, there is a standard maintenance schedule for unit equipment. The maintenance items will be needed on a regular basis. By using the concept of S&RL, the maintenance parts can be pushed to the unit when they are scheduled to be needed. This way, the end user has the part on hand when ready to perform the scheduled maintenance. This will result in an increase in overall equipment availability for operational units.

D. CHAPTER SUMMARY

In conclusion, though it is difficult to predict the added value of the use of an expert system for ordering and reordering supplies, it is clear that there are boundless potential benefits in its use. This, coupled with the future research and trade studies discussed herein, could result in a superior logistics system to reduce the overall burden on forces operating in the littoral regions of the world.

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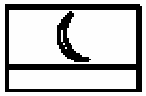
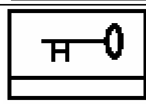
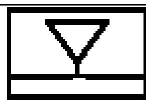
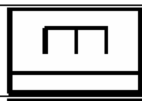
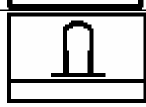
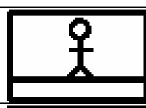
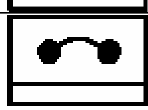
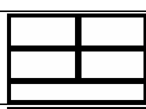
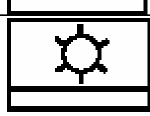
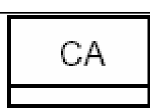
APPENDIX

Class	Symbol	Description	Subclass
I		Subsistence, which includes rations and gratuitous health and welfare items.	A–air (in0flight rations), C–combat rations, R-refrigerated subsistence, and S-non refrigerated.
II		Minor end items, which include clothing, individual equipment, tentage, organizational tool sets and tool kits, hand tools, and administrative and housekeeping supplies and equipment.	B-ground support material, E-general supplies, F-clothing and textiles, M-weapons, and T-industrial supplies (e.g., bearings, black and tackle, cable, chains, wire rope, screws, bolts, studs, steel rods, plates, bars).
III		Petroleum, oils, and lubricants, which include petroleum fuels, lubricants, hydraulic and insulating oils, preservatives, liquid and compressed gases, bulk chemical products, coolants, de-icing and antifreeze compounds and the components and additives of such products, and coal.	A-air and W-ground (surface).
IV		Construction, which includes construction material, installed equipment, and all fortification and barrier material.	
V		Ammunition of all types, which include chemical, biological, radiological, and special weapons, bombs, explosives, mines, fuses, detonators, pyrotechnics, missiles, rockets, propellants, and other associated items.	A-air and W-ground.
VI		Personal demand items and nonmilitary sales items.	
VII		Major end items, which are the final combination of end products assembled and configures in their intended form and ready for use (e.g., launchers, tanks, mobile machine shops and vehicles).	A-air, B-ground support material (includes power generators and construction, barrier, bridging, firefighting, petroleum, and aping equipment), D-administrative vehicles (commercial vehicles used in administrative motor pools), G-electronics, K-tactical vehicles, L-missiles, M-weapons, and N-special weapons
VIII		Medical material, which includes medical unique repair parts.	A-medical and/or dental material and B-blood and blood products.
IX		Repair parts, which include components and kits, assemblies and subassemblies (reparable and non-reparable) required for maintenance support of al equipment.	A-air, B-ground support material, D-administrative vehicles, G-electronics, K-tactical vehicles, L-missiles, M-weapons, N-special weapons, and T-industrial supplies.
X		Nonmilitary material, which includes material to support nonmilitary programs (e.g., agriculture and economic development), that is not included in classes I – IX.	

(Department of Army and Navy, 1997)

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