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An analysis of the joint modular intermodal distribution system

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NAVAL POSTGRADUATE SCHOOL

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MBA PROFESSIONAL REPORT

An Analysis of the
### Joint Modular Intermodal Distribution System

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By: Thomas Louden
         Brian Luebbert
         Nathan Winn

June 2007

Advisors: Aruna Apte
              Douglas Brook
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13. ABSTRACT (*maximum 200 words*) The Joint Modular Intermodal Distribution System (JMIDS) is a Joint Capability Technology Demonstration (JCTD) initiative approved by the Deputy Under Secretary of Defense for Advanced Systems and Concepts. The purpose of JCTD is to evaluate a joint capability through Military Utility Assessments (MUAs) under a variety of military scenarios, while JMIDS aims to address interoperability problems facing the military supply chain. The operational concept of JMIDS is to provide a universal intermodal container system for automated handling, storage, and tracking of supply and ammunition shipments throughout the four Services in order to enhance visibility and increase efficiency in the supply chain. This Joint Modular Intermodal capability is achieved through the use of Joint Modular Intermodal Containers (JMIC), Joint Modular Intermodal Platforms (JMIP), and Automated Identification Technology (AIT). Through the use of these three systems, JMIDS permits the efficient and seamless movement of supplies and retrograde operations through the air, land and sea distribution system to all military locales. The purpose of this thesis is to analyze the costs and benefits of implementing the JMIDS capability within the Defense Distribution System (DDS).			
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AN ANALYSIS OF THE
JOINT MODULAR INTERMODAL DISTRIBUTION SYSTEM

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

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AN ANALYSIS OF THE JOINT MODULAR INTERMODAL DISTRIBUTION SYSTEM

ABSTRACT

The Joint Modular Intermodal Distribution System (JMIDS) is a Joint Capability Technology Demonstration (JCTD) initiative approved by the Deputy Under Secretary of Defense for Advanced Systems and Concepts. The purpose of JCTD is to evaluate a joint capability through Military Utility Assessments (MUAs) under a variety of military scenarios as JMIDS aims to address interoperability problems facing the military supply chain. The current sustainment modules and platforms used among the services lack:

- Transportability across different modes without re-handling/packaging

- Quick reconfiguration for onward movement within an Area of Operation

- Traceability with integrated tags to ensure on-time, direct delivery from depot to end user

- Ease of returnability in retrograde operations.

The operation concept of JMIDS is to provide a universal intermodal container system for automated handling, storage, and tracking of supply and ammunition shipments throughout the four Services in order to enhance visibility and increase efficiency in the supply chain. This Joint Modular Intermodal capability is achieved through the use of Joint Modular Intermodal Containers (JMIC), Joint Modular Intermodal Platforms (JMIP), and Automated Identification Technology (AIT). Through the use of these three systems, JMIDS permits the efficient and seamless movement of supplies and retrograde operations through the air, land and sea distribution system to all military locales. The purpose of this project is to analyze the costs of implementing the JMIDS capability within the Defense Distribution System (DDS). This thesis will:

- Examine the theoretical framework of modularity and its application throughout the commercial marketplace.

- Conduct a life cycle cost analysis of JMIDS.

- Develop a recommendation for the way forward based on the findings of the JMIDS life cycle cost analysis and the feedback from site visit to Defense Distribution Center, San Joaquin (DDJC) where the first MUA took place.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AIS	Automated Information Movement System
ACDS	All-mode Container Delivery System
ACTD	Advanced Concept Technology Demonstration
AIT	Automated Identification Technology
AMRAAM	Advanced Medium Range Air to Air Missile
AUC	Average Unit Cost
CARD	Cost Analysis Requirement Description
CIO	Chief Information Officer
COTS	Commercial Off the Shelf
CROP	Container Roll In/Roll Out Platform
CY	Current Year
DE	Development Engineering
DDJC	Distribution Depot San Joaquin California
DDS	Defense Distribution System
DDSP	Distribution Depot Susquehanna Pennsylvania
DLA	Defense Logistics Agency
DOD	Department of Defense
DTS	Defense Transportation System
DUSD(L)	Deputy Under Secretary of Defense for Logistics
E2E	End to End
FedEx	Federal Express
GAO	Government Accountability Office
GATES	Global Air Transportation Execution System
GPS	Global Positioning System
HEMITT	Heavy Expanded Mobility Tactical Truck Load Handling System
II MEF	Second Marine Expeditionary Force
ISO	International Organization for Standardization
IT	Information Technology
JCS	Joint Chiefs of Staff
JCTD	Joint Capability Technology Demonstration

JDSR	Joint Distance Support and Response
JMIDS	Joint Modular Intermodal Distribution System
JMIC	Joint Modular Intermodal Container
JMIP	Joint Modular Intermodal Platform
LCCA	Life Cycle Cost Analysis
LMUA	Limited Military Utility Assessment
MCS	Management Control System
MHE	Material Handling Equipment
MIP	Modular Intermodal Platform
MUA	Military Utility Assessment
MUC	Multi-Use Container
O&S	Operations and Support
OIF	Operation Iraqi Freedom
OMB	Office of Management and Budget
OMC	Optical Memory Cards
P220	Defense Container
PEP	Producibility, Engineering, and Planning
PD	Production and Deployment
PM	Program Manager
R&D	Research and Development
RFID	Radio Frequency Identification
SWA	Southwest Asia
TEU	Twenty-Foot Equivalent Unit
UPS	United Parcel Service
USTRANSCOM	United States Transportation Command
WBS	Work Breakdown Structure
Wi-Fi	Wireless Fidelity

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I.   INTRODUCTION

This research study examines the concept of modularity and its successes in the commercial marketplace. At the same time, the study determines if the implementation of modularity in the Defense Distribution System (DDS) through the development of a new container system is economical and feasible. Moreover, the study recommends the way forward in terms of a solution for resolving problems of interoperability, visibility, and reliability in the DDS. The research paper begins with a literature review to discuss the history and push for interoperability and improved logistics. Next, the paper addresses the concept of modularity as applied by companies like UPS and FedEx to improve their respective supply chains. Afterwards, the research conducts a life cycle cost analysis of the JMIDS to identify the total cost of the developing such a system and answer the question of affordability and practicality. Based on the cost analysis and information gathered from a site visit by the research group to DDJC, the paper concludes with recommendations for the future of JMIDS and DDS to improve the current supply chain.

A.   LITERATURE REVIEW

Released on May 30, 2000 and signed by the chairman of the Joint Chiefs of Staff, Army General Henry Shelton, "Joint Vision 2020" extends the concept laid out in "Joint Vision 2010" of continuing the transformation of America's armed forces to achieve full-spectrum dominance by having the ability to defeat any adversary and control any situation across a full spectrum of military operations – "persuasive in peace, decisive in war, preeminent in any form of conflict."[1] According to "Joint Vision 2020," the way to achieve the goal of full-spectrum dominance is to invest in and develop new military capabilities in four key areas: dominant maneuver, precision engagement, focused logistics, and full-dimensional protection. The report states that these four

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[1] Jim Garamone. "Joint Vision 2020 Emphasizes Full-spectrum Dominance," American Forces Press Service, June 2, 2000. Last accessed February 15, 2007.
http://www.defenselink.mil/news/Jun2000/n06022000_20006025.html.

capabilities must center on a joint force: "To build the most effective force for 2020, we must be fully joint: intellectually, operationally, organizationally, doctrinally and technically."[2]

The report identifies interoperability as the foundation of effective joint, multinational, and interagency operations and mandates interoperability for the joint force of 2020 – especially in terms of communications, common logistics items, and information sharing: "The joint force has made significant progress toward achieving an optimum level of interoperability, but there must be a concerted effort toward continued improvement."[3] Improvements include further development of common technologies and processes in order to provide responsive, flexible, and precise product support at all levels of operations. Interoperability increases the adaptation of the support to the needs of combat forces that are increasingly more mobile and dispersed and facilitates product support within a shorter amount of time.

Interoperability is a critical element of providing focused logistics. "Joint Vision 2020" defines focused logistics as the ability to provide the joint force the right personnel, equipment, and supplies in the right place, at the right time, and in the right quantity, across the full range of military operations.[4] Through a real-time, web-based information system providing total asset visibility as part of a common relevant operational picture, focused logistics will effectively link the operator and logistician across services and support agencies. With the integration of information, logistics, and transportation technologies, focused logistics will provide the joint warfighter with support for all functions.

"Joint Vision 2020" also outlines that focused logistics will "provide a more seamless connection to the commercial sector to take advantage of applicable advanced business practices and commercial economies," which will combine with innovative processes to dramatically improve end-to-end management of the entire logistics system

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[2] JCS Director for Strategic Plans and Policy. *Joint Vision 2020*. US Government Printing Office. Washington DC, June 2000. p. 2.

[3] Ibid., p. 21.

[4] Ibid., p. 30.

and provide precise real-time control of the logistics pipeline to support the joint force commander's priorities.[5] The integration of advanced transportation systems which are faster and more efficient with greater capacity will further improve deployment, distribution, and sustainment in asymmetric engagements. According to Joint Vision 2020, the asymmetric approaches of our adversaries are perhaps the most serious danger the United States faces in the immediate future. These asymmetric approaches include terrorist attacks in an urban environment, long-range ballistic missiles, and insurgencies in unstable countries which are linked to U.S. interests.

According to a recently published business case analysis on the Joint Distance Support and Response (JDSR) program, the author assessed the current DOD product support infrastructure and processes as being "optimized to meet the military operations of the twentieth century, which operated primarily within well-defined battle lines."[6] The design of the current infrastructure and processes are too slow for the current asymmetric environment. The infrastructure and processes are unique to each branch of service of the military and use aging transportation assets, limited communications networks, and rudimentary tracking capabilities.

In 2005, the Department of Defense (DOD) established a plan to improve some of the systemic weaknesses in supply chain management since the military operations in Iraq and Afghanistan have focused attention on DOD's supply chain management. With the asymmetric warfare in Iraq and Afghanistan, the Government Accountability Office (GAO) reported that the supply chain plays a major role in outcomes on the battlefield, and therefore, substantial investment of resources in improving the supply chain was necessary.[7] With the encouragement of the Office of Management and Budget (OMB), DOD's plan included the integration of supply chain management with broader defense

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[5] JCS Director for Strategic Plans and Policy. *Joint Vision 2020*. US Government Printing Office. Washington DC, June 2000. p. 31.

[6] Sheng Lim Hang. *A Methodological Approach for Conducting a Business Case Analysis for the Joint Distance Support and Response (JDSR) Advanced Concept Technology Demonstration (ACTD),* Naval Postgraduate School, December 2006. p. 6.

[7] United States Government Accountability Office, GAO-07-234, *DOD's High-Risk Areas: Progress Made Implementing Supply Chain Management Recommendations, but Full Extent of Improvement Unknown.* January 17, 2007. p. 1.

business transformation and strategic logistics planning efforts.[8] Later, GAO was asked to monitor the progress in the implementation of the DOD's plan to improve supply chain management.

Released in January 2007, the GAO report concludes that progress in DOD's overall approach to business defense transformation is still needed to confront problems supply chain management. According to the GAO, DOD has focused its efforts towards improving supply chain management, but the department lacks the metrics to demonstrate the full extent of progress.

> Although DOD faces challenges to developing department wide supply chain performance measures, such as the difficulty of obtaining standardized, reliable data from non-interoperable systems, without outcome-focused performance and cost metrics, it is unclear whether DOD is progressing toward meeting its stated goal of improving the provision of supplies to the warfighter and improving readiness of equipment while reducing or avoiding costs through its supply chain initiatives.[9]

In summary, the literature indicates that supply chain management is critical to the warfighter and that improvements are necessary in requirements forecasting, asset visibility, and materiel distribution. In the twenty-first century, operations in Iraq and Afghanistan have shown that in order to adequately support the Future Force of the U.S., the current supply chain will need to undergo transformation to keep up with the operational demands and to be highly responsive, reliable, and visible. The future supply chain must have the capability to deliver products in the right place, at the right time, and in the right quantity in an asymmetric warfare environment.

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[8] United States Government Accountability Office, GAO-07-234, *DOD's High-Risk Areas: Progress Made Implementing Supply Chain Management Recommendations, but Full Extent of Improvement Unknown.* January 17, 2007. p. 1.

[9] Ibid., p. 4.

II. CONCEPT OF MODULARITY TO IMPROVE PROCESSES

A. INTRODUCTION

"An advantage of modularization in the private sector is in managing rapid, sequential innovation and economies of scale."[10] Economies of scale lead to reduction of logistics complexity. Therefore, modularity can achieve reduction in logistics complexity and supply chain costs while incorporating new improving technology and rapid product improvement.[11] In the 21st Century strategic environment, the concept of modularity is essential for flexibility, interoperability, and efficiency. Strategic management of supplies and distribution channels now recognizes the importance of modularity and systems integration in the structure of supply chains to optimize operational performance and maximize efficiency. Modularity has become a general principle in design of products, organizations, and supply chains. As a result of modularity, distribution capabilities of firms are greater than any other time in history with increased accessibility and visibility.

In recent years, suppliers have been drawing attention to the importance of flexibility, reliability, and affordability of delivering products to the markets. Competition demands that firms become more efficient in their supply chain management in order to cut costs and eliminate waste. Principles such as Lean Six Sigma emphasize keeping value-added processes while eliminating those which add no value to the system. In this context, there has been a growing interest in modularity as the means to increase system efficiency and product availability. No longer a mere concept written in engineering design manuals, modularity is now broad systems principle applicable to a wide range of products, processes, and organizations.[12] We now live in a modular age.[13]

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[10] Aruna Apte. Spiral Development: A Perspective, Naval Postgraduate School Acquisition Research Project Report, June 30, 2005, p. 23.

[11] Ibid., p. 23.

[12] Luis Araujo. Modularity, Systems Integration, and Supply Chain Leadership, Lancaster University Management School. 2006. p. 2.

B.   PRINCIPLE OF MODULARITY

According to the Webster Dictionary, the word "modular" describes a physical component which is constructed with standardized units or dimensions for flexibility and variety in use. A modular architecture involves conformity of these physical components and allows for linkage and interoperability. In a supply chain, modularity is synonymous with systems integration due to the numerous linkages among different channels of distribution. In the world of integrated logistics, that means that ground, rail, air, and sea modes of transportation must all tie in together in order to form a network of connected nodes.

These linkages between different modes of transportation require modularity through standardization of shipping containers, container handling equipment, and tracking methods in order to achieve economies of scale and homogeneous transportation, which results in reduction of logistics complexity and hence reduction of cycle time. Standardization aspect of modularity for shipping containers implies that the containers can fit into the cargo space of all types of transportation assets.   By considering the dimensions and capacity of the transportation asset, the system is able to eliminate the need for repackaging and the time delays associated with the process. Modularity also demands that the shipping containers must also be compatible with the MHE (Material Handling Equipment).

The final element of modularity is tracking the containers. The key to a tracking system is visibility, meaning that the tracking system must allow suppliers and customers to locate the shipment at every node throughout the supply chain. This implies that both the suppliers and customers have the technology to access the same network. To allow interoperability among the supply chain network, the technology must allow user interface for tracking to be easy and reliable.

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[13] R., A. Kumaraswamy Garud and R. Langlois. Managing in the Modular Age. Architectures, Networks and Organizations. New York: Blackwell, 2002. p. 149.

1. Benefits of Modularity

One of the important results of modularity is consistency. There have been empirical studies which support the argument that consistency amongst product, processes, and supply chain architectures improves performance. supply chain consistency is characterized as the degree to which production and distribution are scale-efficient no matter what the distance of the supplier is from the target market. High-volume firms with scale-efficient production and distribution have a high degree of consistency and are associated with lower costs. Empirical results suggest that firms with consistency in products, processes, and supply chain outperform those without.[14]

2. Critics of Modularity

The main problem with achieving modularity in a supply chain is that interactions between different organizations vary based on design, capabilities, and activities. The interdependencies between these organizations exist but may not be significant. Each organization is an independent node in the network, and there is very little incentive to become more interdependent. In the adoption of modularity, interaction and cooperation between different organizations are critical. To achieve modularity, the interaction of organizations at different levels involves significant systems integration capabilities. In many cases, firms do not have the time or the money to invest in such an effort. On the cooperation side, organizations have territorial boundaries which prevent the coordination amongst the players within supply chain.

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[14] Luis Araujo, *Modularity, Systems Integration, and Supply Chain Leadership*, Lancaster University Management School. 2006. p. 5.

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III.   CIVILIAN MODELS OF SUPPLY MODULARITY

A.   INTRODUCTION

In the area of supply chain management, global courier operations depend on the efficiency of their chains, and two companies are at the forefront when it comes to running their operations efficiently: Federal Express (FedEx) and UPS.   With technological innovation, UPS and FedEx use modularization to expedite delivery and logistics.   They also use tracking to keep the supply visible.   "The information about a package is as important as the delivery of the package itself," said FedEx founder Frederick Smith in 1979.[15]

An examination of their supply chains is valuable for any company involved in managing complex logistics and supply chain with fast turnaround times and precise deadlines.   Both FedEx and UPS specialize in fast deliveries of letters and packages using both air and ground transportation methods.   Their supply chains are highly dependent on information technology (IT) systems which allow them to process, track, and deliver the parcels with reliability and accountability.   Since IT is critical to their business operations, both companies invest highly in the turnover of their technology.   Currently, wireless networking and smart tagging using radio frequency identification (RFID) tags have been incorporated into their supply chains.   In the last twenty years, FedEx and UPS have implemented innovative technologies as they become available in order to improve efficiency and customer service.

B.   SUPPLY CHAIN

Most U.S. companies still face inefficient supply chains according to a survey sponsored by UPS.[16]   As a result, companies are undergoing large capital investments in

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[15] "Competition takes FedEx and UPS to the forefront of technological innovation," *Rethink IT*. July 2004. Last accessed March 13, 2007. p. 1.
http://findarticles.com/p/articles/mi_m0PAT/is_2004_July/ai_n6148566.

[16] Ibid., p. 1.

synchronizing the entire interaction between vendors, customers and suppliers, not just optimizing small components of the process. For FedEx and UPS, they established this synchronicity through modularity and visibility.[17] Visibility, which is an essential element of an effective supply chain, is the ability to capture and use real time information as products move through the supply chain. By building massive IT networks over the last twenty years, FedEx and UPS now possess the capability to track the flow of goods throughout the supply chain.[18] These large IT networks permit transparency of the movement of goods inside their global network. These IT infrastructures support everything from the rapid dispatch of spare parts needed to repair customer equipment to the real time transfer of funds as a package is delivered.

C.   EVOLUTION THROUGH TECHNOLOGY

Through emerging technology, FedEx and UPS plan to reduce the time and money required to operate their supply chains. Modularity is a key element of both companies' approaches and both believe implicitly in its ability to reduce their costs, improve their efficiency, and increase their customer satisfaction. Both companies have had modular strategies since the late 1980s, based on proprietary containers, platforms, and tracking methods. Now, the latest wireless technologies are allowing modularity in visibility.

FedEx and UPS feel strongly that acceptance and incorporation of commercial wireless technologies into their supply chains improves visibility and operations in general. In recent years, both FedEx and UPS have taken advantage of new wireless capabilities which have come into the marketplace, including Wi-Fi, Bluetooth, cellular networks, GPS satellite location systems, and RFID smart tagging. All these technologies are modular since their construction and operation are standardized, and companies can use them in a variety of ways. For example, FedEx and UPS use various wireless data collection devices, which can scan bar codes on envelopes and packages as

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[17] "Competition takes FedEx and UPS to the forefront of technological innovation," Rethink IT. July 2004. Last accessed March 13, 2007. p. 1.
http://findarticles.com/p/articles/mi_m0PAT/is_2004_July/ai_n6148566.

[18] Ibid., p. 1.

well as RFID tags to determine the location and status of the shipments. These wireless data collection devices can maintain the history of shipment from pickup to delivery, and they are similar to many web-enabled wireless devices used by the customers. Through cellular phones and PDAs, the customers can access the same information for package tracking and drop-off locations.

FedEx and UPS are among the first international courier and transportation companies to adopt wireless technology. According to Rob Carter, FedEx executive vice president and CIO, "Wireless data connectivity is something we've done for many years, but we had to provide our own bandwidth and had to develop technology to manage it."[19] However, wireless technology used in supply chains for pick-ups and deliveries are now off-the-shelf commercial technologies. Both companies feel that this gives them a competitive edge since they can concentrate on implementation rather than spending time and effort on the development of the technologies. According to Ken Lacy, UPS CIO, "You only have a six-month advantage in this industry. The technology is not a secret, and it's what you do with it."[20] Both companies are now looking at using RFID smart tags which have recently been made available in the marketplace. RFID smart tags contain a higher degree of intelligence and make tracking packages easier.

D.   INVESTING IN THE FUTURE

For the next three to five years, the two companies are spending about $120 million on wireless, and each company has an annual budget of $1 billion. Wireless technology will continue to be at the forefront for improvements in the future. For supply chain management, wireless technology is the best way to collect the real time data necessary to manage their operations. Modularity standards of wireless have made a significant contribution to lowering the total cost of ownership of the systems and making them more efficient, especially when they need to be integrated with those of partners and customers. With technology investments in significant improvement of information,

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[19] "Competition takes FedEx and UPS to the forefront of technological innovation," *Rethink IT.* July 2004. Last accessed March 13, 2007.
http://findarticles.com/p/articles/mi_m0PAT/is_2004_July/ai_n6148566.

[20] Ibid., p. 1.

FedEx and UPS continue to improve performance and leverage their supply chains. Having accurate data, on-time deliveries, and smooth rapid border crossings, there is great return on investment associated with information accuracy in this international business.[21]

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[21] Ann Grackin, "RFID for Consumer/Retail Supply Chains," ChainLink Research. March 2004. p. 5.

IV.   JMIDS OVERVIEW

A.   RESEARCH QUESTION

In this thesis we propose to research the following question: What are the benefits gained or efficiencies lost by implementation of the Joint Modular Intermodal Distribution System (JMIDS) at the Defense Distribution Depot (DDJC) in San Joaquin, California?

1.   Why is It Important?

On 21 March 2005, the Joint Chiefs of Staff issued a memorandum stating the need for a standardized approach to packaging and containerization (Figure 1). They felt that "common containers would reduce cargo handling which results in faster distribution with less in-transit losses." [22] Operation Enduring Freedom and Operation Iraqi Freedom (OIF) identified problems in transferring cargo between vehicles of different services. For example, cargo going from a docked Navy ship to an Army truck and then driven to an Air Force plane can be delayed substantially because of differing cargo regulations and container systems.

Sue C. Payton, Deputy Undersecretary of Defense for Advanced Systems and Concepts, reiterated the problem that the current system takes too long: "You can't imagine how long that takes, and how difficult that can be. Grass grows a lot faster than that."[23] At an estimated cost of $27 million, Payton wanted to speed up getting water and food to U.S. forces and other DOD customers through the Joint Modular Intermodal Distribution System (JMIDS), providing a universal intermodal container system for automated handling, storage, and tracking.[24]

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[22] U.S. Department of Defense. *Memorandum for the Office of Secretary of Defense, Chairman Joint Chiefs of Staff, Services, COCOMS, Acquisition Commands, and Agencies.* 21 March 2005.

[23] Mark Tarrallo. "Proof of Concept: Demonstration program puts new technology on a fast track," *Government Computer News.* May 22, 2006. Last accessed December 10, 2006. http://www.gcn.com/print/25_13/40776-1.html.

[24] Ibid., p. 1.

MEMORANDUM FOR THE OFFICE OF SECRETARY OF DEFENSE, CHAIRMAN JOINT CHIEFS OF STAFF, SERVICES, COCOMS, ACQUISITION COMMANDS, AND AGENCIES

SUBJECT: Joint Common Packaging / Containerization

Lessons relearned during OEF, OIF, and other current operations have reinforced the need for a standardized approach for packaging and containerization. To achieve this, we agree a common approach and set of standards must be adopted as quickly as possible. Common containers reduce cargo handling which results in faster distribution with less in-transit losses.

We recommend Commander, United States Transportation Command, as the Distribution Process Owner, coordinate and develop common joint packaging and containerization standards and that the already functioning Joint Intermodal Working Group serve as the action agency for this effort. The Joint Modular Intermodal Container (JMIC) concept, initially developed for ammunition but now broadened to include all classes of supply, is an example of a common modular package that can move throughout the Defense Transportation System (DTS). As a potential end-to-end packaging solution the JMIC meets all DTS constraints and Joint distribution requirements. It can be loaded at a depot, move globally via any means throughout the Defense Transportation System (DTS) without the need for repackaging, and arrive unchanged at the using unit. A common packaging and containerization capability such as the JMIC supports emerging operational concepts and architectures.

Service requirements offices and acquisition agencies shall take distribution, packaging, and containerization into account during planning and budgeting. Additionally, we recommend that distribution needs be identified during material solution briefings in the Joint Capabilities Integration and Development System (JCIDS).

When common standards are established, Services and acquisition agencies will have guidance to use in obtaining systems that will operate in the most effective manner within the DTS. The use of common packaging and containers will ensure cargo moves quicker, more securely, and offer a better opportunity to provide Automatic Identification Technology (AIT) information to the Combatant Commander. We are committed to this capability improvement for distribution.
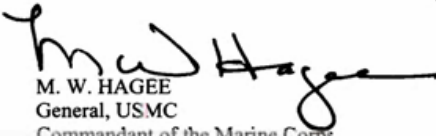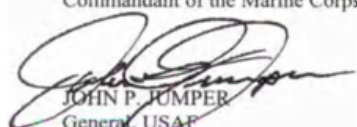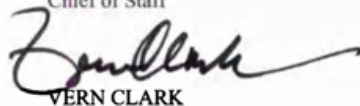
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PETER J. SCHOOMAKER
General, USA
Chief of Staff

JOHN P. JUMPER
General, USAF
Chief of Staff

VERN CLARK
Admiral, USN
Chief of Naval Operations

Figure 1.   JOINT CHIEFS MEMORANDUM.

U.S. Transportation Command (USTRANSCOM) is pursuing JMIDS in order to establish multiple-sized containers that combine build and break down a 20/40-foot ISO container or 463L pallet into pallet/module sized loads. The goal of USTRANSCOM is to reduce overall the theater logistics footprint, including retrograde, while complementing automated loading, handling, and storage systems. JMIDS can increase

interoperability and interchangeability while maintaining compatibility with current transportation modes and common/joint handling equipment. JMIDS characteristics can be described as follows: JMIDS

- withstands harsh environments
- has long service life
- has easy accessibility to contents
- is collapsible to minimize transport of empty containers
- has high durability / strength

As the end-to-end (E2E) strategic distribution process transforms, the Department of Defense (DOD) remains focused on modernizing sustainment packaging to allow for rapid inter-modal transfer of supplies with minimal repackaging requirements. The JMIDS is an example of such a packaging initiative.[25]

2. Addressing the Need

USTRANSCOM is conducting a Joint Capability Technology Demonstration (JCTD), which was approved by the Deputy Under Secretary of Defense for Advanced Systems and Concepts. JCTD consists of Military Utility Assessments (MUAs) for evaluation of the JMIDS concept. These MUAs include the principal scenarios: stability and support operations from depots to end users (air, land and sea) and unit deployment operations related to a joint warfighting exercise. One of the locations for an MUA is the DDJC at San Joaquin, CA.

B. JMIDS CONCEPT

USTRANSCOM is the Combatant Commander (COCOM) sponsor and operational manager for the JMIDS program. USTRANSCOM is supported by two deputy operational managers – the U.S. Army Combined Arms Support Command at Fort Lee, Virginia, and the Naval Surface Warfare Center Indian Head, Detachment Earle at

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[25] United States Army. Deputy Chief of Staff G-4. "Modernize Theatre Distribution." Army Logistics. April 2005. Last accessed February 12, 2007. www.hqda.army.mil/logweb/UpdatedCombinedpapers.pdf.

Colts Neck, New Jersey. The Army's Armament Research Development and Engineering Center at Picatinny Arsenal, New Jersey, is the technical manager and transition manager for the effort and provides all of the material and training for the demonstration. Additionally, the JMIDS management team is working through the Office of the Secretary of Defense International Programs Office with the United Kingdom's Ministry of Defense to establish JMIDS as a formal Coalition Warfare initiative.[26]

There are three components that make up the JMIDS: Joint Modular Intermodal Container (JMIC), Joint Modular Intermodal Platform (JMIP), and Automated Identification Technology (AIT).[27] (Figure 2)
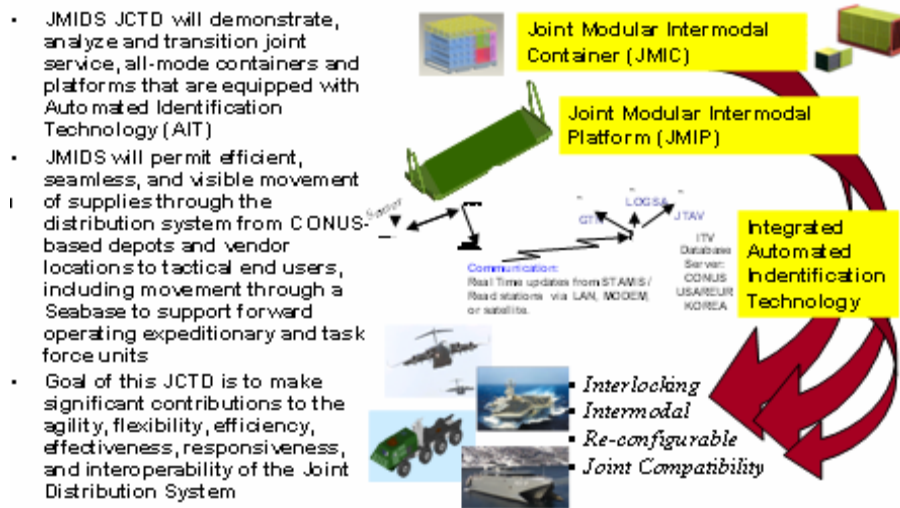

Figure 2. Joint Capabilities Demonstration Overview.[28]

[26] "JMIDS Demonstration." *DPO Update.* 28 September 2006. Last accessed December 5, 2006. https://acc.dau.mil/CommunityBrowser.aspx?id=119440. p. 1.

[27] Ibid., p. 1.

[28] Anna Wojciechowski. "Joint Standardization Board for Intermodal Equipment." *Joint Intermodal Working Group.* 22 May 2006. Last accessed December 12, 2006. Slide # 15. www.dsp.dla.mil/2006-DSP-conf/Wojciechowski.ppt.

JMICs augment the Joint Distribution System through the use of standardized interlocking cargo packaging modules which enable fast access, rapid assembly/reconfiguration of loads, and eliminate resource intensive cargo handling, and may be used to provide more effective distribution from strategic to tactical levels to ensure better sustainment out to the point of effect. JMIPs provide interoperability among all modes of commercial and military transportation through a compatible cargo platform to include direct access to Air Force aircraft. The JMIP all-mode capability permits the movement of cargo from origin to user without time- and resource-intensive handling and reconfiguration. AIT will be integrated in JMICs and JMIPs to provide In Transit Visibility and Total Asset Visibility to improve the situational awareness of supply and unit movements. The JMIDS JCTD will investigate several RFID and satellite technologies to include sensitive cargo sensors that monitor temperature and shock.[29]

Currently, USTRANSCOM is funding assessment of commercial off the shelf, modular-type containers and how they stand up within the defense transportation system (air, ocean, land) and in the underway replenishment and airdrop delivery systems. Containers being used in Phase I and II are: Multi-Use Container (MUC) and Reusable Bulk Container (RBC) are in current Navy inventory; P2 Pack is the standard container used by Distribution Depot Susquehanna Pennsylvania (DDSP). All-mode Container Delivery System (ACDS) is a lightweight plastic commercial container; Clip-Lok is a commercial plywood semi custom (size) container; Uni-pak is commercial fiberboard sidewall, plastic base, and cover container. There is a wide variety of sizes and types of modular containers with different attributes. The goal is to set DOD standards for a family of containers.

For Phase I, USTRANSCOM conducted a unitization demonstration which focused on moving supplies in various types of commercial off the shelf (COTS) containers in the defense transportation system (Figure 3). It shipped general supplies from DDSP to Second Marine Expeditionary Force (II MEF) in Southwest Asia (SWA)

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[29] "JMIDS Demonstration." DPO Update. 28 September 2006. Last accessed December 5, 2006. https://acc.dau.mil/CommunityBrowser.aspx?id=119440.

using COTS containers packed on pure pallet via both Air (on 463L) and Sea (TEU). The demonstration used ACDS, RBC, and P220/P230. An analysis was conducted based on the survey results of DDSP and II MEF.[30]
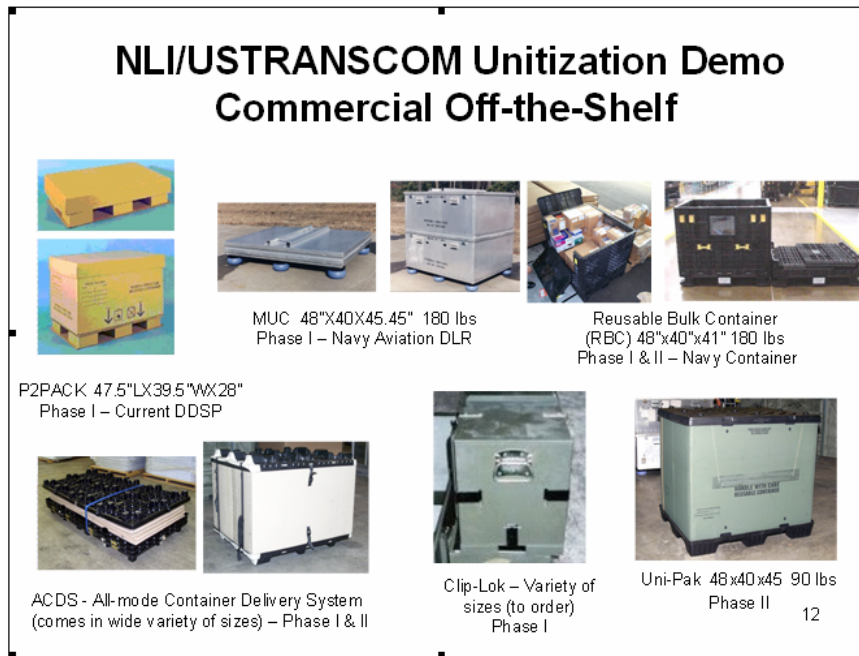
Figure 3.   JMIC Visual Depiction.[31]

II MEF users (Rear and Forward Deployed) provided limited but favorable feedback. Defense Logistics Agency (DLA) warehouse setup required off line processing of all sizes of ACDS due to the current physical setup which is designed for 48x40 containers. RBC worked well but weight was an issue. P230 (DLA standard) was the most cost effective for single trip (or limited reuse up to about 5 trips). In order for the containers to be more cost effective, they must be reusable more than 5 trips.[32]

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[30] Anna Wojciechowski. "Joint Standardization Board for Intermodal Equipment." Joint Intermodal Working Group. 22 May 2006. Last accessed December 12, 2006. Slide # 13. www.dsp.dla.mil/2006-DSP-conf/Wojciechowski.ppt.

[31] Ibid., Slide # 12.

[32] Ibid., Slide # 13.

C.   SYSTEM EXPLANATION

The foundation for JMIDS is the JMIP. The JMIP, as seen in Figure 4 along with 8 JMICS, is reconfigurable to allow many different applications. It also maintains compatibility with commercial and industrial container systems in order for the Department of Defense to utilize existing infrastructure networks to deliver supplies through numerous channels. At the time of this writing the platform was being developed by two companies who are vying for the contract. Boeing Corporation is developing a two piece and a single piece platform. The two piece platform will break down into two identical platforms with an adjustable width from 88 inches to 108 inches and will fit in an International Organization for Standardization (ISO) container which is either twenty or forty feet long, eight feet wide, and eight and a half feet high. The JMIP is configurable for air, rail, road, and shipboard shipment. The underside of the platform has multiple moving parts that allow the different configurations. For example, the Boeing Modular Intermodal Platform MIP when configured for aerial port operations, the sides of the platform extend and the retractable wheels extend in preparation for loading. Also, the K-loader skids are extended for use with the Army's Heavy Expanded Mobility Tactical Truck Load Handling System (HEMITT LHS). The extended side rails on the platform allow for the platform to interact with the track system in the C-130 aircraft. The extended wheels allow for the interaction between the platform and the moveable loading vehicle. The Sea Box MIP is configured very similar to the Boeing MIP in all matters except where the Boeing MIP has extendable wheels, the Sea Box MIP has and extendable platform to allow interaction between the MIP, the moveable loading vehicle, and the aircraft. These various configurations allow the JMIP to be employed in a variety of transportation modes. The JMIP will complement and ultimately replace the Container Roll In/Roll Out Platform (CROP).[33]

Current CROP handling procedures and configurations are well suited for Army, Navy and Marine Corps uses. However, when faced with today's rapidly changing

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[33] Anna Wojciechowski. "Joint Standardization Board for Intermodal Equipment." *Joint Intermodal Working Group.* 22 May 2006. Last accessed December 12, 2006. Slide # 16. www.dsp.dla.mil/2006-DSP-conf/Wojciechowski.ppt.

political and military environments, there is a need to move more and more cargo using Air Force assets. The CROP cannot directly adapt to Air Force aircraft footprints. Therefore the CROP must be changed to meet these requirements of the differing airframes. "Two methods are available to move a CROP-load of ammunition:

1. Reconfigure the load from the CROP onto multiple 463L pallets to load onto the aircraft, with reconfiguration back onto the CROP.

2. Moving the CROPs onto triple married 463L pallets."[34] (Figure 4)

These methods require tremendous amounts of labor and material handling equipment (MHE) to accomplish. These methods also make poor use of the space in the aircraft. It is predicted that the use of the JMIP will result in the following: "...aircraft turnaround time will decrease by up to 75%; MHE utilization time will decrease by at least 50%; and man-hours per platform will decrease by 55%.[35]

Figure 4.   JMIP. From Ref 57.

The JMIC accompanies the JMIP Both containers are intended to transform the way logistics is handled within the Department of Defense. They are completely collapsible and will eliminate the need to repackage supplies at intermediate shipping

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[34] Anna Wojciechowski. "Joint Standardization Board for Intermodal Equipment." *Joint Intermodal Working Group.* 22 May 2006. Last accessed December 12, 2006. Slide # 10. www.dsp.dla.mil/2006-DSP-conf/Wojciechowski.ppt.

[35] Ibid., Slide #11.

nodes. "JMICs will augment the DTS [Defense Transportation System] through the use of standardized cargo packaging modules. [They] will enable fast access, enhance rapid assembly/reconfiguration of loads, and eliminate resource intensive cargo handling."[36] This reconfiguration capability allows the JMIC to be deployed in a vast array of uses. Further, in the Department of Defense's need to instill a more joint environment, all services will be able to use the JMIC to reduce inefficiencies and increase throughput at transshipment nodes and deliver the supplies to the end user in a streamlined fashion. Some of these uses are as follows: Standard JMIC (Figure 5); JMIC frame with rigid plastic insert (Figure 6); Liquid tank in JMIC frame (Figure 7); and the sealed controlled breathing JMIC. (Figure 8)

Figure 5.   JMIC. From Ref 57.

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[36] U.S. Department of Defense. *JMIDS DRAFT JCTD Management Plan.* Version 3.1. 15 June 2006, p. 2.
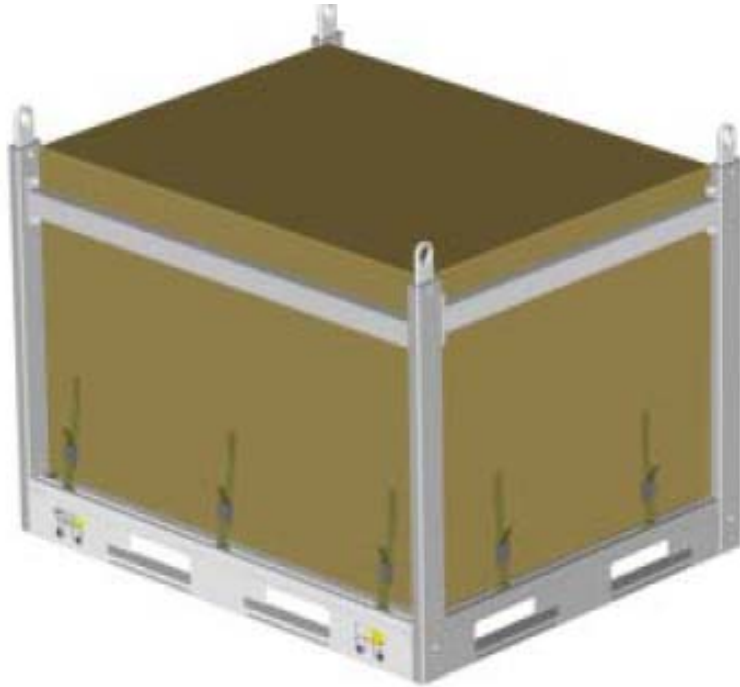
Figure 6.   JMIC Frame. From Ref 57.
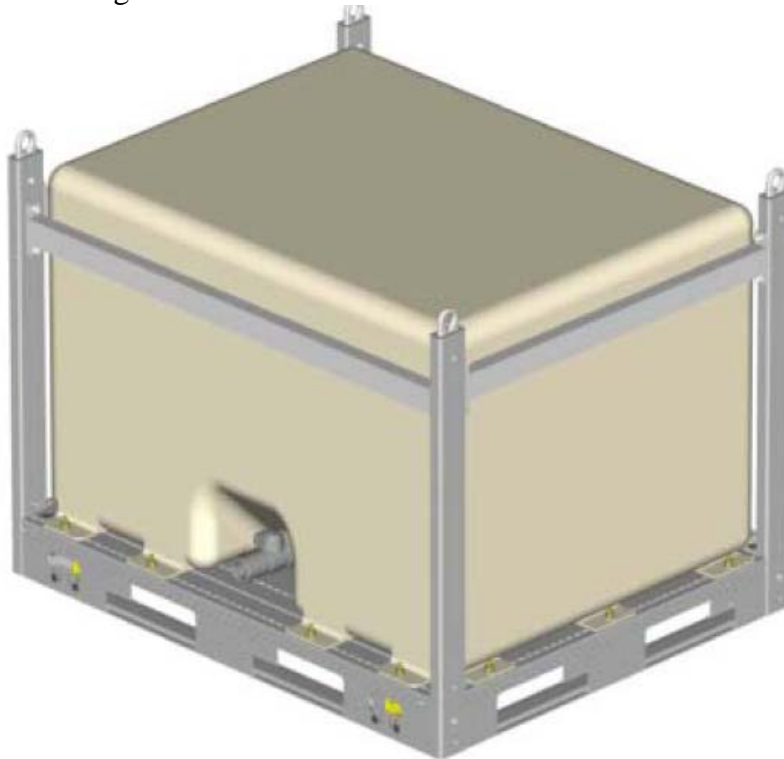
Figure 7.   Modified JMIC Frame with cargo. From Ref 57.
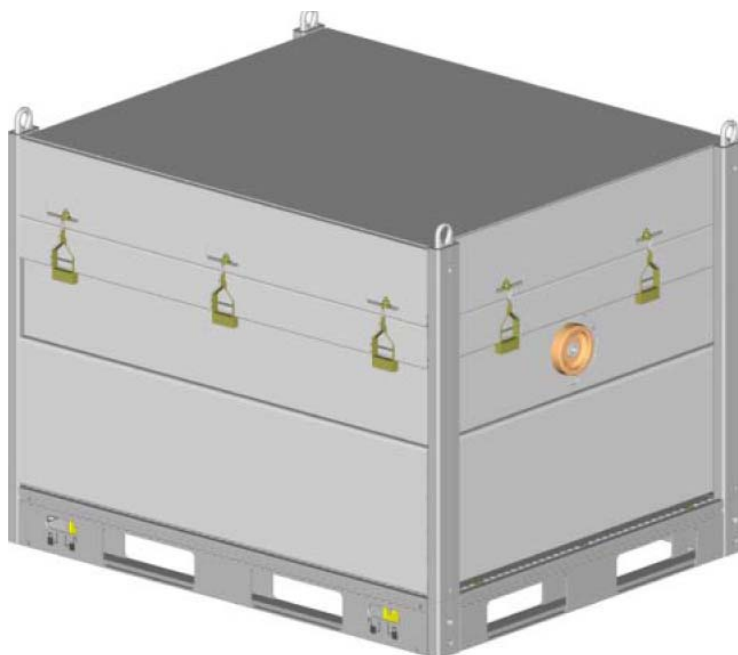
Figure 8.   Modified JMIC Frame. From Ref 57.

Figures 5 through 8 demonstrate some of the versatility, due to the modularity and standardization that will be delivered by the JMIC. The standard JMIC (Figure 6) will be used for smaller shipments of supplies destined for a common user. The supplies can be packaged in one or multiple JMICS, labeled or identified as a single shipment through the use of RFID, and delivered as one unit via interlocking devices that are integrated into the JMIC. While the standard JMIC weighs around 300 pounds empty, it will be capable of handling loads up to 3000 pounds.[37]

The JMIC frame with rigid plastic insert (Figure 6) will be used for larger single pieces of gear or machinery. The third configuration mentioned, the Liquid Tank (Figure 7), can be used for a variety of substances from potable drinking water to lubricating liquids for military machinery in the field. The last configuration show, the Sealed Controlled Breathable JMIC (Figure 8) will be used to deliver supplies that require constant protection from the weather changes and pressure changes due to altitude variations.

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[37] United States Department of Defense. *JMIDS DRAFT JCTD Management Plan*. Version 3.1. 15 June 2006. p. 6.

The JMIC is founded on a "building block" concept that will allow smaller shipment containers to be connected together, as demonstrated in Figure 5, with other shipment containers to conform to the size requirements of current ISO containers or Flatracks (Figure 9).[38]


Figure 9.   Flatracks. From Ref 57.

Additionally, multiple JMICS can be combined to deliver much larger supplies such as projectiles or missiles. Figure 10 shows three JMICs connected to accept 5 AMRAAM missiles. This aspect of the JMIC allows the legacy methods of packaging munitions to be replaced by a reusable container that allows for rapid staging and combat preparations.

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[38] United States Department of Defense. *JMIDS DRAFT JCTD Management Plan.* Version 3.1. 15 June 2006, p. 9.
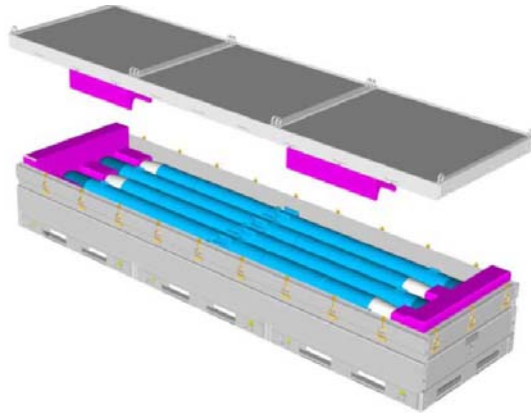
Figure 10.   JMICs with AMRAAM missiles. From Ref 57.

The JMIC is also completely collapsible.   This offers many benefits to the Department of Defense. One benefit is the reusability of the JMIC. The container has the ability to be used repeatedly. It can be rebuilt from the collapsed configuration with self sustaining parts, thus eliminating the need for repairs or patching with wood materials. Figure 11 shows the JMIC in the collapsed configuration and Figure 12 displays twelve collapsed JMICs configured for redistribution to other customers.
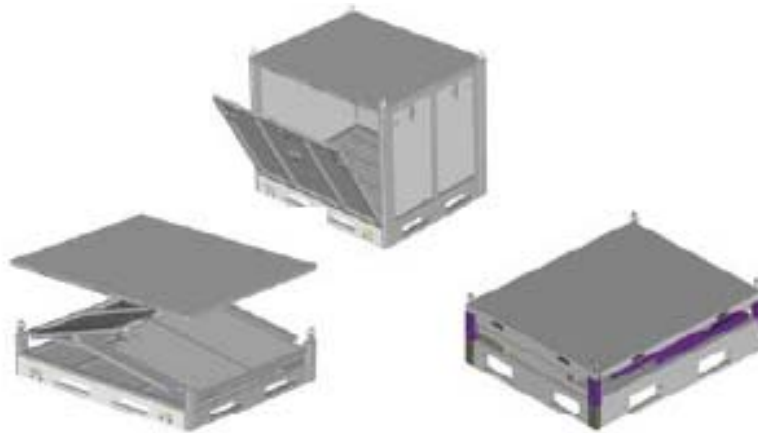

Figure 11.   JMIC Collapsed. From Ref 57.

Figure 12.   12 Collapsed JMICs. From Ref 57.

Another key development in the logistics community is the use of Automated Identification Technology (AIT) as mentioned earlier. The Deputy Under Secretary of Defense for Logistics DUSD(L) developed the AIT task force in 1997. The technologies to be used are as follows: Optical Memory Cards (OMC); Radio Frequency Identification (RFID); Smart Cards paired with the Automated Information Movement System (AIS) and the Global Air Transportation Execution System (GATES); commercial satellite tracking systems. AIT will be integrated into the JMIDS program and will be the cornerstone of shipment tracking. With the use of AIT, the supplier and the customer will have in-transit visibility of their supplies. Integrating the use of AIT is essential for the Department of Defense to reduce inefficiencies in the current supply chain. [39]

D.   MANAGEMENT AND CONTROL OF JMIDS

1.   Purpose

Viewing the Joint Modular Intermodal Distribution System (JMIDS) from a Management Control System (MCS) framework sheds a different light on the system as a whole. Some insights into processes can be gleaned from this perspective. The MCS

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[39] United States Government. *DOD Implementation plan for Logistics Automatic Identification Technology*. 17 March 2000. p. vi.

construct utilizes control methods to achieve desired results within a systems model. Regarding the JMIDS model the MCS can be applied to activities and processes to ensure the system performs in an acceptable manner. The general framework that captures the major design and use aspects of JMIDS is the results based accountability framework. However, in some dimensions of JMIDS, the action based control framework captures the major design of some sub-systems. As acknowledged in the Joint Capabilities Technology Demonstration FY-06, the JMIDS advanced concept solution requires, "Joint multi-modal/service containers and platforms with integrated asset tracking that permit the efficient and seamless movement of supplies through the distribution system to include retrograde operations."[40] Some key desired outcomes are highlighted in this statement. First, the system must be efficient and seamless both to the supplier and destination nodes. The supply needs to be shipped and received on time, have minimal delays enroute and arrive fully intact. Second, as the supply is traversing the Defense Transportation System (DTS) the carrier personnel must be aware of exactly where the supply is going and minimize and anticipate any delays that may occur. If a delay occurs enroute the carrier must be able to transfer the cargo to a more rapid carrier to ensure on time delivery. Finally, once the end state user receives the goods, the JMIC's and JMIP's must be visible to the supply system for inclusion back into JMIDS or retrograde back to the supplier. Each of these outcomes highlights the need for a results based MCS framework.

2.   Situational Influences

JMIDS is unique in structure and therefore must be analyzed first from a situational influence perspective. JMIDS by nature is a system that may potentially cross many companies, cultures, and nationalities as supplies traverse the system from end to end users. By no means is the system contained within one certain construct. Therefore, recognizing the environmental uncertainty of JMIDS is paramount in deciding what types of controls are to be implemented. As Kenneth Merchant states, "Uncertainty can stem

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[40] J. R. McDonald. "Joint Modular Intermodal Distribution System Presentation." Joint *Capabilities Technology Demonstration for FY-06*. March 2006. Slide 3.

from changes (or potential changes) in natural conditions …in the political and economic climate, or in the actions of competitors, customers, suppliers (including labor), and regulators."[41] Along with these uncertainties comes an unknown amount of risk when placing the JMIP in the supply system. Questions that need to be addressed include "will each carrier be familiar with JMIDS, will the automatic identification technology be understood on a global level, and will the users have a full grasp of retrograde operations?" As mentioned earlier, the goal of JMIDS is to provide an efficient supply system packaging model and network to DOD personnel. From the MCS perspective if the proper controls are put into place much of the environmental uncertainty and risk can be mitigated.

Multinational capability must also be considered when selecting controls for JMIDS. An MCS that is effective for a commercial carrier in the United States may not be effective for a foreign carrier. Different management practices, cultures, and nationalities may affect the type of control that needs to be in place for a certain part of the system. For instance, an international transportation company which focuses on uncertainty avoidance may respond better to an action control rather than a personnel control. Within the same genre *similarities* across nationalities need to be incorporated into the implementation of controls. For example in a capitalistic and socialistic culture, financial controls will be a good way to gain a desired end result.[42] Money can be a powerful motivator across the world and must be considered carefully when instituting financial controls. Multinational capability can reduce or enhance efficiency depending on the sensitivity to the instituted control.

3.   Management and Control Systems within JMIDS

While JMIDS is not fully implemented into the DTS, some control problems can be recognized and possibly avoided if the correct controls are applied to the system. One problem identified is creating a seamless transportation system across multiple carriers,

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[41] Kenneth A. Merchant and Wim A Ven der Stede. *Management Control Systems*. England: Prentice Hall Financial Times. p. 588.

[42] Ibid., pp. 594-95.

nations, and environments enabling a rapid JMIDS structure. The AIT and RFID technology goes a long way in facilitating many of the problems that may arise. However, AIT is only as effective as the human element involved with the technology. Further, AIT is mainly a passive tracking system. An active RFID system is in place within DTS however the cost of the active RFID transmitters are such that not every JMIC or JMIP will be able to be retrofitted with an active RFID tag.[43] One of the key attributes of JMIDS is the interoperability and intermodalability of JMIC's and JMIP's with each carrier. This is to say that when the supplies on the same JMIP need to be separated this can be done in an efficient manner by the carrier. Also if the supplies need to be diverted while enroute JMIDS assumes the carrier will know exactly how to handle the JMIP. The problem arises when the carrier is not familiar with JMIDS or does not prioritize separating the JMIP from the shipment. Supplies can literally sit for days until the carrier addresses the change in status. AIT will let the end user know where the supplies are located, but will not allow for any inputs to be actively placed into the system alerting the carrier. JMIDS relies heavily on the carrier's knowledge of the JMIP and JMIC. A control that addresses the end to end user and carrier efficiency needs to be implemented within JMIDS.

Controlling for results appears to be the best fit to facilitate the end to end user problem. Merchant states that results controls are very effective with motivational issues within a system. He continues by saying that there are four steps to be addressed when applying results controls. The four steps include "defining the dimensions on which results are desired, measuring performance on those dimensions, setting performance targets, and providing rewards or punishment for the behaviors that will lead to the desired results."[44] For JMIDS to be successful, each carrier must be motivated to ensure that the delay of the JMIP is minimal when traversing the system. The most effective control in this case will be implementing a financial based result control. A timeframe will be given to the carrier for the supplies to reach their next destination. If the supplies

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[43] "Radio Frequency Identification." *Acquisition Community Connection.* 5 December 2006. https://acc.dau.mil/CommunityBrowser.aspx?id=22423.

[44] Kenneth A. Merchant, and Wim A. Ven der Stede. *Management Control Systems*. England: Prentice Hall Financial Times. Pp *Systems*. England: Prentice Hall Financial Times. p. 26.

are not delivered within that window then the payment for transporting those goods will be reduced exponentially as the delay becomes longer. This will ensure that the carrier holds the JMIP as a high priority item and will be actively engaged in the tracking process. If any kind of delay occurs the carrier will transfer the JMIP to another form of transportation to ensure the supplies will arrive within the allotted timeframe. The implemented results controls can be related to the result control framework through the following steps:

- Dimension – flexible, intermodal transportation leading to on time delivery.
- Performance measure – timeframe for delivery
- Performance targets – understanding JMIDS and AIT which will help accomplish the first two steps
- Providing rewards – full payment for delivery of the supplies.

As with any control a few problems are possible. First, the financial result control chosen places a certain amount of risk on the carrier. The risk will need to be rewarded with a risk premium when the carrier meets the window for delivery. This MCS assumes the financial capital is in place to reward the risk that the carrier is taking with transporting the JMIP. While compensating for risk premiums has not been a traditional process within DTS the idea is not outside the realm of fiscal possibility. Money saved through efficiency can be diverted to help pay for the transportation risk premiums. Other budgetary options are also available such as programming the premiums into the future budgets of end users thus making this MCS a viable option.

Another problem arises with the variability of environmental factors such as weather or other transportation not being available to minimize delays. These factors are often beyond the influence of the carrier and need to be incorporated into the result control reward mechanism. Reducing payment to a carrier due to factors out of their control will not be a desired result of the MCS in this instance. In this case an active AIT system will alleviate the problem by notifying the end user of the unavoidable delay. AIT might also provide a solution by rerouting another carrier to pick up the JMIP if that diversion does not cause delays of supplies. Despite these potential problems the result based financial control is the best fit for JMIDS end to end efficiency.

In evaluating the financial result control the tightness is a major factor when weighing the risk. This is to say that the MCS must not only be consistent with the reward structure, but also keenly defined and responsive to the results achieved. One solution will be to base the tightness of the control on a variety of factors to include the method of transportation, locale, and remoteness of the destination. Based on the broad data from the present global transportation network a matrix can be developed that will give insight into the potential risk borne by the carrier. Again risk will be defined as the propensity for delay for any reason. The tightness of the control will expand or contract the delivery window based on the aforementioned factors. Setting the tightness in this manner will allow for risk sharing both by the JMIDS end user and the supply carrier.

4.   Retrograde of JMIP/JMIC

Another MCS problem with JMIDS is the retrograde capability of the system. When the JMIP reaches the end user a system is not in place that will require the JMIP to be either placed back into the supply system or collapsed for return to the shipment node. AIT again facilitates this issue up to a point. The supply system can see the JMIP, but has no authority as to how rapidly the end user places the containers back into the supply system. With an unlimited amount of JMIP's this will not be a problem. However, with constrained resources a domino effect can be observed here if each end user is not prompt in their actions with the retrograde of the JMIP. Other supplies will have to wait for empty containers to be placed back into the system and the problem will continue to escalate.

Action controls will provide an acceptable solution to ensuring retrograde operations occur in a fastidious manner. Action controls are the most direct form of MCS because they ensure that people perform duties in an exact and desired manner. Action accountability holds people accountable for the actions they take. As with results controls four steps are required for proper implementation. These steps are "defining what actions are acceptable, communicating those definitions to employees, observing or otherwise tracking what happens, and rewarding good actions or punishing actions that

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deviate from acceptable."[45]   Action controls are able to be implemented in this case because the end user will be a member of the DOD and therefore be accountable to members of DOD. JMIDS will have a more considerable amount of influence on the end users than with the end to end efficiency problem. Therefore, action controls will be effective if chosen correctly.

Requiring strict procedures and guidelines for placing JMIPs and JMICs either back into the supply system or collapsing them for return is an action control that will be effective for retrograde operations. These procedures will be communicated via AIT. AIT will provide the next location for the JMIP and the means by which the JMIP is to be shipped to that location. If AIT directs the end user to collapse and return the JMIP then a deadline to do so will be stated. When the deadlines expire and the containers are not rapidly placed back into the supply system, JMIDS will take punitive action against that end user. The punitive action might be administered in a variety of ways. One form will be to impose some kind of supply restriction on the end user until those containers are properly transferred. Another form of punitive action will be to levy a monetary fine on the end user for the JMIPs. The implemented action controls can be related to the action control framework by meeting the following criteria:

- Define acceptable criteria – the placement of the JMIP/JMIC back into the supply system either via shipment through DTS carrier or retrograde operations.

- Communicate definitions – AIT will provide instructions to the end user as to the desired action to be taken to be determined by JMIDS decision nodes.

- Tracking what happens – AIT will monitor, via tracking device, the location of the JMIP/JMIC.

- Rewarding/Punishing actions – administering restrictions if the AIT directions are not followed.

One of the problems that might arise from this control is that the end user simply is not able to meet the requirements of AIT for a variety of valid reasons. Some acceptable criteria for not returning the containers will have to be put in place to avoid

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[45] Kenneth A. Merchant, and Wim A. Ven der Stede, Management Control Systems. England: Prentice Hall Financial Times. p. 69.

punishing an end user that will not be able to meet the timeframe for placing the containers back into JMIDS. Another problem that might occur with this type of action control is potentially punishing the user of the supplies for the actions of the supply officer. This might be alleviated by identifying commanding officers (COs) with authority over the supply officers and establishing a line of communication that will give those COs the opportunity to remedy the situation before the punishment is enacted.

The degree of tightness of this control will be subject to the actions of the end user. An evaluation scorecard will be kept at a central database which monitors the actions of the end users. If an end user is very consistent with placing the JMIPs back into the supply system then the action control can be loose to a certain degree. If at some point the end user is not able to meet the time requirement their "good behavior" will be rewarded by the system granting a degree of slack instead of instant punishment. Along the same lines for an end user that is consistently placing containers back into JMIDS after the time requirement, the action control will be tight and punishment will be levied immediately. The degree of tightness will provide some latitude and the control will be that much more effective.

Instituting results and action controls framework within JMIDS will address potential gaps in the system and provide more manageability of the components. Each control addresses the situational factors that are present due to the global nature of JMIDS. The degree of rigidity of the controls will produce the desired results as they relate to the efficiency of the system and retrograde capability. Risk sharing is a major factor in making JMIDS a successful supply distribution network and must be mitigated throughout the system. Environmental uncertainty and multinationality will be a continual monitoring process to ensure the controls are sensitive to the ever changing global supply network.

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V.   LIFE CYCLE COST ANALYSIS[46]

Note: The following analysis is not based on actual JMIDS data. This data was unavailable to the authors. Since actual JMIDS data is not available, the authors have used notional data to develop and apply an approach to the life cycle cost analysis. The resulting analytical model could be used by JMIDS managers or by future researchers to determine actual lifecycle costs. Therefore, all of the following numerical data are strictly hypothetical and are solely the views expressed by the authors who are portraying the PMO and the technical experts. Further, the percentages applied to the model were based on a Life Cycle Cost Analysis of a weapon system. The authors took those percentages and lowered them to reflect the non-technical nature of JMIDS. Professor Greg Mislick at the Naval Postgraduate School in Monterey, CA has given his permission to use this model as a practical application in the LCCA for JMIDS. Thus, we have referenced the material from his class in preparing this portion.

A.   LIFE CYCLE COST ANALYSIS OVERVIEW[47]

The Department of Defense life cycle cost analysis (LCCA) is a comprehensive cost overview of the total cost allocated to a particular system, program, or element over the lifetime of that particular entity. The LCCA is performed and documented in the form of a Cost Analysis Requirements Description (CARD). The Naval Center for Cost Analysis states the following regarding the requirements and implementation of a thorough cost analysis.

> DOD Instruction 5000.2 and DOD 5000.2-M (references (a) and (b)) require that both a program office estimate (POE) and a DOD Component

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[46] United States Government. Department of Defense. *DOD 5000.4-M: Cost Analysis Guidance and Procedures.* December 1992. 10 March 2007. p. 24.

[47] The complete LCCA breakdown is listed in Appendix A.

cost analysis (CCA) estimate be prepared in support of acquisition milestone reviews. As part of this requirement, reference (b) specifies that the DOD Component sponsoring an acquisition program establish, as a basis for cost-estimating, a description of the salient features of the program and of the system being acquired. This information is presented in a Cost Analysis Requirements Description (CARD).[48]

The CARD is a "living" document that can be continually updated when cost estimates are revised based on new information, technology, etc. Defense Acquisition Boards are the primary users of the CARD. The data in the CARD should be concise yet clear with regard to costs in each program.[49] Any DOD program typically has four main cost pools: Research and Development (R&D), Production and Deployment (PD), Operating and Support (O&S), and disposal costs. As can be seen in figure 13 the majority of the costs of a typical DOD program can be attributed to the O&S phase of the life cycle cost with disposal often negligible in comparison. This figure does not hold true in the JMIDS LCCA. O&S is not the primary cost element. A cost estimation expert at the Naval Postgraduate School agrees that Operations and Support would not be the major cost component within JMIDS,[50] because with traditional DOD acquisition systems there are large numbers of people who work solely for the purpose of that acquisition system. For example, any given weapon system in the U.S. Navy has specific designated personnel assigned to operate and repair that weapon system and if that weapon system did not exist, those personnel would not be employed by DOD. Consequently, JMIDS will have no personnel directly assigned within the framework of any of the U.S. Armed Forces for the purpose of maintaining the JMIDS equipment. PD is actually the most significant cost when applied to the JMIDS cost structure.

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[48] United States Government. Department of Defense. DOD 5000.4-M: Cost Analysis Guidance and Procedures. December 1992. 10 March 2007. p. 8.

[49] Ibid., p. 8.

[50] Daniel Nussbaum. Professor, Naval Postgraduate School. Monterey, CA. Personal Interview. 20 March 2007.
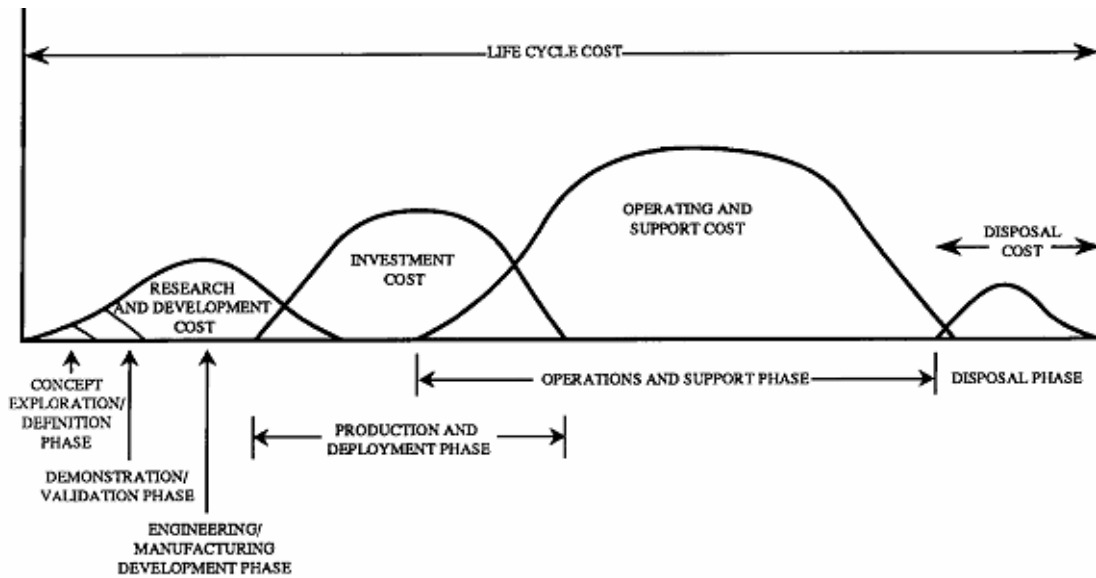
Figure 13.   Typical Life Cycle Cost Distribution[51]

B.   RESEARCH AND DEVELOPMENT COST ESTIMATION[52]

1.   Development Engineering

The development engineering cost estimation element includes the following: cost of the study, analysis, design development, evaluation, testing and redesign of the system components.   It includes, but is not limited to the preparation of specifications, engineering drawings, parts lists, and report preparations.   Also included are the quality assurance costs, cost of the raw materials required, semi-fabricated materiel and purchased parts consumed in the course of engineering, the analysis of reliability, and the systems maintainability.   The Program Manager's Office has estimated that it will take 4 staff years to complete the development engineering phase of the JMIC (WBS01), and 10 staff years to complete the staff years to complete development engineering phase of

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[51] United States Government. Department of Defense. *Operating and Support Cost Estimating Guide*. 1 May 1992. Last accessed April 1, 2007. p. 2-2. http://www.ncca.navy.mil/resources/caig_os_guide.pdf.

[52] The complete R&D breakdown can be seen in Appendix B.

the JMIP (WBS02). JMIDS is a strictly experimental technology and has no historical cost data that can be used for analysis from previous logistical systems. The cost of a structural and mechanical engineering staff month has be estimated to be roughly $4,000 (CY06). (All cost figures from here on will be listed in CY06$.)[53]

Table 1 shows that the total Development Engineering costs were calculated by multiplying the cost of one staff month by the total number of staff months required to complete each WBS. As is listed, the total estimated cost for the JMIC in the DE phase is $192,000.00, and the total cost for the JMIP in the DE phase is $480,000.00 bringing the total of the two to $672,000.00. The justification for the higher overall cost for the JMIP is the number of staff years required for completion. The driving force for the higher number of staff years to complete is the requirement for the JMIP to be multi-configurable. The JMIP must be able to transition seamlessly between being transported by the HEMITT and being loaded into the cargo hold of a C-130. Further, the JMIP must be able to withstand high amounts of stress that will be exerted on it when the locking mechanisms are engaged from the transporting vehicle. The forces that will be exerted are from mechanical means. However, the locking mechanisms for the JMIC will be engaged manually by the user and the forces will not be nearly as high. JMIC standards require that they:

- Define interface to increase interoperability and interchangeability
- Lifting and tie downs (MIL STD 209 and NATO STANAG 4062)
- Stackable
- Locking interfaces
- Platform size footprint / internal dimensions
- Compatible with transportation modes
- Compatible with common/joint handling equipment
- Withstands harsh environments
- Service life
- Accessibility to contents

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[53] Greg Mislick. "Life Cycle Cost Analysis." Cost Estimation course (OA4702). Naval Postgraduate School. Monterey CA. p. 3.

- Collapsible to minimize transport of empty containers
- Durability / strength
- Gross Weight Capacity [54]

The JMIP standards have not yet been codified. They are projected to be released in FY07 therefore the information listed above regarding the JMIP's transfigurability is speculative.

WBS	01 JMIC	02 JMIP
PMO (Staff years)	4	10
Cost per staff month	$4,000.00	$4,000.00
Staff months to complete	48.00	120.00
	$192,000.00	$480,000.00

Table 1.   Development Engineering Estimate. After Ref 61.

2.   Producibility, Engineering and Planning (PEP)

This cost estimation element includes costs that are incurred in assuring an item's producibility. PEP includes the tasks involved in guaranteeing timely, efficient, and economic production of necessary materiel and is essentially of a planning nature. Some examples of costs in this section are quality assurance plans, special production processes, dimensional and tolerance information, and all data and calculations necessary to ensure the equipment works as promised.[55] The costs associated with PEP were calculated by taking an arbitrary percentage of the combined total of Prototype Manufacturing and Development Engineering. This method is common among acquisition and cost estimation professionals.[56] The percentage chosen for this project was 6%. This figured was based on the fact that JMIDS is a "dumb" system and one that is not technical in nature. Other systems, such as weapons or software, usually have a

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[54] Anna Wojciechowski. "Joint Standardization Board for Intermodal Equipment." Joint Intermodal Working Group. 22 May 2006. Last accessed March 5, 2006. Slide 10. www.dsp.dla.mil/2006-DSP-conf/Wojciechowski.ppt.

[55] Greg Mislick. "Life Cycle Cost Analysis." Cost Estimation course (OA4702), Naval Postgraduate School. Monterey, CA. p. 2.

[56] Ibid., p. 3.

much higher percentage applied in this section. Therefore, by taking 6% of the PM and DE costs for the JMIC we arrived at a PEP cost of $128,443. And the 6% PEP costs for the JMIP is $39,969.

3.   Tooling

Technical experts estimate that tooling costs will be about 16%, of the prototype manufacturing costs for each, the JMIC and JMIP. They arrived at this cost by looking at a more sophisticated system and downgrading the percentage based on the low technical nature of JMIDS as compared to the more technical system. The tooling costs totaled $341,580 which breaks down to $311,795 for the JMIC and $29,785 for the JMIP.

4.   Prototype Manufacturing

The PMO has determined that the program will require 10 JMIPs and 500 JMICs. These Containers and Platforms will be dispersed at the participating Limited Military Utility Assessment (LMUA) locations. This will afford the operating personnel the opportunity to become familiar with the configurability of the JMIC. The breakdown is as follows[57]:

> JMIP Demonstration Phase Hardware Required:
> 1 JMIP (1 piece or 2 piece)
>
> LMUA 1A-D Hardware Required:
>   JMICs 28 (2 Train-up, 8 floor loaded in ISO, 8 on
>   JMIP in ISO, 10 in Commercial Truck)
>   JMIPs 1 (Either 1-Piece or 2-Piece JMIP will be
>   sufficient)
>
> LMUA 1E-G Hardware Required:
>   JMICs 42 (2 Train-up, 16 loaded in ISO, 8 on 463Ls, 16 in
>   Dedicated Truck)
>   JMIPs 1 (To function efficiently the 2-Piece JMIP will be required)
>
> LMUA 2A-C Hardware Required:
>   JMICs 120 (24 Bomb JMICs, 32 Bomb component JMICs, 32
>   Artillery JMICs, 32 Small Ordnance JMICs)

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[57] Chris Allen. "Joint Modular Intermodal Distribution System." USTRANSCOM Power Point Presentation. 6 April 2006. Slide 15.

JMIPs 0

LMUA 2D-E Hardware Required:
JMICs 56 (24 Bomb JMICs, 32 Bomb component JMICs)
JMIPs 0

Capstone MUA (TALISMAN SABRE-07) Hardware Required:
JMICs 164 (64 for transport on JMIP, 80 for Seabase, 20 for air transport)
JMIPs 3 (3 JMIPs for use w/the US Army LHS Trucks (Model TBD)

Coalition Warfare Demo Hardware Required:
JMICs 16
JMIPs 1

Configuration issues associated with the Container and the Platform will hopefully be eliminated during this assessment period. The issues include but are not limited to the connecting of two or more Containers to accommodate larger weapons or machinery. To estimate the costs associated with Prototype Manufacturing, Cumulative Average Theory was used because most of the following holds true.

> [The containers in question will be] used in situations where the initial production of an item is expected to have large variations in cost due to:

- use of "soft" or prototype tooling
- inadequate supplier base established
- early design changes
- short lead times

> This theory is preferred in these situations because the effect of averaging the production costs "smoothes out" initial cost variations.[58]

The equation and process used for Cumulative Average Theory is stated as and is:

Defined by the equation $Y_N = AN^b$ where

Y_N = the average cost of N units

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[58] Greg Mislick. "Learning Curves." Power Point Presentation. Cost Estimation OA 4702. Naval Postgraduate School. Monterey, CA. Slide 29.

A = the theoretical cost of unit 1

N = the cumulative number of units produce

b = a constant representing the slope (2^b) [59]

The costs for the Prototype Manufacturing section are shown in Figure 14. The costs are broken down into sections by WBS. The JMIC has a theoretical first unit cost of $10,000 (purely arbitrary but was chosen relatively low considering the fact that it is simply a mechanical piece of equipment and not a highly sophisticated and technological piece of electronic gear). Using the lot costs for the prototype gear, the totals for the JMIC come to roughly $1.95M with an average cost of $3,179. The learning curve for the JMIC is estimated to be 88%. The JMIP on the other hand has a learning curve of 91%. The costs for the JMIP are considerably higher per unit. At an average unit cost of $16,082, the Platform is about five times the cost of the JMIC. This higher cost is again explained by the stressful nature and the vast array of configurations needed to be accomplished by the Platform. The total lot cost for the Platform prototype gear is roughly $186,000. This is relatively low compared to the Containers lot cost, however, we are only producing 10 Platforms as opposed to 500 Containers. All of the calculations dealing with the PM costs were derived by using the formula in Figure 14. The variables for the equation in Figure 14 have the same description as the variables in Table 2.

WBS	01 JMIC	02 JMIP
Prototype Manufacturing (CTn)	$1,948,720.19	$186,156.55
Theoretical First Unit Cost (A)	$10,000.00	$22,000.00
Learning Curve	0.88	0.91
Prototypes produced(n)	500	10
Average cost per unit (Y 500/10)	$3,178.66	$16,082.78

Table 2.   PM Total and Average Cost. After Ref 61.

[59] Greg Mislick. "Learning Curves." Power Point Presentation. Cost Estimation OA 4702. Naval Postgraduate School. Monterey, CA. Slide 29.

$$CT_N \cong \frac{A(N)^{b+1}}{b+1}$$

Figure 14.   Total Lot Cost Equation. From Ref 60.

5.   System Engineering/Program Management

All of the costs associated with the JMIDS in this section are linked to WBS03 (other). Sunk costs are routinely accounted for in this section though our research has not led us to any contractor prepaid expenses for JMIDS. Since costs in this section are completely unknown, we estimate that the System Engineering and Program Management phase will be around 12% of the Prototype Manufacturing and Development Engineering costs as well as the contractor portion of the System Test and Evaluation.[60] This 12% comes out to $504,000 for JMIDs.

6.   System Test and Evaluation

The PM has asked for a total of $3.0M for the Test and Evaluation of JMIDs. Of this $3.0M, $1.6M is allocated to the government and $1.4M to the contractor. These costs include but are not limited to the travel and associated expenses for the engineers doing the assessments. Also included are the costs for the other personnel involved in completing the tests i.e. military and civilian personnel at each LMUA site that is directly involved with the testing of any JMIDs item.

7.   Training

All costs in this section are grouped with the WBS03 (other) and are explained by Table 3. This category includes the cost of development of services, devices, accessories and training aids. Also included is the software and parts used to facilitate instructions by which personnel are trained to have sufficient skills in order to operate and maintain the

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[60] Greg Mislick. "Life Cycle Cost Analysis." Cost Estimation OA 4702. Naval Postgraduate School. Monterey, CA. Slide 29.

system.[61]   The PM and Technical Experts have laid out training plan that involves maintenance and configuration field training. Along with this they have hired a graphics designer to develop a course demonstration video to accompany the students upon completion for future reference and on the job training.   It was estimated that the development of the training course will require two Field Technical trainers, one Graphics Designer, and one Supervisor. Salaries for the different positions are based on generalizations gleaned from their respective fields.[62]   The hours required for each is detailed in Table 3. The total cost for the training section is $8,450.

Training for JMIC and JMIP	Training hours per trainer			
	Field Technical Trainer	Graphics Designer	Supervisor	Total Cost
Training Course Development (Hrs)	20	50	15	
Configuration Field Training (Hrs)	20	0	20	
Maintenance Field Training (Hrs)	10	0	10	
Total Hours	50	50	45	
Cost per hour	$40.00	$35.00	$60.00	
Number of personnel in category	2	1	1	
Total Cost	$4,000.00	$1750.00	$2700.00	$8,450.00

Table 3.   Training Cost Table. After Ref 61.

8.   Risk

"This section identifies the program manager's assessment of the program and the measures being taken or planned to reduce those risks. Relevant sources of risk include: design concept, technology development, test requirements, schedule, acquisition strategy, funding availability, contract stability, or any other aspect that might cause a significant deviation from the planned program.   Any related external technology programs (planned or on-going) should be identified, their potential contribution to the program described, and their funding prospects and potential for success assessed. This

[61] Greg Mislick, Professor Naval Postgraduate School, OA4702, Winter QTR 2007/Life Cycle Cost Exercise. p. 4.

[62] Moseley Technical Services, Inc. Job Listing for Test and Evaluation engineer. 23 March 2007. Last accessed March 28, 2007. http://www.careerbuilder.com/JobSeeker/Jobs/JobDetails.aspx?IPath=OCCG&job_did=J8C7JK60KYG61 5QDQ7T&cbRecursionCnt=2&cbsid=801c9b1c033048039892188fbfcf9484-228934476-J2-5.

section should identify these risks for each acquisition phase (DEM/VAL, EMD, production and deployment, and O&S)."[63]   Taking all of the above factors into consideration, the technical experts estimate the risk factors to be 2% and 3.5% for the JMIC and JMIP respectively.   These percentages are applied to the total of the Development Engineering, PEP, Tooling, and Prototype Manufacturing.   Therefore the total Risk costs estimated for JMIDs is $77,376 and is broken down as $51,619 for the JMIC and $25,756 for the JMIP.

C.   PRODUCTION COST ESTIMATION[64]

1.   Nonrecurring Production

a.   Initial Production Facilities

Cost for initial production facilities are estimated by the contractor along with the program manager.   In the case of JMIDs, we estimate that the amount for initial production facilities will be minimal based on an existing and reprogrammable infrastructure.   The majority of the costs associated with the section deal with retooling and reprogramming machinery.   The program manager and contractor estimate these costs to be $1.5M for the JMIP (WBS02) and $800,000 for the JMIC (WBS01).

b.   Other Nonrecurring Production

All costs in this section are attributable to WBS03 (other).   We concluded that our cost factors for this section should be constant with commonly used cost factors used in acquiring other DOD systems. The costs for Nonrecurring Production are derived by taking the product of Training costs and the Nonrecurring Manufacturing factor.

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[63] United States Government. Department of Defense. *DOD 5000.4-M: Cost Analysis Guidance and Procedures.* December 1992. p. 17.

[64] The complete production breakdown can be seen in Appendix C.

2.   Recurring Production

a.   Manufacturing

The Program Manager has decided to use the same manufacturer for the Container and the Platform. We have determined that we will need at least 150,000 JMICs and 7000 JMIPs. Traditionally the PM Office would use analogous system costs and lot size and run a simple regression to determine first unit cost. The assumptions are that JMIDs is brand new and there is no analogous systems exist to use in estimating first unit costs. Therefore, the PM has used a step down factor of 29% of the AUC used in the Prototype Manufacturing Phase. This leaves 71% of the PM cost to be used as the first unit cost (T1) in the manufacturing phase. This comes out to be $2,256 for the JMIC and $11,418. We are maintaining the 87% learning curve for this section. Applying the total cost formula from Figure 15, we come to a total Manufacturing cost of $38.6M for the JMIC and $16.8M for the JMIP.

$$CT_N \cong \frac{A(N)^{b+1}}{b+1}$$

Figure 15.   Total Cost Formula. From Ref 60

Under WBS03, other manufacturing costs are based on contractor estimates. The Program Office will continually update the estimates, but at the current time the other manufacturing costs are projected to be $800,000. This brings total Manufacturing Costs to $56.3M.

b.   Recurring Engineering

All costs in this section fall under WBS03. "Other costs associated with this cost element are the sum of the costs for engineering services and production support engineering." [65] Each of these costs can be calculated by multiplying the appropriate factor times the total manufacturing costs. Once again, we concluded that our cost

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[65] Greg Mislick. "Life Cycle Cost Analysis." Cost Estimation OA 4702. Naval Postgraduate School. Monterey, CA. p. 5.

factors for this section should be constant with commonly used cost factors used in acquiring other DOD systems. Thus, the costs for this section total $2.2M and are listed in Appendix C.

c. Sustaining Tooling

Sustaining tooling costs are step down costs from the tooling costs in the Development Phase. These costs are calculated on the same traditional DOD step down percentage.[66] This cost is estimated as 50% of the costs in the DE Tooling phase. This comes to $155,897 for the JMIC and $14,892 for the JMIP for a total of $177,790.

d. Quality Control

Quality control costs are calculated by the taking the respective manufacturing costs for each product and multiplying them time by the quality control factor. For the JMIC, this comes to $1.15M, and for the JMIP it comes to $506,658 for a total of $1.66M

3. Engineering Changes

Costs for the JMIC and JMIP are equal to the respective costs times the Engineering Change Order factor.[67] This totals $1.66M which is broken down exactly the same as the Quality Control section due to the factors being the same.

4. Training

Theses costs will not be material because the training containers will have been produced during the Research and Development. This section is therefore not applicable because there are no extra costs associated with the production of containers designed specifically for training.

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[66] Greg Mislick. "Life Cycle Cost Analysis." Cost Estimation OA 4702. Naval Postgraduate School. Monterey, CA. p. 5.

[67] Ibid., p. 5.

5. Initial Spares-Repairables (ISR)

The costs associated with this section fall under WBS01 and WBS02 and are equal to their respective manufacturing costs times the initial spares factor.[68] This brings the total ISR cost to $7.2M. This breaks down to $5M for the JMIC and $2.2M for the JMIP.

D. OPERATING AND SUPPORT COST ESTIMATION[69]

As stated earlier the O&S portion of the JMIDS system is not the most substantial cost element in the LCCA. This is due to the fact that virtually no personnel positions will be created specifically for JMIDS which is a requirement of the CARD in order to qualify as a cost for any program. The defense distribution system will have all of the personnel in place through the existing transportation structure and can be classified as a sunk cost and therefore not applicable to the Life Cycle Cost of JMIDS. Further the maintenance of the system will not be material in nature when compared to the R&D and PD costs. Following the PD phase of the LCCA, the JMIDS system will be ready for implementation. The AIT will already be actively engaged in the system and simply transferred from the palletized platforms to the new containers. The two main categories of the O&S cost WBS for JMIDS are maintenance and sustaining support.[70]

1. Maintenance

Maintenance can be broken down into two categories to include intermediate and depot level. According to the CARD, intermediate maintenance is classified as, "Labor, material, and other costs expended by designated activities and/or units (third and fourth echelons) performed external to the unit. This includes calibration, repair and replacement of parts, components or assemblies and technical assistance to the mission

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[68] Greg Mislick. "Life Cycle Cost Analysis." Cost Estimation OA 4702. Naval Postgraduate School. Monterey, CA, p. 6.

[69] The complete O&S breakdown can be seen in Appendix D-F.

[70] United States Government. Department of Defense. DOD 5000.4-M: Cost Analysis Guidance and Procedures. December 1992. pp. 48-49.

unit."[71] Inventory management control of the JMICs will be a substantial cost element for intermediate maintenance. A large cost factor in O&S will be the non-retrograde JMIC containers. As mentioned earlier in the Management and Control Systems chapter, a control will need to be in place to facilitate and "incentivize" not only returning the JMIC back into JMIDS, but also properly handling, constructing, and breaking down the container. Even with this control in place costs must be allotted for containers that are lost, damaged, or simply not returned via retrograde. In addition to the inventory control the damage and lost parts cost must be allocated over the life of the program. The depot level maintenance of the JMICs will not be as substantial as the JMIPs due to the rudimentary construct of the container when compared to the JMIP. However certain circumstances may necessitate the depot level repair of a JMIC container due to heavy damage, broken parts, etc. The intermediate maintenance for the JMIP will consist of parts replacement, repair due to mishandling/breakage, and unforeseen failures of equipment. The majority of the maintenance costs for the JMIP will occur in the depot level repairs due to the fact that the JMIP is constantly in contact with moving parts of carriers and the platform will be continually adjusted to fit the various travel platforms. In essence the overall maintenance picture for the JMIDS system is significant but not a substantial part of the overall costing of the system.

A common practice in the cost estimation community is to cost the maintenance of a product as a percentage of the production or procurement cost. In order to cost the system for the JMICs and JMIPs the numbers of containers and platforms in the system must be identified. Based on an arbitrary incremental procurement cycle and life cycle timeframe of 20 years, the costs can be accurately captured and are displayed in appendix E and F. To cost JIMDS, we began by taking the average production costs per JMIC, which totaled around $257.00 per container. We then took one half of one percent of the per MIC average production costs to calculate the annual repair cost per container. This comes to roughly $193,000 by year 2011 which is when the full compliment of 150,000 JMICs will be in the logistical system. The total repair costs over the 20 year lifecycle

[71] United States Government. Department of Defense. *DOD 5000.4-M: Cost Analysis Guidance and Procedures.* December 1992, p. 48.

sums to $3.4M for the JMIC. We conducted a similar costing for the JMIP by taking one quarter of one percent of the per MIP average production costs. The average production costs for the JMIP came out to $2400. Taking one quarter of one percent of the $2400 came out to a total of $42,000 by year 2011. Again, looking at the total cost after the 20-year lifecycle we came up with $755,000 dollars for the repair costs for the JMIP.

2. Sustaining and Support

According to the CARD, Sustaining and Support is described as, "Procurement (exclusive of war readiness materiel) of replacement support equipment, modification kits, sustaining engineering, software maintenance support, and simulator operations provided for a defense system."[72] In figuring the Sustaining and Support costs, we determined that the replacement factor for the JMIC would be 1% and the replacement factor for the JMIP would be 0.5%. These replacement factors when applied bring the total JMICs that need to be replaced in 2011 to 1,500 and 35 for the JMIP. These replacements will be necessary due to lost control of inventory. These total replacement costs sum to $386,000 for the JMIC and $84,000 for the JMIP. These costs will also carry forward through the lifecycle of the program. Next we calculated the sustaining support cost by taking 3% of the repair and replacement added together. The repair and replacement costs total $579,000 in 2011 for the JMIC. Taking 3% of the total we came up with $17,388 for the sustaining costs per year from 2011 on. After the 20 year lifecycle, the total sustaining costs for the JMIC are $311,000. For the JMIP, we used the same calculations to figure sustaining costs with one exception. We took 5% of the totaled repair and replacement costs and came to a total of $6,300 per year from 2011 on. This brings the total sustaining lifecycle costs to $113,364. The increase in the percentage in this section is due to the more technical nature of the JMIP as compared to the JMIC. The JMIP has many more moving parts and is therefore more prone to needing upgrades and possible modifications. After considering all of the factors associated with the Operations and Support section of the analysis, we arrived at a total

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[72] United States Government. Department of Defense. DOD 5000.4-M: Cost Analysis Guidance and Procedures. December 1992. p. 49.

O&S cost of $13.067M which breaks down to $10.6M for the JMIC and $2.4M for the JMIP. Again, a full breakdown of these costs is listed in Appendix E and F.

As discussed above a steady state logistics operation during peacetime. All of the containers would remain within the confines of the DOD's logistics management control. Meaning the tracking and control of every container, save the replacement factors for each, is possible. However, when tensions heat up outside of U.S. borders and troops must be deployed, the establishment of forward operating areas takes tremendous resources to accomplish. Table 4 breaks down the replacement costs if JMIDS were used in this capacity. We propose that the replacement factor has the potential to rise to about 50%. What this means is that during the force buildup in the campaign region, as many as 50,000 JMICs (arbitrary) would be needed to establish the area of operations. Taking a conservative replacement factor and calculating lost costs due to replacement, the total cost is about $6.44M. What that means is that upon operation execution, the DOD would likely lose almost $6.5M worth of containers. Once the initial buildup is complete, we estimate that the number of containers being sent to the war zones or operating regions will be around 10,000 containers per year in order to support the operation. Of those, we expect that the replacement factor would be around 25%. This, in terms of a dollar figure, comes to about $644,000 per year in lost containers. The reasoning behind this is one of an economic nature: a trade deficit. When a force build is ordered, the logistical systems within the Armed Services rolls into action and begins flooding the battlespace with needed supplies and machinery to carry out the operation. Recent articles on trade between the United States and China allude to the fact that it is cheaper for China to build new ISO containers than pay to ship empty ISO containers back from the U.S., thus consuming valuable cargo space on large container ships.[73] This is exactly the situation faced by logistics personnel during a time of force buildup. There is no immediate concern for the return of the shipping containers during the massive export of supplies and equipment from U.S. soil to the foreign operating region. However, when

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[73] Nick Carey. "Containers pile up as imports from China soar." Washington Times. 15 June 2006. Last accessed April 3, 2007. http://washingtontimes.com/business/2006061522003-3483r.htm.

the dust settles and the fighting is deemed finished, the amount of supplies and machinery that went into the battlespace does not even come close to that which needs to be removed.

JMIC Wartime Costs	JMICs	10% Replacement Cost	25% Replacement Cost	50% Replacement Cost
Steady State JMICs	150,000	$3,864,172.91	$9,660,432.28	$19,320,864.55
Initial Wartime Need	50,000	$1,288,057.64	$3,220,144.09	$6,440,288.18
Wartime Sustainment (JMIC/Yr)	10,000	$257,611.53	$644,028.82	$1,288,057.64
Cost Per JMIC	$257.61			

Table 4.   JMIC Wartime Replacement Estimates. After Ref 61.

With all of the analysis to the Life Cycle Cost of the Joint Intermodal Distribution System that is mentioned above, the authors have determined the overall cost for the system to be $91.6M in calendar year 2006. Of the $91.6M total cost, roughly 80% comes from the Production section of the program and comes to roughly $71M. Looking at Table 4, it is not advisable to take JMIDS much further without some thought on the potential for lost containers. On a conservative estimate, it is possible to spend about $4M per year to keep the inventory of JMICS at the 150,000 level. However, a more liberal estimate brings the replacement cost up to about $20M to maintain the required number of JMICS in service.

It is the opinion of the authors that the JMIDS program is heading in the wrong direction based on the dollar figures derived in this analysis. The main item that led to this conclusion is the high potential for loss of the JIMCS. The authors feel that JMIDS would be successful if used as a possible "InterNodal" Distribution System rather than a one size fits all solution. Further, while JMIDS could be used as the primary shipping method from major shipping node to major shipping node, it is recommended that an alternate and more economical mode of shipping be used for the last mile of the shipment.

VI.   CONCLUSIONS AND RECOMMENDATIONS

To completely analyze JMIDS we first gained an understanding of the system by reviewing the current literature of modularity. Next, we took a step back and reviewed the concept of modularity noting the proponents and critics of the concept. Then, we reviewed some civilian models of modularity and how those systems provided efficiencies to users. We also took a detailed look at the current concept and design of JMIDS to include the concept, explanation, and management and control of the system. Finally, we conducted a notional cost estimation of the current project and provided a model for future research and cost analysis.

The concept of modularity has the potential to increase efficiency of a supply chain through uniform modular containers that will reduce handling. However, the current construct for an intermodal container in JMIDS poses many hurdles to overcome in creating a successful and efficient supply chain. While conceptually strong, a new avenue must be taken in making JMIDS a reality. The management and control of a containerized framework presents significant problems of retrograde especially in a wartime scenario. The potential for waste, damage, and loss creates a fiscal pitfall which will need to be addressed in a more tightly controlled system analysis. Therefore, while developing a new container system may be a way forward in the future the current communication and tracking network must first be standardized in order to gain end to end efficiency. Once this is accomplished, a system such as JMIDS could possibly be a way forward. While conceptually strong, a new avenue must be taken in making JMIDS a reality.

DOD planners thought that "JMIDS [would] permit efficient, seamless, and visible movement of supplies through the distribution system from CONUS-based depots and vendor locations to tactical end users, including movement through the Seabase to support forward operating expeditionary and task force units."[74]   However, we have

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[74] Chris Allen. "Joint Modular Intermodal Distribution System." USTRANSCOM Power Point Presentation. 6 April 2006. Slide 20.

determined that JMIDS does not permit efficient containerization of supplies nor does it solve the problem faced by the DOD's supply chain. According to research conducted on the current legacy supply system the efficiency problem of the military supply chain lies not in the containers themselves but in the operation of the distribution centers, linkages between the various supply chain nodes, and tracking throughout the supply chain.[75] Poor communication between different transportation nodes, the lack of a standardized tracking system used by commercial firms like FedEx or UPS, and redundancy all contribute to the current delays in moving supplies within the DTS. Though we understand that total standardization like the commercial carriers may be an impossible task, it would be essential for cost reduction and efficiency to standardize for the bulk of the commodities.

On our visits to the Defense Distribution Depot at San Joaquin (DDJC), our team noted that the system which is currently in place runs extremely efficiently, as confirmed by the numerous regional and national awards earned by DDJC. When we spoke with personnel at DDJC, they indicated that the initial testing of the JMIDS containers hampered their operations. Problems noted by DDJC personnel included that the JMIC was difficult to handle based on its heavy weight and metallic composition. The test container had an empty weight of 329 pounds, and in its empty configuration, the container required four personnel to move it, which means that only MHE can feasibly move the container. Also, the design of the container calls for a collapsible and reconfigurable container. During the testing, personnel at DDJC did not find the prototype easily configurable and noted that simply configuring the JMIC into the standard container created a slowdown in the system. Numerous safety concerns were noted and it was revealed that the JMIC is not user friendly.[76] If the distribution center is having problems with the container, it is highly likely that these same problems would manifest at the intermediate and end user nodes as well.

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[75] Bryan Lundgren, et. al. *Optimizing The Department Of Defense Baseline Transportation And Distribution Processes With Considerations For The Joint Modular Intermodal Distribution System (Jmids) Implementation.* Naval Postgraduate School, Graduate School of Business and Public Policy Master's Thesis. Monterey, CA. June 2007.

[76] Interview with DDJC personnel 15 February 2007.

Other considerations are at hand with the implementation of JMIDS. With the current system, the wooden pallets that are in use are disposable, to a point. They will be used for the useful life and then sold to a wholesaler who repairs them and resells them. To fix a wooden pallet, the requirements are pieces of wood and nails which are inexpensive and quickly accessible. However, with JMIDS, the DOD owns them and they are not easily disposable once they break. In addition, since the JMIDS containers are not easily repairable, replacement and repair costs are higher. As noted in the LCCA the repair of a JMIC or JMIP would require substantially more money and assets for repair as compared to wooden pallets.

With JMIDS the economic theory of the Tragedy of the Commons also comes into play. Aristotle said "…that which is common to the greatest number has the least care bestowed upon it."[77] What this means is that when the container or platform is introduced to the logistical pipeline, it is common to everyone and yet no one really owns it. No one is essentially held accountable for the containers and the end user at the Forward Operating Bases bears no responsibility and does not care about returning the containers to the distribution centers. According to DDJC, units in combat zones could easily use the JMICs as lockable storage containers because they have no incentive to return them.

Therefore, at a time of crisis or war, all JMICs or JMIPs introduced into the theater of operations may or may not be returned for reuse or for repair. The difficulty of storing and managing literally hundreds of metal containers presents a logistical nightmare for the supply chain. No longer would the wooden pallets be easily broken down, but heavy metal containers would need to be tracked and sent back through the supply system. No incentive exists for soldiers and units in the combat zones to return the containers. As a result, more containers will have to be manufactured, causing JMIDS program costs to spiral out of control.

Another item of concern is the management of the JMIDS inventory. Part of the Operations and Support cost estimation includes the maintenance, unit level

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[77] Benjamin Jowett, translation of Aristotle, Politics, Book II, Last accessed April 1, 2007. http://www.constitution.org/ari/polit_00.htm.

consumption, and inventory and management control. With JMIDS, how would one manage an inventory that they have very little control over? This problem can be compared to that of a trade deficit between countries like the U.S. and China. When the U.S. imports more Chinese goods than it exports to China, the shipping containers pile up at the shipyards or railroad depots as is the case at the Port of Los Angeles where yards are full of ISO shipping containers.[78] This scenario is comparable to the logistics operations during a time of conflict or war where the U.S. ships considerably more into the combat zone than is shipped out. Thus, the shipping containers will begin to stockpile in the region. A solution to this problem would be to create logistical personnel positions that have the primary duty of managing the JMIDS inventory. Yet to make this solution a feasible one, there would need to be JMIDS inventory personnel sent to the front lines for the sole purpose of making sure the containers are sent back. However, as noted in the LCCA no dedicated personnel positions have been planned under the current construct and thus the inventory management is left to the supply system.

Based on our observations and analysis in order to improve the current military supply chain, our recommendations are as follows. First, other distribution centers should follow the example of DDJC, which has won numerous awards, by implementing continuous improvements through the application of Lean Six Sigma. Secondly, the lines of communication between different transportation nodes within the supply chain must be improved. For example, if a shipment is priority and urgent, then the rule of holding the supplies until the trucks and planes are full should be waived. Last but not the least, the tracking system must be standardized in terms of hardware and software in order to gain better visibility. Once the current supply chain inefficiencies are corrected we would then recommend looking at a standard container. To improve the concept of JMIDS we recommend designing a common container with the end user in mind. We believe that the current JMIC was designed to be a "jack of all trades and master of none." The DTS requires that no one JMIC be designed for every possible load, delivery method, or configuration. The designers should look at common supplies and tailor a reconfigurable

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[78] Carey, Nick. "Containers pile up as imports from China soar." Washington Times. June 15, 2006. Last accessed April 3, 2007. http://washingtontimes.com/business/20060615-122003-3483r.htm.

container for those supplies at a much lower cost and weight. The JMIC may not be the end-all solution. Another option would be to modify the current JMIP so that it may carry the current wooden pallets across multiple carriers to the end user. The end-goal is to create a user friendly intermodal system with minimal logistical and maintenance requirement from the end user.

Areas for future research would include taking the LCCA of this report and conducting a cost estimate with the actual data when available. From the LCCA with the real numbers a more feasible and cost friendly system could be designed and implemented into DTS. Also an analysis of node to node pallet use and breakdown methods would be useful to truly gain an appreciation of the inefficiencies in the current DOD supply system. As of the writing of this thesis a truly intermodal and efficient container system appears unattainable under the current supply system construct.

The authors cannot recommend that JMIDS go forward. It is plausible that this model is off by a factor of 10 percent or so. That being said, $91.6M is very small in contrast to the overall DOD budget of over $600B. However, this is still real money and should be treated as such and given the same scrutiny as a billion dollar program. If in the future actual data is made available, future research should be done and applied to this model to either substantiate or dispel these findings and this conclusion.

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APPENDIX A: JMIDS LIFE CYCLE COST TABLE

All costs in CY06$	01 JMIC	02 JMIP	03 Other	Total Cost
R&D	$ 2,632,577.81	$ 761,667.88	$ 3,513,275.21	$ 6,907,520.90
Production	$ 46,939,555.25	$ 21,612,355.81	$ 3,053,214.15	$ 71,605,125.22
O&S	$ 10,686,563.39	$ 2,380,662.75		$ 13,067,226.14
Total Cost	$ 60,258,696.46	$ 24,754,686.44	$ 6,566,489.36	$ 91,579,872.25

	R&D CY06$				
	Cost Element	01 JMIC	02 JMIP	03 Other	Total Cost
1.0	R&D Totals	$ 2,632,577.81	$ 761,667.88	$ 3,513,275.21	$ 6,907,520.90
1.01	Development Engineering	$ 192,000.00	$ 480,000.00		$ 672,000.00
1.02	PEP	$ 128,443.21	$ 39,969.39		$ 168,412.60
1.03	Tooling	$ 311,795.23	$ 29,785.05		$ 341,580.28
1.04	Prototype Manufacturing	$ 1,948,720.19	$ 186,156.55		$ 2,134,876.75
1.05	System Engineering/ Program Management			$ 504,825.21	$ 504,825.21
1.06	System T&E			$ 3,000,000.00	$ 3,000,000.00
1.07	Training			$ 8,450.00	$ 8,450.00
1.08	Risk	$ 51,619.17	$ 25,756.88		$ 77,376.06
	Production CY06$				
	Cost Element	01 JMIC	02 JMIP	03 Other	Total Cost
2.0	Production Totals	$ 46,939,555.25	$ 21,612,355.81	$ 3,053,214.15	$ 71,605,125.22
2.01	Non-recurring production	$ 800,000.00	$ 1,500,000.00		$ 2,300,000.00
2.011	Initial Production Facilities	$ 800,000.00	$ 1,500,000.00		$ 2,300,000.00
2.012	Other Non-recurring Prod				$ -
2.02	Recurring prod	$ 39,956,878.60	$ 17,410,175.87	$ 3,053,214.15	$ 60,420,268.62
2.021	Manufacturing	$ 38,641,729.11	$ 16,888,624.61	$ 800,000.00	$ 56,330,353.72
2.022	Recurring Engineering			$ 2,253,214.15	$ 2,253,214.15
2.023	Sustaining Tooling	$ 155,897.62	$ 14,892.52		$ 170,790.14
2.024	Quality Control	$ 1,159,251.87	$ 506,658.74		$ 1,665,910.61
2.03	Engineering Changes	$ 1,159,251.87	$ 506,658.74		$ 1,665,910.61
2.04	Training			N/A	$ -
2.05	Initial Spares Reparables	$ 5,023,424.78	$ 2,195,521.20		$ 7,218,945.98
	O&S CY06$				
	Cost Element	01 JMIC	02 JMIP	03 Other	Total Cost
3.0	O&S Totals	$ 10,686,563.39	$ 2,380,662.75		$ 13,067,226.14
3.1	Military Personnel Dir Fund Elements	N/A	N/A	N/A	
3.2	O&M Funded Elements	$ 10,686,563.39	$ 2,380,662.75		
3.21	Annual Repair Cost	$ 3,458,434.76	$ 755,765.95		
3.22	Replacement Cost	$ 6,916,869.51	$ 1,511,531.90		
3.23	Sustainment Cost	$ 311,259.13	$ 113,364.89		

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APPENDIX B: R&D LIFE CYCLE COST TABLE

	R&D CY06$				
	Cost Element	**01 JMIC**	**02 JMIP**	**03 Other**	**Total Cost**
1.0	R&D Totals	$ 2,632,577.81	$ 761,667.88	$ 3,513,275.21	$ 3,907,520.90
1.01	Development Engineering	$ 192,000.00	$ 480,000.00		$ 672,000.00
	PMO (Staff years)	4	10		
	Cost per staff month	$ 4,000	$ 4,000		
	Staff months to complete	48	120		
		$ 192,000.00	$ 480,000.00		
1.02	PEP Totals	$ 128,443.21	$ 39,969.39		$ 168,412.60
	PEP Percentage	6.00%			
1.03	Tooling	$ 311,795.23	$ 29,785.05		$ 341,580.28
	Tooling arbitrary percentage	16.0%			
1.04	Prototype Manufacturing (CTn)	$ 1,948,720.19	$ 186,156.55		$ 2,134,876.75
	Theoretical First Unit Cost (A)	$ 10,000.00	$ 22,000.00		
	Learning Curve	0.88	0.91		
	Prototypes produced(n)	500	10		
	JMIC b+1	0.81558			
	JMIP b+1		0.86394		
	JMIC (b)	(0.18442)			
	JMIP (b)		(0.13606)		
	LN 2		0.69315		
	LN slope JMIC	(0.12783)			
	LN slope JMIP		(0.09431)		
	Total Cost for respective units	$ 1,948,720.19	$ 186,156.55		
	Average cost per unit (Y 500)	$ 3,178.66	$ 16,082.78		
1.05	System Engineering/Program Management CY01 $			$ 504,825.21	$ 504,825.21
		12%			
1.06	System T&E			$ 3,000,000.00	$ 3,000,000.00
	Contractor			$ 1,400,000.00	$ 1,400,000.00
	Gov't			$ 1,600,000.00	$ 1,600,000.00
1.07	Training			$ 8,450.00	$ 8,450.00
	Training for JMIC and JMIP	Field Technical Trn	Graphics Designer	Supervisor	
	Training Course Development (Hrs)	20	50	15	
	Configuration Field Training (Hrs)	20	0	20	
	Maintanence Field Training (Hrs)	10	0	10	
	Total Hours per	50	50	45	
	Cost per hour	$ 40.00	$ 35.00	$ 60.00	
	Number each	2	1	1	
	Total Cost	$ 4,000.00	$ 1,750.00	$ 2,700.00	$ 8,450.00
1.08	Risk	$ 51,619.17	$ 25,756.88		$ 77,376.06
	Estimated Risk Factor	2.0%	3.5%		

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APPENDIX C: PRODUCTION LIFE CYCLE COST ANALYSIS TABLE

	Production CY06$				
	Cost Element	**01 JMIC**	**02 JMIP**	**03 Other**	**Total Cost**
2.0	Production Totals	$ 46,939,555.25	$ 21,612,355.81	$ 3,053,214.15	$ 71,605,125.22
2.01	Non-recurring production	$ 800,000.00	$ 1,500,000.00		$ 2,300,000.00
2.011	Initial Production Facilities	$ 800,000.00	$ 1,500,000.00		
2.012	Other Non-recurring Prod				
	Non-recurring manufact factor			0.16	$ 8,730.00
2.02	Recurring production	$ 39,956,878.60	$ 17,410,175.87	$ 3,053,214.15	$ 60,420,268.62
2.021	Manufacturing	$ 38,641,729.11	$ 16,888,624.61	$ 800,000.00	$ 56,330,353.72
	LC	0.87	0.87		
	Slope(b)	-0.200913	-0.200913		
	First Unit Cost T1	$ 2,256.8462	$ 11,418.7741		
	b+1	0.799087306	0.799087306		
	N	150,000.00	7,000.00		
2.022	Recurring Engineering			$ 2,253,214.15	$ 2,253,214.15
	Eng Services Factor		0.01	$ 563,303.54	
	Prod Suppt Eng Factor		0.03	$ 1,689,910.61	
2.023	Sustaining Tooling	$ 155,897.62	$ 14,892.52		$ 170,790.14
	Historical Step down factor	0.5			
2.024	Quality Control	$ 1,159,251.87	$ 506,658.74		$ 1,665,910.61
	Quality Control Factor	0.03			
2.03	Engineering Changes	$ 1,159,251.87	$ 506,658.74		$ 1,665,910.61
	ECO Factor	0.03			
2.04	Training	N/A	N/A	N/A	
2.05	Initial Spares Reparables	$ 5,023,424.78	$ 2,195,521.20		$ 7,218,945.98
	Initial Spares Factor		0.13		

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APPENDIX D: O&S LIFE CYCLE COST ANALYSIS TABLE

	O&S CY06$				
	Cost Element	**01 JMIC**	**02 JMIP**	**03 Other**	**Total Cost**
3.0	O&S Totals	$ 10,686,563.39	$ 2,380,662.75		$ 13,067,226.14
3.1	Military Personnel Dir Fund Elements	N/A	N/A	N/A	
3.2	O&M Funded Elements	$ 10,686,563.39	$ 2,380,662.75		$ 13,067,226.14
3.21	Annual Repair Cost	$ 3,458,434.76	$ 755,765.95		$ 4,214,200.71
3.22	Replacement Cost	$ 6,916,869.51	$ 1,511,531.90		$ 8,428,401.41
3.23	Sustainment Cost	$ 311,259.13	$ 113,364.89		

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APPENDIX E: JMIC O&S COST TABLE

JMIDS Operational Years	Theoretical JMICs in use per year (Steady State Ops)	Annual repair cost for JMICs	JMIC Inventory Replacements (1% factor)	JMIC Replacement Cost	Repair and Replacement Costs	JMIC Sustaining Cost (.03 Repair and Replacement Cost)	JMIC Total O&S Costs
2007	10,000	$ 12,880.58	100	$ 25,761.15	$ 38,641.73	$ 1,159.25	
2008	50,000	$ 64,402.88	500	$ 128,805.76	$ 193,208.65	$ 5,796.26	
2009	100,000	$ 128,805.76	1,000	$ 257,611.53	$ 386,417.29	$ 11,592.52	
2010	125,000	$ 161,007.20	1,250	$ 322,014.41	$ 483,021.61	$ 14,490.65	
2011	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2012	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2013	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2014	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2015	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2016	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2017	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2018	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2019	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2020	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2021	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2022	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2023	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2024	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2025	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
2026	150,000	$ 193,208.65	1,500	$ 386,417.29	$ 579,625.94	$ 17,388.78	
Totals	2,685,000	$ 3,458,434.76	26,850	$ 6,916,869.51	$ 10,375,304.27	$ 311,259.13	$ 10,686,563.39

JMIC Repair Costs

Average prod cost 150K JMIC	$	257.61
Annual repair cost per JMIC	$	1.29

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APPENDIX F: JMIP O&S COST TABLE

JMIDS Operational Years	Theoretical JMIPs in use per year (Steady State Ops)	Annual repair cost for JMIPs	JMIP Inventory Replacements (0.5% factor)	JMIP Replacement Cost	Repair and Replacement Costs	JMIP Sustaining Cost (5% Repair and Replacement Cost)	JMIP Total O&S Costs	JMIDS O&S Costs
2007	467	$ 2,814.77	2	$ 5,629.54	$ 8,444.31	$ 422.22		
2008	2,333	$ 14,073.85	12	$ 28,147.71	$ 42,221.56	$ 2,111.08		
2009	4,667	$ 28,147.71	23	$ 56,295.42	$ 84,443.12	$ 4,222.16		
2010	5,833	$ 35,184.63	29	$ 70,369.27	$ 105,553.90	$ 5,277.70		
2011	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2012	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2013	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2014	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2015	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2016	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2017	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2018	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2019	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2020	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2021	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2022	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2023	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2024	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2025	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
2026	7,000	$ 42,221.56	35	$ 84,443.12	$ 126,664.68	$ 6,333.23		
Totals	125,300	$ 755,765.95	627	$ 1,511,531.90	$ 2,267,297.86	$ 113,364.89	$ 2,380,662.75	$ 13,067,226.14

JMIP Repair Costs

Avg prod cost 7K JMIP	$ 2,412.66
Annual repair cost per JMIP	$ 6.03

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