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An arena-based simulation of capacity planning in Stage I of the Voluntary Intermodal Sealift Agreement program

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MBA PROFESSIONAL REPORT

An Arena-Based Simulation of Capacity Planning for Stage I of the Voluntary Intermodal Sealift Agreement Program

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December 2004

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13. ABSTRACT *(maximum 200 words)*

The Voluntary Intermodal Sealift Agreement (VISA) was established as an Emergency Preparedness Program on January 30, 1997 following the passage of the Maritime Security Act of 1996 that led to the subsequent establishment of the Maritime Security Program (MSP). VISA is complemented by MSP; which provides the Department of Defense (DOD) with assured access to 47 militarily useful U.S.-flag commercial vessels as a condition for receiving government incentives that include preference to peacetime shipping contracts and a $2.1 million subsidy per ship/year to help defray the cost of U.S. registry. Specifically, VISA augments the organic sealift capability of DOD during a contingency or national emergency by providing assured access to time-phased U.S.-flag commercial sealift capacity, mariners, global infrastructure and intermodal facilities. The objective of this thesis-project is to apply various shipping data relevant to VISA Stage I in an Arena-based simulation model. Specifically, the model will explore capacity-planning events as they may occur during a two major theater war scenario, as well as examine elements of variability and risk that may be inherent to VISA Stage I events.

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AN ARENA-BASED SIMULATION OF CAPACITY PLANNING IN STAGE I OF THE VOLUNTARY INTERMODAL SEALIFT AGREEMENT PROGRAM

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The Voluntary Intermodal Sealift Agreement (VISA) was established as an Emergency Preparedness Program on January 30, 1997 following the passage of the Maritime Security Act of 1996 that led to the subsequent establishment of the Maritime Security Program (MSP). VISA is complemented by MSP; which provides the Department of Defense (DOD) with assured access to 47 militarily useful U.S.-flag commercial vessels as a condition for receiving government incentives that include preference to peacetime shipping contracts and a $2.1 million subsidy per ship/year to help defray the cost of U.S. registry. Specifically, VISA augments the organic sealift capability of DOD during a contingency or national emergency by providing assured access to time-phased U.S.-flag commercial sealift capacity, mariners, global infrastructure and intermodal facilities. The objective of this thesis-project is to apply various shipping data relevant to VISA Stage I in an Arena-based simulation model. Specifically, the model will explore capacity-planning events as they may occur during a two major theater war scenario, as well as examine elements of variability and risk that may be inherent to VISA Stage I events.

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LIST OF ABBREVIATIONS AND ACRONYMS

AMC	Army Material Command
CBO	Congressional Budget Office
CONUS	Continental United States
CONOPS	Concept of Operation
CPF	Combat Prepositioning Force
DOD	Department of Defense
DOE	Department of Energy
DTS	Defense Transportation System
EUSC	Effective United Sates Control
FSS	Fast Sealift Ships
GAO	Government Accountability Office
JPAG	Joint Planning Advisory Group
LASH	Light Aboard Ship
LMSR	Light Medium Speed Roll-on/Roll-off
LPF	Logistic Prepositioning Force
MAGTF	Major Air to Ground Task Force
MARAD	Maritime Administration
MPF	Maritime Prepositioning Force
MPS	Maritime Prepositioned Ships
MRS BURU	Mobility Requirements Study Bottom-UP Review Update
MSC	Military Sealift Command
MSP	Maritime Security Program
MTBF	Mean Time between Failures
MTW	Major Theatre War
NDRF	National Defense Reserve Fleet
OIF	Operation Iraqi Freedom
OPLAN	Operations Plan
ORM	Operational Risk Management
QDR	Quadrennial Defense Review
RFP	Request for Proposal
RORO	Roll-on/Roll-off
ROS	Reduced Operating Status
RRF	Ready Reserve Fleet/Force
SDDC	Surface Deployment and Distribution Command
SECDEF	Secretary of Defense
SRP	Sealift Readiness Program
TEU	Twenty-foot Equivalent Unit
U.S.	United States
USTRANSCOM	United States Transportation Command
VISA	Voluntary Intermodal Sealift Agreement
WMD	Weapons of Mass Destruction

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I. INTRODUCTION

A. BACKGROUND

Sealift is a key component of the United States (U.S.) Defense Transportation System and is also a supporting pillar of the United States Transportation Command (USTRANSCOM) strategic mobility triad (sealift, airlift and prepositioning). This networked alignment of transportation assets enables the Department of Defense (DOD) to support the execution of the National Security Strategy and National Military Strategy of the United States. To this end, a robust maritime capability consisting of U.S. citizen mariners and militarily useful U.S.-flag commercial vessels that can augment DOD organic sealift capability during peacetime and war remains a vitally important requirement. In an October 8, 2002 testimony to the House Armed Services Committee Merchant Marine Panel, USTRANSCOM's General John W. Handy stated the following:

> Only 33 percent of the vessels we may require reside in our organic fleets. The remainder of the sealift capacity needed to transport military equipment and supplies comes from the commercial sector. (Ref. 1)

To this end, the U.S. Maritime Administration conceived and formulated the basic tenets and concepts for establishment of the VISA program. Patterned after the Civil Reserve Air Fleet – an airlift mobilization program that was implemented in 1951; VISA was approved on January 30, 1997 by the Secretary of Defense as a cooperative initiative among DOD, the Department of Transportation – Maritime Administration (MARAD) and the U.S.-flag commercial carrier industry. Sponsorship of VISA is delegated to the Administrator of MARAD under the authority of the Secretary of the Department of Transportation (DOT). However, operational control of shipping capacity reverts to USTRANSCOM's Military Sealift Command (MSC) during any VISA stage activation.

VISA encompasses over 75 percent of available dry-cargo capacity in the U.S.-flag commercial fleet. (Ref. 2) Seventy percent of this capacity is derived from 47 ships that comprise the Maritime Security Program. In 2003, the combined capacity metric for VISA/MSP was 174,500 twenty-foot container equivalents (TEUs), which exceeded the DOD requirement for 165,000 TEUs. (Ref. 3) This underscores the scope of VISA as well as the level of capacity augmentation that would convey to DOD during any phase activation. However, VISA is only activated after U.S. government-owned vessels and available foreign flag shipping capacity are totally exhausted. Upon VISA Stage I activation, non-MSP U.S.-flag commercial operators can volunteer up to 15 percent of their capacity. In Stage II, non-MSP vessel capacity can volunteer as much as 40 percent of available capacity. However, in Stage III, carriers must volunteer a minimum of 50 percent of their non-MSP vessel capacity. The Commander USTRANSCOM can activate any of the VISA stages with the approval of the SECDEF.

U.S. military sealift capability is generally derived from organic (government-owned or controlled) or commercial – privately owned ship capacity. This recalls a key aspect or tenet of VISA is to leverage the capabilities of the U.S.-flag commercial fleet, thereby augmenting the sealift capabilities provided in military vessels. (Ref. 4)

In other words, VISA augments DOD's organic shipping assets contained in the National Defense Reserve Fleet (NDRF) and Ready Reserve Fleet (RRF) by guaranteeing access to the capacity of commercial carriers and is therefore an improvement over the SRP and requisitioning programs. Details about the NDRF and RRF are covered in Chapter II.

VISA also exists in a joint planning environment that facilitates the exchange of information. Simply stated, a VISA Joint Planning Advisory Group (JPAG) consisting of representatives from USTRANSCOM, Joint Staff, Office of the Secretary of Defense, Combatant Commanders, MARAD and appropriate carriers convene periodically to plan and determine "how best to use VISA carriers' sealift capacity to meet DOD contingency requirements." (Ref.5) This high-level planning and coordination fosters cooperation among agency representatives and provides transparency to the DOD sealift planning process with the commercial carrier industry. As a result, military logistics planners are more aware of the capacity they can expect from the commercial industry during a contingency as well as peacetime. Likewise, carriers obtain a better idea of DOD's sealift needs. The planning process is summarized and illustrated in Figure 1 below. (Ref. 6)

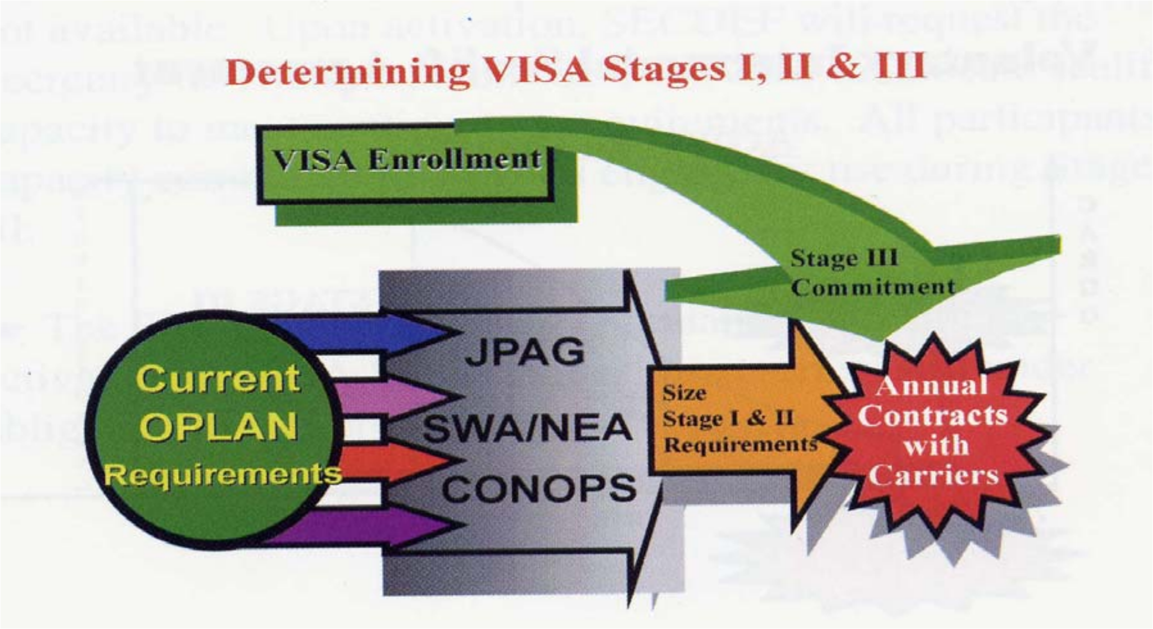

Figure 1. Determining VISA Stages I, II and III (From Ref. 7)

Other benefits of the VISA planning process include carrier coordination agreements (CCAs) that provide carriers with the flexibility to coordinate shipping efforts without violating anti-trust laws; and a pre-determined compensation or rate system that streamlines the transition to a contingency or war footing in the event of VISA activation. The diagram in Figure 2 illustrates the key steps, coordination and feedback involved in the VISA activation process. (Ref. 8)

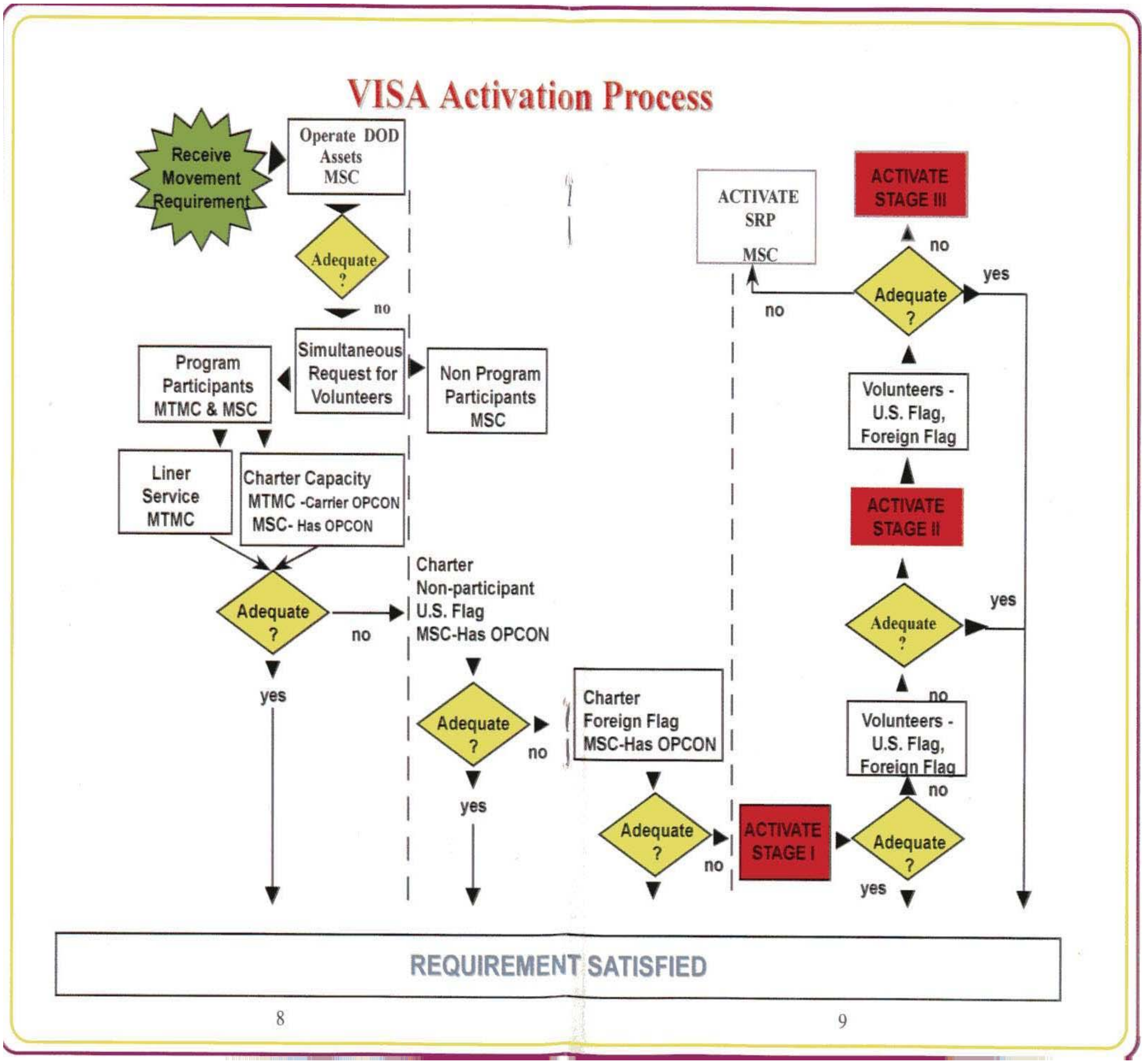

Figure 2. VISA Activation Process (From Ref. 9)

B. ALTERNATE SEALIFT PROGRAMS

1. Sealift Readiness Program (SRP)

Prior to the approval and implementation of VISA, two other sealift mobilization programs or modalities for accessing commercial shipping capacity during national emergencies or contingencies existed: (1) The Sealift Readiness Program (SRP) and (2) Requisitioning. SRP can be traced back to the establishment of the Commercial Sealift Augmentation Program in 1969. However, a subsequent re-identification of the program in 1971 led to the current SRP designation. Even though SRP pre-dates VISA by nearly three decades, it has never been activated during a contingency. The closest the program came to activation was the Persian Gulf War – Desert Shield/Desert Storm. However, general concern for the impact activation would have on competition in the commercial carrier industry and the availability of alternate commercial shipping capacity caused USTRANSCOM to forego its use. SRP remains in existence today as an alternate sealift mobility program and can be applied to carriers not enrolled in VISA.

2. Requisitioning

Requisitioning is an alternative to VISA and SRP that allows the U.S. government – the Department of Transportation MARAD to invoke Section 902 of the Merchant Marine Act of 1936 to gain access (charter or purchase) to the capacity of vessels that may be fully or partially-owned by U.S. citizens but under foreign registry. In this regard, U.S.-owned or majority owned vessels under foreign registry are subject to the "Effective U.S. Control" (EUSC) rule that allows MARAD to submit a requisition for use when sealift requirements exceed that of VISA and SRP. However, this is permissible only if shipping capacity in all stages of VISA and SRP are exhausted. In other words, requisitioning is a program of last resort.

C. RESEARCH QUESTION

The key questions raised by this research project are as follows: (1) What is the material that is possible to be transported during Stage 1 of VISA activation using the normal commercial trade routes and schedules? (2) In terms of material transported, what is the marginal benefit of adding one more ship to the existing the commercial trade route and similarly what is the marginal cost of losing one ship from the trade route? (3) What is the amount of material that can be transported given a specific vessel capacity and assuming a "risk contingent" case scenario? (4) What are the risks involved after activation of the VISA/MSP program? (5) How will these risks impact the DOD sealift capability i.e. the time it takes to deliver the materiel? Note that "actual" military material to be transported for a two-major theater war (2MTW) scenario was not simulated, as specific data from prior and current Mobility Requirements Study/Bottom-Up Review documents remain classified.

D. RESEARCH OBJECTIVE

The objective of this thesis-project is to conduct an Arena-based model simulation analysis that examines the projected employment and utilization of U.S.-flag commercial shipping capacity in Stage I of the Voluntary Intermodal Sealift Agreement (VISA) program.

E. RESEARCH SCOPE AND ASSUMPTIONS

The research objective of this project is to explore the Voluntary Intermodal Sealift Agreement (VISA) program in conjunction with an Arena-based simulation analysis that examines the utilization of U.S.-flag commercial shipping capacity in VISA Stage I. Specifically, this project will explore sealift capability by modeling commercial vessel transit time, schedules, routes and capacity. Military planners base sealift requirements on estimates established in current Mobility Requirements Study documents. Specifically, the 1993 Bottom-Up Review and 1995 Mobility Requirements Study Bottom-Up Review Update (MRS BURU) estimated that the U.S. might face a foe or foes in two nearly simultaneous regional conflicts somewhere on the Korean Peninsula or in the Persian Gulf. The most current (2005) Mobility Requirements Study (MRS 05) supported the findings of the earlier studies. However, these documents remain classified, so the specifics on actual vessel capacity (vessel volume or square footage) required to move the combat support materiel of U.S. forces during the sustainment phase of VISA Stage 1 could not be examined in this unclassified report. As a result, any references to MRS BURU are based on second-hand sources. In other words, extensive use was made of information available in the public realm – Internet sources that provided commercial carrier routes, schedules, capacity and speed.

In general, vessels in the VISA program are of the Roll-on/Roll-off (RO/RO) variety, Lighter Aboard Ship (LASH), combination RO/RO and container, breakbulk, seagoing tugs and barges. (Ref. 10) However, the simulation modeling undertaken in this research project was limited to ships of the container, RO/RO and LASH convention. VISA has never been activated since its implementation in 1997. For example, DOD achieved its sealift mobilization goals during the first Gulf War – Desert Shield/Desert Storm, Kosovo, Somalia, Haiti, Operation Enduring Freedom (OEF) and Operation Iraqi

Freedom (OIF); using government organic shipping assets, contractual agreements and request for proposals (RFPs) to utilize U.S.-flag and foreign flag commercial vessels. Therefore, it is assumed that VISA might only be activated if requirements exceeded that of a Desert Shield/Desert Storm equivalent contingency, for example, if two nearly simultaneous contingencies on the scale of Desert Shield/Desert Storm were to occur. Despite the constraints outlined above, the simulation model is a useful tool that the user can apply to make predictions about materiel transportation via sealift.

F. ORGANIZATION

Chapter II will establish the rationale for the establishment of VISA by exploring the role of sealift in strategic mobility. A brief discussion of the Strategic Mobility Triad – airlift, prepositioning and sealift will be discussed to compare and contrast these transportation modalities and their relevance to VISA. The remainder of the chapter will explore the decline of the maritime industry; the ongoing flag of convenience trend; the role of legislation in sealift revitalization. Chapter III will focus on a brief overview of risk management and assessment, followed by an exploration of the impact of risk on the activities in VISA Stage I. Chapter IV will establish the basis for the development of the Arena model simulation as well as serve as a guide for documenting and interpreting the output data. Finally, Chapter V will develop conclusions, discuss limitations, and address possible topics and questions that can be researched in the future.

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II. RATIONALE FOR THE ESTABLISHMENT OF VISA

A. THE ROLE OF SEALIFT IN STRATEGIC MOBILITY

> Strategic mobility, the capability to transport military forces rapidly across intercontinental distances into an operational theater, lies at the heart of US military strategy. (Ref. 11)
>
> - JOHN M. SHALIKASHVILLI
> Chairman of the Joint Chiefs of Staff

Sealift is predicated on meeting DOD transportation requirements in three areas: pre-positioned materiel for ready response to warfighter needs; surge to achieve rapid power projection; sustainment for ongoing contingency operations. (Ref. 12) To this end, ships carried 72 percent of the dry cargo during the Persian Gulf War – Desert Shield/Desert Storm; with an additional 13 percent dedicated to forward deployed prepositioned vessels. Commercial carriers accounted for nearly half of the total shipping capacity during this period; much of it coming from foreign flag carriers. It is estimated that 130,000 twenty-foot equivalents units (TEUs) and 825,000 square feet of roll-on/roll-off U.S.-flag commercial container capacity is required to meet the sealift transportation requirements stipulated for a two major theater war threat scenario. However, this capacity far exceeds that which is available in DOD's organic sealift capability. As a result, DOD has always looked to the U.S. commercial maritime industry to make up for any shortfall in sealift capability during a national emergency, war or contingency. VISA helps maintain a viable U.S.-owned and U.S.-flag commercial fleet that is crewed by a pool of U.S. citizen-mariners who are subject to U.S. laws. This requirement has been underscored in many transportation-oriented journals, as well as articles and speeches made by industry experts and US policy makers. For example, in signing the Maritime Security Act of 1996, President Bill Clinton stated the following:

> The American Merchant Marine is an important component of the sealift needed by the DOD. By contracting with the owners and operators of U.S. Flag commercial vessels, the Government will gain access to a fleet of modern commercial ships, along with the sophisticated intermodal transportation systems supporting it. (Ref. 13)

President George Bush echoed similar sentiments in a 1991 proclamation that linked the victory achieved during the First Gulf War (Desert Shield /Desert Storm) to "…the importance of the American merchant marine to maintaining an adequate and reliable sealift capacity for the United States." (Ref. 14) The significance of the 1996 Maritime Security Act as an amendment to the Maritime Security Act of 1936 was that the 1996 Maritime Security Act established the basis for the creation of Maritime Security Program; the foundation or overarching document for the VISA program. A primary goal of this amendment was to insure that, U.S.-flag commercial shipping and the mariners that crew the vessels remain a vital part of the nation's maritime capability in peacetime, as well as in the event of a national emergency or contingency.

An important driver behind the resurgence of sealift as a key marker of military capability was based on lessons learned from the Persian Gulf War – Operation Desert Shield/Desert Storm, from August 1990 to March 1991. "In the aftermath of that war, the Office of the Joint Chiefs of Staff concluded that although the deployment was largely successful, those troops who were deployed earliest faced considerable risk…" (Ref. 15) The impact of "lessons learned" from the First Gulf War – Desert Shield/Desert Storm were also highlighted in a 1997 GAO study that suggested that the Army would need to deploy a full heavy division in two weeks in the event of a contingency in the Persian Gulf region. (Ref. 16) The study also estimated that the plan would place significant strains on U.S. strategic mobility. (Ref. 17)

As a follow-up to lessons from Desert Shield/Desert Storm, a 1993 Mobility Requirements Study-Bottom-Up Review (MRS-BURU) was conducted within the context of a thawing Cold War environment and as a result focused on the achievement of military objectives, while keeping cost in check. Specifically, military experts applied computer simulations of combat and deployments to assess the level of risk US forces would face in a "Two-Major Regional Conflict or Theater War" scenario. Having established the basis for developing capabilities to respond to two-near simultaneous regional conflicts, senior civilian and military leadership of DOD expanded the breadth of their study in the 2001 Quadrennial Defense Review (QDR) by including the Post-Cold War period and the uncertain security environment posed of the Global War on

Terrorism threat. As a result, the need for force transformation to combat the asymmetric threats of terrorism and weapons of mass destruction (WMD) has taken center stage in defense policy. Additionally, the planned withdrawal of troops from overseas forward theaters is forging a new reality that is predicated on deployment speed and force agility. To this end, the MRS BURU recommended that DOD attain a surge sealift capacity of ten million square feet. (Ref. 18) The findings of the MRS BURU also drove the requirement for DOD to procure 19 Large Medium-Speed Roll-on/Roll-off vessels that have since made a significant impact on Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) sealift.

B. MSP OVERVIEW AND RELEVANCE TO VISA

The Merchant Marine Act of 1936 and the Maritime Security Act of 1996 provided the basis for the establishment of the Maritime Security Program (MSP). Specifically, the Merchant Marine Act stated that it was necessary for the U.S. to retain a Merchant Marine as a naval auxiliary for national defense; for foreign commerce or international trade; for domestic and import trade; for maintaining a pool of trained U.S. citizen mariners that can crew U.S. flag ships during a contingency. Ocean carriers enrolled in the MSP benefit by receiving subsidies ($2.1 million per year per ship) that help offset the cost of operating vessels under U.S. registry. Carriers enrolled in MSP also benefit by receiving preferences for DOD peacetime-related shipping contracts. In return for these incentives, carrier operators are required to enroll 100 percent of their MSP ship capacity and intermodal resources in VISA Stage III. (Ref. 19) More importantly, the 47-ship fleet that comprises MSP conveys approximately 110,000 TEUs (twenty-foot container equivalent units) or 10 million square feet of militarily useful deck space to DOD. (Ref. 20) This equates to nearly 70 percent of VISA capacity. Altogether, the relevance of MSP to VISA; hence, DOD sealift capability is that it underpins VISA by guaranteeing sustainment sealift capacity that would be vital if the U.S. chose to "go it alone" in a contingency. (Ref. 21) The Maritime Security Act of 2003 expanded the number of U.S.-flag ships permissible under MSP to 60. Under the revised program that takes effect in fiscal year (FY) 2006, participating carriers will receive incentives in the amount of $2.6 million per vessel through FY 2008; $2.9 million (FY 2009-11); $3.1 million FY 2012-15. (Ref. 22)

C. THE CASE FOR STRATEGIC AIRLIFT

The Strategic Mobility Triad - Strategic Airlift, Strategic Sealift and Pre-positioned Equipment is geared towards fulfilling the transportation objectives of DOD by capitalizing on the speed of airlift, the gross capacity of sealift, and the benefits and advantages of forward-staging or pre-positioning of war materiel. The modality of airlift capitalizes on speed, while pre-positioning takes advantage of forward-staging of heavy equipment and support materiel. For example, a standing goal of the Army is to deploy a brigade contingent to any operational theater in 96 hours. (Ref. 23) Such a requirement can be met only through airlift. However, each mode has its drawbacks. Specifically, the movement of materiel via airlift is a high-cost option. Considering that cost would be a secondary concern under conditions of national security and operational necessity, the practicality of transporting sufficient heavy equipment within required timelines would largely depend on available airlift capacity.

In this regard, adequate airlift may be constrained by budget realities. For example, it is not uncommon for Congress to fund a defense acquisition program at a level far lower than that requested by war-fighters and Combatant Commanders. This was the reasoning behind Robert C. Owen's contention that three tensions; high demand, fleet structure and budget affect airlift policy. (Ref. 24) To this end, "effective airlift policy-making involves asking for what one can get instead of what one actually needs." (Ref. 25) As a consequence, airlift requirements will likely exceed the capacity demanded by war-fighters in a future conflict; thus, justifying the need for a robust sealift force that includes U.S.-flag commercial vessels and its associated globally networked intermodal infrastructure and management services.

D. PREPOSITIONING

As the third leg of the mobility triad, pre-positioning assets provides Combatant Commanders with the flexibility to respond to a specific threat using assets that are forward-staged in host nations (allies) or on vessels strategically located in nearby oceans (international waters) that can be quickly dispatched to trouble spots. Since 2001, afloat pre-positioning has consisted of the Maritime Pre-positioning Force (MPF), the Combat Pre-positioning Force (CPF), and the Logistics Pre-positioning Force (LPF). (Ref. 26)

The Military Sealift Command oversees 36 pre-positioning ships. In the MPF configuration, 16 ships are organized into three squadrons whose primary function is to serve as a storehouse for the equipment and materiel for a contingent of 17,000 Marines that make up a Marine Air to Ground Task Force (MAGTF). The CPF consists of 10 ships loaded combat equipment and sustainment supplies for Army ground forces. Similarly, 10 ships comprise the LPF that stages materiel assets for the Navy, Air Force and the Defense Logistics Agency. Overall, the key benefit of pre-positioning is that it shortens the response time required to transport materiel to war-fighters. Despite these advantages, both the ashore and afloat pre-positioning option has its drawbacks. First, ashore stocks are subjected to materiel obsolescence; present a target or are vulnerable to attack from enemy forces or internal extremist groups; political and diplomatic issues in host nation may limit conditions under which war materiel are used; staging materiel on foreign soil carries an implied U.S. commitment to defend the host-nation, which can discourage an ally from mounting their own self-defense. (Ref. 27) Finally, afloat pre-positioning is more costly than ashore staging. More importantly, materiel staged aboard ships have to be adaptable to a greater number of conflicts, suggesting that there is a likelihood that the afloat pre-positioned stocks may not properly match the requirements of a given contingency. (Ref. 28)

E. SEALIFT

The point to be made by comparing and contrasting airlift and pre-positioning with sealift is to illustrate that despite its slower transit time, sealift is by far the most efficient and cost-effective mode of transporting military equipment. What sealift gives up to airlift in terms of transit-time, it makes up for in sheer payload; especially cargo of the dry-bulk outsized variety – tanks and artillery. For example, a CBO analysis estimated that to obtain the equivalent of the cargo space (250,000 square feet) possible on one large medium-speed roll-on/roll-off ship, it would take 160 to 225 C-17s. In the same vein, the study suggested that to transport a 250,000 square feet load would entail the employment of 38 to 52 C-17 aircraft. (Ref. 29)

A significant portion of this sealift capacity comes from the commercial carrier industry. The reason is that there is simply not enough shipping capacity in the DOD organic fleet. For example, during Desert Shield/Desert Storm; 72 percent of the military dry cargo from the U.S. traveled by ship to their destinations in the Middle East. (Ref. 30) The organic or military vessel contingent was 60.76 percent and consisted of MSC Fast Sealift Ships (FSS), Prepositioned Ships, Maritime Prepositioned Ships (MPS) and Ready Reserve Force (RRF) vessels from MARAD. To make up for any shortfall in organic capacity, the Military Sealift Command (MSC – one of three component commands of USTRANSCOM) chartered shipping from the commercial industry to move unit equipment and sustainment cargo. As a result, materiel and equipment transported on U.S.-flag commercial ships comprised 12.68 percent of total Desert Shield /Desert Storm capacity. Surprisingly, total foreign flag commercial capacity was 26.58 percent – more than twice the commercial U.S.-flag capacity utilized. (Ref. 31) It could not be determined from the research literature whether the greater usage of foreign-flag shipping was due to unavailability of U.S.-flag vessel capacity.

The most current research data available on the ongoing Iraq War states that 40 RRF vessels collectively transported 22 percent of the total Operation Iraqi Freedom (OIF) cargo. (Ref. 32) Other key data points that add perspective to the achievements of sealift during Operation Enduring Freedom (OEF) and OIF are as follows: (1) Over 3 million short tons of cargo were transported to the OIF/OEF operational theater during the period of September 2001 to February 2004; (2) Eighteen of the 20 LMSRs procured as a result of the MRS 05 recommendations made a total of 38 trips for a grand total of over 5.3 million square feet of materiel – 26 percent of the total DOD requirement. (Ref. 33) At a capacity of approximately 300,000 square feet, each LMSR in one trip transported the equivalent capacity of six Desert Shield/Desert Storm ships; greatly enhancing the organic sealift capability of DOD. Altogether, 74 percent of the 3.1 million short tons of cargo transported during OIF/OEF were accomplished via sealift. (Ref. 34)

1. Organic Sealift Composition

Organic sealift consists of vessels that are under government control or long-term charter. Specifically, organic sealift are the prepositioned ships; Fast Sealift Ships (FSS); (LMSR) vessels, ships from the Ready Reserve Force (RRF); tankers; Lighter Aboard

Ships (LASH) and other vessels that provide military useful capacity. These vessels provide DOD with emergency as well as surge response capabilities to deploy combat and support forces on short notice.

a. National Defense Reserve Fleet (NDRF) Composition

The National Defense Reserve Fleet (NDRF) is a key component of DOD's organic sealift capacity. These vessels are maintained by MARAD and are comprised of inactive dry cargo ships, tankers, military auxiliaries, and other ship types that can be activated between 20 – 120 days in the event of a national emergency. (Ref. 35) As of September 30, 2003, the NDRF consisted of 297 vessels; down from a high of 2,277 in 1950. (Ref. 36)

b. Ready Reserve Force (RRF) Composition

The readiness level (activation in <20 days) of Ready Reserve Force ships enable their employment in a surge capacity, making them a vital part of DOD sealift capability during a contingency or national emergency. MARAD exercises control over RRF ships. As a component of the NDRF, RRF vessels are maintained in a higher readiness state and are used for transporting unit and military equipment during the surge stage of a contingency. (Ref. 37) Sixty-eight vessels comprise the RRF and are maintained in either a reduced operating status (ROS) or lay-up condition. Ships in ROS status are manned with small crews (eight to nine personnel) to facilitate rapid activation according to a schedule of 4 or 5 days. On the other hand, ships kept in lay-up condition (RRF-10, RRF-20, and RRF-30) do not have crews assigned and therefore, undergo a longer activation process - 10, 20 or 30 days that must be completed in a shipyard.

2. Commercial Sealift

Commercial sealift can be broken down into two main categories: privately owned and operated U.S.-flag ships and foreign flag vessels.

F. VISA AND CONTINGENCY SEALIFT

Contingency sealift occurs according to the following priorities: (1) Prepositioned Ships, (2) Fast Sealift Ships (FSS), (3) Ready Reserve Force (RRF), (4) Volunteer U.S.-Flag (5) Foreign Flag vessels, (6) Visa Stages I, II and III, (7) Requisitioning. Pre-positioned, FSS and RRF sealift are derived from DOD organic shipping assets; while capacity contributions to (4) through (7) are tapped from commercial capacity.

According to military planners, the response to a contingency or conflict take place in three distinct stages: In the first stage – commonly referred to as the halting phase; forces and high demand assets are deployed rapidly to the operational theater to defeat the initial attack and stop the advance of the enemy. Under these circumstances, airlift is the primary means of transporting troops, high-demand materiel and equipment to the battlefield. However, prepositioned assets from host-nation shore-based stores or maritime prepositioning ships (MPS) such as forward-deployed large, medium-speed roll-on/roll-off (LMSRs) and MSC charters are also used to meet the sealift needs of combatant commanders or war-fighters. The second stage or buildup phase is executed with fast sealift ships (FSS) capable of traveling at speeds in excess of 30 knots; LMSRs and Ready Reserve Force (RRF) ships under the operational control of MSC. The third and final stage is sustainment and involves the use of U.S.-flag commercial carriers, as well as foreign flag commercial carriers to satisfy DOD capacity requirements. Ships from the organic fleet would also be re-employed during this phase.

This is also the stage where insufficient U.S.-flag and foreign flag commercial lift capacity might trigger the activation of VISA Stage I, if volunteered commercial capacity were not sufficient. The diagram in Figure 3 illustrates the various stages of VISA activation during a contingency.

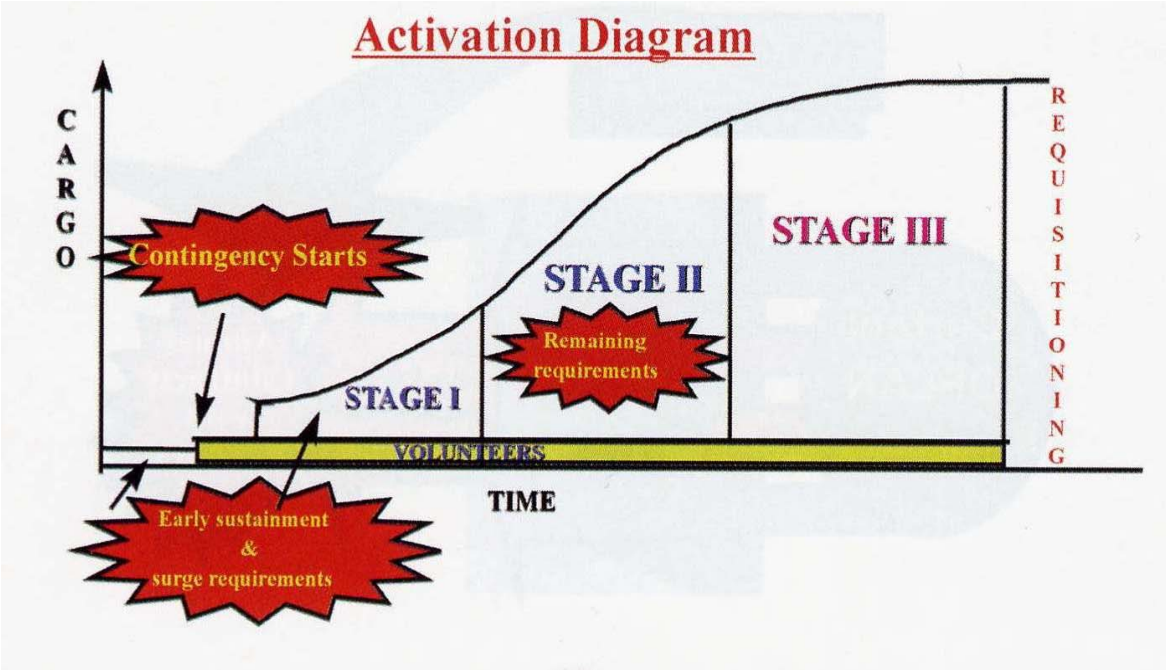

Figure 3. VISA Activation Diagram (From Ref. 38)

G. THE DECLINE OF THE MARITIME INDUSTRY

In an assessment of the state of the US Merchant Marine Fleet, the Maritime Administration made the prediction that the number of militarily useful dry cargo ships would continue to decline from a 1990 level of 168 to 35 by the year 2005. (Ref. 39) The downward trend of the U.S. Maritime industry started during the post-World War II (WW II) period, where the U.S.-flag commercial fleet numbered around 2300 ships, but by 2002 had declined to 115 ships. (Ref. 40) U.S.-flag commercial shipping also accounted for over 50 percent of the nation's ocean-going commerce during the early post-WW II years, but these numbers have declined steadily over the years and as a result, have garnered the attention of U.S. policy makers and senior military logisticians. In fact, the decline in the number of U.S.-flag vessels not only impacts the commercial maritime industry, but also affects the number of trained U.S. mariners available to do the job during a national emergency or conflict. To this end, the issue of risk is reiterated in Chapter II, sub-paragraph J and again in greater detail in Chapter III.

H. THE FLAG OF CONVENIENCE TREND

The vastly changed security environment of the post-September 11, 2001 period has underscored the importance of maintaining a robust U.S. maritime policy to anchor the sealift capability of the DOD. In a June 13, 2002 hearing before the Armed Services Committee of the U.S. House of Representatives, the Maritime Administrator, Mr. William Schubert expressed concern over the lack of transparency in open registries. In other words, there was a disturbing trend in the proliferation of non-U.S.-flag shipping that had effectively contributed to the following state of affairs: (1) Open registries controlled nearly 60 percent of the world merchant fleet; (2) During 2000, open registries occupied four of the top five registry positions in the industry; (3) In 2000, the U.S. ranked 12th place among registry nations of the world. (Ref. 41) In a nutshell, the primary reason for the trend away from U.S.-flag or registered shipping is that costs related to construction, maintenance, environmental, safety standards are higher in the U.S. compared to foreign registries. Reduced overall operating costs in the form of lower tax liabilities; lower registration fees; lower crew costs and liberal maritime laws are also factors in the declining U.S.-flag trend. (Ref. 42) Schubert further contends that unlike countries with reputable or high registry standards, open registries can pose a risk of criminal or terrorist activity because owners do not need to have a connection or link to the country sponsoring the registry.

This assertion is supported in the article titled *Flags of Inconvenience* in which Chris Gillis suggests that the inherent risks and security vulnerabilities that foreign flagged vessels pose to the United States may result from a multiplicity of vessel operation standards. (Ref. 43) As a result, some security experts question the validity of documents offered up by foreign flagged carriers who enter U.S. ports in large numbers on a daily basis. According to Gillis (2002, p. 60), the registered vessel owner is often only a shell entity that has no actual control of the vessel. This would make it difficult at best to trace or establish a clear line of legal accountability in the event a convenience flagged vessel was used to perpetrate a terrorist act against the U.S. In addition, a point was made that countries with lower registry standards made it difficult to determine who was manning the ships and what level of training the crew possessed.

The trends outlined above do not bode well for the U.S. maritime industry, because in the pursuit of profits and economic self-interest, carrier owners will seek a lower operating cost structure; which is achievable under a foreign registry. Whether operating subsidies provided by MSP-VISA are the answer to the foreign registry trend remains an open question. Based on the discussion outlined in the preceding paragraph, one can conclude that owners of MSP enrolled vessels are able to lower their financial and business risk because of the benefits received from the subsidy, as well as the priority access afforded to DOD peacetime business. Similarly, DOD benefits from MSP by lowering its mobility (sealift) risk through the assured access guarantee to 100 percent of that vessel's capacity in the event of VISA activation.

There is also a level of security assuredness and risk-reduction benefit that accrues to the U.S. based on the higher registry standards required for MSP enrolled vessels. For example, in the aftermath of the "9-11" environment, Congress is exploring various legislative approaches to close loopholes that allowed carriers to circumvent U.S. maritime regulations and standards that U.S. flagged vessels and other reputable international maritime operators have to follow.

To this end, Congress passed the Merchant Marine Cost Parity Act of 2001 to ease the tax, wage; insurance and vessel inspection costs that U.S.-flag carriers have to bear. (Ref. 44)

I. THE ROLE OF LEGISLATION IN SEALIFT REVITALIZATION

The aim of this paragraph is to outline the impact various items of legislation have had on the evolution of sealift within the context of the various relationships pursued by DOD with the commercial maritime industry. Many of the laws were implemented during the early stages of the twentieth century and remain in effect as implemented or in amended forms. In effect, many of the laws that will be discussed in the foregoing paragraphs have laid the foundation for the structure of VISA.

For instance, the requirement to use U.S.-flag ships to transport all military cargo is based on the Military Cargo Preference Act of 1904. The exception to this requirement is when DOD determines that no U.S.-flag vessel is available. (Ref. 45) The Cargo Preference Act of 1954 applies to government agencies and stipulates that at least 50 percent of the cargo must be transported on privately owned U.S.-flag vessels. (Ref. 46) In the case of humanitarian aid cargo, the requirement is 75 percent. In each instance outlined previously, the cargo rates charged to the government or DOD must be reasonable.

Compared to the legislation described in the previous paragraph, the Jones Act (Section 27 of the Merchant Marine Act of 1920) established rules for the transport of cargo between points in the U.S. – districts, territories and possessions. (Ref. 47) However, the constraints outlined in this item of legislation went a step further by requiring the vessels to not only be U.S-flag, but U.S.-built; U.S.-owned; U.S. citizen crewed. (Ref. 48)

Passage of the Maritime Security Act of 1936 established the basis for maintaining a viable Merchant Marine to augment the naval capability of the U.S. in time of war or national emergency. However, the post-World War II decline of available U.S.-flag commercial shipping provided the impetus for the amendment of the Maritime Security Act of 1936 with the passage of House Resolution (H.R. 1350). The result was the Maritime Security Act of 1996 that set the stage for the establishment of the Maritime Security Program (MSP). Administered by MARAD, 47 MSP contracts were initially apportioned among 10 U.S.-flag carriers or shipping companies. To partially offset the cost of maintaining vessels under U.S.-flag registry, MSP participating carriers receive a $2.1 million annual subsidy for each ship enrolled along with priority access to DOD peacetime shipping. In return, carriers agree to commit 100 percent of vessel capacity upon activation of VISA Stage III.

The Goldwater-Nichols Department of Defense Reorganization Act of 1986 played a crucial role in the streamlining of various fragmented mobility assets that resided under the control of the various services (Air Force, Army and Navy). Specifically, the Goldwater-Nichols legislation provided the SECDEF with the authority to repeal the long-standing prohibition against consolidating transportation functions of military transportation commands. (Ref. 49) This in turn paved the way for the establishment of the United States Transportation Command (USTRANSCOM) in July 1987.

The Defense Production Act (DPA) of 1950 laid the foundation that allowed VISA to function as a voluntary agreement between DOD and the Maritime industry. Specifically, this item of legislation provided the authorization for the Government, industry and labor to coordinate efforts to establish voluntary agreements in the pursuit of sealift capacity during a contingency. (Ref. 50) In the event of VISA activation, the DPA also provides the statutory benefit of limited antitrust defense to participants.

J. THE VISA PROGRAM AND CURRENT AND FUTURE SEALIFT RISKS

Over the years the commercial industry has invested heavily in technology, infrastructure and intermodal services. This system of services and management is integrated on a global scale; enabling carriers to achieve a level of shipping visibility, reliability and competence that would take years to replicate in a DOD organic environment, as well as be cost-prohibitive to maintain over the long-term. This system of round-the-clock operation allows carriers to readily substitute vessels on a given route to mitigate capacity shortfalls. The flexibility afforded by the high level of visibility that carriers have also reduces ship movement delays due to unforeseen technical difficulties or mechanical breakdowns. This transfers into a higher level of readiness and reduced risk for the DOD. For example, a report issued by the Military Sealift Committee of the National Defense Transportation Association asserted that the global commercial intermodal system is in continuous operation. For example, on any given day (other than Sunday) ships depart U.S. ports for destinations in the Middle East. (Ref. 51)

The War Risk Insurance Program is another means of reducing the level of financial risk that commercial carriers operating on behalf of the U.S. government or DOD under conditions of war or contingency would have to bear. To this end, the 2003 value of the War Risk fund totaled over $37 million. (Ref. 52)

In exploring the issue of risk as it relates to the use of U.S.-flag commercial shipping capacity operating in a contingency environment, the crucial questions that come to the forefront are: (1) What is the probability that VISA would be activated in the face of a given threat situation to the United States? (2) If activated, would VISA provide the level of capacity, efficiency and effectiveness that DOD expects? (3) Since VISA capacity is derived from MSP and non-MSP participants; what level of assuredness can one expect among non-MSP carriers? In other words, would non-MSP carriers be willing to volunteer for VISA in large numbers and risk abandoning more lucrative and less risky commercial contracts and routes? (4) In view of the changed security environment of the post-“September 11, 2001” period and the retained option of the U.S. to “go it alone” during a contingency if necessary; what level of balking can one expect among potential VISA volunteers? (5) Since U.S. Merchant Mariners will be expected to crew vessels in the RRF, NDRF and MSP fleet; what impact would this demand have on crews available for non-MSP VISA ships? (6) Can mariner skill and experience be a factor in the safety and preparedness of VISA volunteer vessels? (7) Could the average age of RRF vessels (>32 years as of 2001) affect organic fleet readiness, thereby creating a greater need or demand for capacity from the commercial industry?

A review of MSC’s Lift Summary Reports from the Persian Gulf War for the period from August 7, 1990 to March 10, 1991 shows that 60.76 percent of dry cargo capacity was transported on DOD organic shipping. U.S-flag commercial shipping transported 12.68 percent of capacity, while foreign flag commercial vessels accounted for the remaining 26.58 percent of total cargo capacity. (Ref. 53) This suggests that utilization of non-U.S.-flag commercial shipping was high during Desert Shield/Desert Storm and that this tendency may again be adopted by USTRANSCOM/MSC in future contingencies. In response to the organic capacity shortfalls identified during Desert Shield/Desert Storm and recommendations of the MRS BURU; the Clinton Administration earmarked over $20 billion towards the modernization of strategic mobility forces. Specifically, 19 new LMSRs – each providing nearly 300,000 square feet of cargo deck space were to be purchased from 1997 to 2001. This additional organic capacity reduces the risk of a shortfall in filling sealift requirements, but it also reduces the probability that VISA will be needed.

III. BACKGROUND THEORY

A. RISK

1. Introduction

Virtually all sealift decisions are made within the context of risk, because in effect, risk is a measure of potential inability to achieve desired objectives. (Ref.54) Risk is also future-oriented: an un-materialized threat encompasses several unknown characteristics that have a probability of occurring at some point in the future and therefore, embodies risk. Today, risk assessment and risk management are used by a variety of commercial business entities, as well as federal and local government organizations to help predict the chance of a system failing at some point in the future.

The insurance industry was the first to apply risk management (actuarial tables) as a tool for executing its business strategy (Ref. 55). Insurers are in the business of providing actuarial risk pooling through their major products such as life, property/casualty and health insurance, annuities, etc. (Ref. 56) The goal of risk management in the insurance industry is to offer viable economic reasons for firm managers to engage themselves with not only expected profit but with the *distribution* of firm returns around their expected value. (Ref. 57) That is, insurance assists managers in valuing risk probabilities (percentiles) as contingencies.

In risk management, the insurance industry begins by identifying the risks involved in providing insurance services. These risks are broken down into two categories viz. actuarial risks and financial risks. (Ref. 58) The latter includes asset risk, pricing risk, asset/liability matching risk, and miscellaneous risk. While the former, includes systematic risk, credit risk, liquidity risk, operational risk and legal risks. The insurance companies then use tools such as simulation to model various scenarios that have influence on the various risks based on the type of risk. For example, for the asset/liability matching (liquidity) risk, some insurance companies modeled various interest rate scenarios to measure the net cash flow. (Ref. 59) The various net cash flow values were then aggregated and put on a distribution. Negative net cash flows will represent the unfavorable outcome, hence risk. Thus, a firm manager may want a small risk; e.g. no more than 5th-percentile that net cash flow outcomes may be negative. In this example, the 5th-percentile is the amount of risk the firm manager would be willing to take. That is, the probability of a negative net cash flow outcome must be less than the 5th-percentile of the entire distribution of outcomes.

The use of risk assessment and management soon spread to other areas of business and society as knowledge became more widespread and accepted. Risk management first formally found its way into the Navy in the early 90's as operational risk management (ORM). The current ORM instruction authorized by the Chief of Naval Operations (OPNAVINST 3500.39A, 2000, 1) states that "uncertainty and risk are inherent in the nature of military action…success is based upon a willingness to balance risk with opportunity." (Ref. 60) The Naval Safety Center was the first Navy organization to recognize the utility of ORM and adopted it to help mitigate the inherent risks present in naval aviation.

Today, risk management is integrated into the decision-making of virtually every defense organization as managers seek ways to mitigate contingencies. Thus, the logistics arm of the Department of Defense (DOD), USTRANSCOM, now also uses risk management to mitigate any risks associated with transportation of military cargo. By mitigating the risk, USTRANSCOM may decrease the probability that the material will not reach its destination on time. If the military cargo does not reach the battlefield on time the U.S. may lose its competitive advantage on the battlefield.

2. Risk in Logistics and Mobility

In serving the logistics and strategic mobility needs of the DTS, USTRANSCOM must be prepared to provide sealift, airlift and surface transportation, both globally and domestically for U.S forces; often on short notice or within the constraints of compressed timelines. During peacetime, the factors of time relative to available transportation assets are not as critical an issue as they are in time of conflict. For example, the number of U.S.-flag ships that would be available to MSC in time of conflict has always been an area of concern to decision makers. For example, in a special report to the Strom Thurmond Institute, (Whitehurst 2001, p. 5) contended that the number of militarily useful U.S.-flag merchant vessels amounted to only 342. This number was in stark contrast to the Maritime Administration's year 2000 estimate of a U.S-flag fleet numbering between 29,000 and 37,000 vessels over 1,000 tons. The significance of the foregoing claim is that a gross overestimation of available ship capacity would pose a significant risk to mobility in the event of a crisis. Another cautionary point is that "the VISA program is activated only after MSC, RRF and volunteer ships (U.S. and foreign) are deemed insufficient" (Ref. 61) Of equal importance is whether the available ships are of the right type (Roll-on Roll-off, LASH or break bulk) for the intended mission and operating environment. In a nutshell, these questions all relate to the subject of risk.

How then does one classify, assess and manage risk to meet the requirements of DOD's Global Transportation Network? A solution to the preceding question lies in the immense capability of the Defense Transportation System (DTS), which is underpinned by the service triad of AMC, MSC, and SDDC. The mission statement of USTRANSCOM clearly states that its purpose is "to provide air, land, and sea transportation for DOD, both in time of peace and time of war." (Ref. 62) It is one thing to discuss the concept of risk as it relates to transportation in general. However, when the subject of war is included in the mix, the number variables that can affect a given decision grow exponentially. For starters, military decision makers have to determine how best to employ the scarce transportation resources to meet the variable requirements and demands of each service entity. In this case, risk of failure or consequences is not just about competitive advantage, market share and threatened survival as in the commercial industry; but of fulfilling operational requirements for deployed U.S. forces wherever it is needed – delivered at the right place and at the right time. These operational outcomes are the measures that truly define logistics and transportation risk.

B. RISK QUANTIFICATION AND ASSESSMENT

1. Risk Quantification

a. Statistics

The study of statistics refers to the collection, presentation, analysis and use of numerical data to infer and make decisions based on sample observations, where the actual population is not known. (Ref. 63) A population is defined as a group of all possible items or observations of interest to a statistical practitioner. (Ref. 64) For example, it could refer to a population of container ships that sail the North America to Asia route. A descriptive measure of a population is known as a parameter. For instance, the parameter of interest in the population of ships that sail a specific route could be the mean quantity of goods carried on all the ships on that route. However, since it is not always feasible to examine the entire population, a sample of the population can be examined instead, and statistics used to draw inferences from the sample to the population.

b. Statistics of Risk

(1) Range. The range is the difference between the most extreme outcomes i.e. the largest value and the smallest value. (Ref. 65) The range is, therefore, a measure of risk because it measures the spread of the outcomes. However, the range is not a popular measure of risk because it only considers the most extreme values and neglects the values in between. (Ref. 66)

(2) The Standard Deviation. The standard deviation is a measure of the average variation of outcomes from the expected value – the mean. The standard deviation is the more popular and accurate measurement of risk. When the standard deviation increases, the distributional width or variance also increases. That is, the variation of possible outcomes also increases; therefore, the greater the risk. (Ref. 67)

(3) Coefficient of Variation. The coefficient of variation is defined as the ratio of the standard deviation to the expected value or mean. The measure of risk is applicable when the estimates of the variables, their measures, magnitudes, or units differ. (Ref. 68)

c. Probability Distributions

Probability distributions are used to represent the whole pattern of variability in a population. (Ref. 69) A probability distribution is a table, formula, or graph that describes the possible values of a random variable and their respective probabilities. These values are, in turn, used to compute the mean and the variance of the population. The population mean is the weighted average of all its values where the weights are the probabilities. The population mean is also known as the expected value. (Ref. 70)

(1) Types of Probability Distributions. There are two types of probability distributions namely discrete and continuous. Discrete probability distributions are used when a random variable can be assumed to only take distinct values, usually integers as possible values, with no intermediate values possible. Continuous probability distributions, on the other hand, assume the possibility that the random variable may take an infinite number of possible values within a range. (Ref. 71)

(2) Selecting a Probability Distribution. Another way to categorize distributions is as being either empirical or analytical. Empirical distributions are based on data, usually observations from a sample, without necessarily conforming to any pre-determined mathematical function to describe the relationship between the possible values and their attendant probabilities. Analytical distributions can be described with mathematical functions that usually have some sort of theoretical basis. Arena®, the simulation tool that was used in this analysis, allows the user to choose from seventeen types of analytical probability distributions, or to specify an empirical distribution. However, only a few of these are usually used. For the intents and purposes of this study, only the following analytical distributions will be used: normal, uniform and triangular. These probability distributions have different shapes that characterize different types of risk since the variability possible outcomes represent in a distribution represent the risk. Empirical distributions will discussed (as well as other analytical distributions) briefly again in Chapter V, when estimating risk percentiles.

(a) Uniform Distribution. The uniform distribution describes an outcome that is equally likely to fall anywhere between a minimum and a maximum value. (Ref. 72) That is, there is an equal probability that all values of an outcome will fall between the minimum and maximum value. Furthermore, this distribution is used when the maximum and minimum values are fixed. (Ref. 73)

(b) Normal Distribution. The normal distribution describes an outcome that is most likely to be in the middle of the distribution, with progressively smaller likelihoods or probabilities moving away from the most likely value – the mean. (Ref. 74) The normal distribution is used when the following conditions are satisfied:

- Some value of the uncertain variable is the most likely i.e. the mean of the distribution.

- The uncertain variable could as likely be above the mean as it could be below the mean i.e., the uncertain variable is symmetrical about the mean.
- The uncertain variable is more likely to be close to the mean than further away. (Ref. 75)

(c) Triangular Distribution. The triangular distribution describes an outcome that has a minimum and a maximum value. However, the outcome is most likely to occur at an intermediate point. This distribution is well suited to situations where the most likely outcome, as well as the smallest and largest possible outcomes, can be identified. (Ref. 76) There are three conditions that underlie the triangular distribution namely:

- The minimum number of items is fixed.
- The maximum number of items if fixed.
- The most likely number of items falls between the minimum and the maximum values, forms a triangular-shaped distribution, which shows that the values towards the minimum and maximum are less likely to occur than those near the most likely value. (Ref. 77)

(3) Interpretation of the Parameters of the Distributions.

(a) The Center of the Distribution – The First Moment. The first moment of the distribution measures the expected value of the possible outcomes. Common statistics of the first moment include the mean, median, and the mode. The mean is the average value of all the outcomes; the median is the center of the distribution; and the mode is the most frequently occurring value. The first moment of a distribution is commonly measured by the mean (μ) or average value as shown in Figure 4 below.

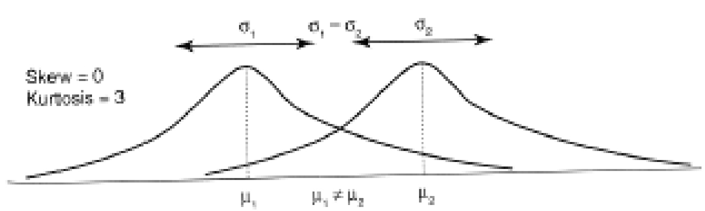

Figure 4. The First Moment (From Ref. 79)

(b) The Spread of the Distribution – The Second Moment. The second moment measures the variation or spread of the outcomes from the

expected value, which is a measure of risk. This measure of risk is also known as the standard deviation (σ). The standard deviation is a measure of the variation of outcomes from the expected value. That is, it measures the potentiality that the outcomes will fall into different regions of the distribution. A higher standard deviation means that there is a great variation in possible outcomes. A great variation in possible outcomes, in turn, means that there is greater risk. (Ref. 79) Therefore, Figure 5 below shows that the solid line has a higher standard deviation while the dotted graph has a lower one. This means that the former has less risk while the latter has more risk. For example, say the two graphs represent two shipping companies (Company A – dotted line and Company B – solid line) both with the same expected delivery times. Using Company B is more risky because it has a greater fluctuation (standard deviation) of potential outcomes (delivery times) than Company A.

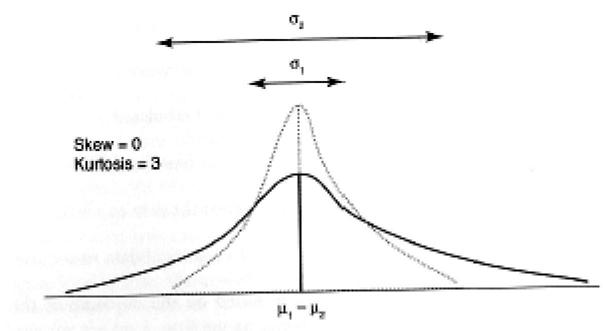

Figure 5. The Second Moment (From Ref. 81)

d. *The Relationship of the First and Second Moment in Determining Operational Risk*

Consider Figure 4 once more, and assume the two graphs represent two shipping companies with different distributions in the amount of material delivered on time to a particular port. The first firm, indicated by the distribution on the left, delivers less material on average to the port, but an equal amount of variability, or risk in the amount of material delivered (σ). Now note that, even though the risk in the two distributions is the same, the probability of obtaining a particular value is quite different. For example, in the first distribution, there is a 50% chance of obtaining a value (amount of material delivered) less than μ_1. However, the second company has only a negligible chance of delivering less than μ_1 material.

Similarly, by adding more ships, VISA will effectively shift the distribution of performance, and reduce the probability (percentile) of delivering less than the required amount of material. Also, for the same amount of risk, one would predict a greater amount of material delivered on time.

e. The Need for Simulation

A simulation is capable of not only describing what the outcomes of a given decision could be, but also the probability with which these outcomes will occur. Simulations are used to generate statistics that can be analyzed. Furthermore, simulations result in the entire probability distribution of outcomes. (Ref. 81) These distributions can then be interpreted using the methods discussed in the part c of this section. The interpretations will then define the types of risks that are involved in the process, in this case, the transportation of military cargo.

f. Simulation Analysis

(1) Simulation Input and Modeling. The distributions discussed in part d of this chapter will be used as input to the simulation model in Chapter IV. The two graphs in Figure 5, above, may describe outcomes from two scenarios from a different amount of risk sources. These risk sources will be discussed in Section D of this chapter. Thus, in the simulation, one scenario was set in which the model of risk was constrained – “best-case” scenario and another where more comprehensive risk was used – “risk contingent” scenario. The solid line might represent the “risk contingent” scenario while the dotted line would be the result of a “best-case” scenario. Although the average delivery time is the same, any particular delivery time (Quantile) would have a much greater risk (percentile) of not being met in the “risk contingency” scenario.

(2) Percentile Analysis. A percentile is a statistic that describes how the data are spread over the interval from the smallest value to the largest value in percentage increments. For example, if data does not have numerous repeated values, the *p*th percentile divides the data into two parts. The *p*th percentile is defined as a value such

that *at least p* percent of the observations are less than or equal to this value and at least (100 – *p*) percent of the observations are greater than or equal to this value. (Ref. 82)

(3) Quantile Analysis. According to Gibbons (Ref. 83), a Quantile of a continuous distribution of a random variable is a real number that divides the area under the probability density function into two parts of specified amounts. However, only the area to the left of the number need be specified since the entire area in equal to 1. In general, a q-Quantile of a random variable X is any value x such that the probability of the random variable (x) being less than or equal to the value (x) is q. (Ref. 84)

(4) The Goodness-of-Fit Test. There are various Goodness-of-fit tests that can be used to test the accuracy of the simulation model. These include, but are not limited to, the chi-square test, Kolmogorov-Smirnov test, Cramer-von Mises test. For the purpose of this paper, the Anderson-Darling statistic, which is part of the Cramer-von Mises family, is used to test. The Cramer-von Mises family statistics is known as quadratic statistics and is based on Empirical Distribution Function (EDF) Statistics. (Ref. 85) According to Stephens, "EDF statistics are measures of the discrepancy between the EDF and a given distribution, and are used for testing the fit of the sample to the distribution…" (Ref. 86)

2. Risk Assessment

Risk assessment is the process of identifying and analyzing program areas and critical technical process risk to increase the probability of meeting the (VISA) operation's cost, schedule and performance objectives. In addition, risk assessment is further broken into two parts: risk identification and risk analysis. Risk identification is the process of examining the program areas and each critical technical process to identify and document the associated risk. On the other hand, risk analysis is the process of examining each identified risk issue or process to refine the description of the risk, isolating the cause, and determining the consequences. (Ref. 87)

C. RISK ASSESSMENT IN VISA

When VISA is activated, there is a sequence of events that needs to take place. For starters, the military cargo that needs to be transported to the war zone has to be taken to the CONUS ports. This is accomplished by using the intermodal systems that are part of the VISA global network, which includes trucking, rail assets, intermodal terminals, etc. (Ref. 88) Thereafter, the cargo will be loaded onto U.S.-flag commercial ships that are enrolled in VISA. These ships will then sail along their international routes to the region which U.S. national interests may be placed at risk. Once, the cargo arrives at the destination it will be unloaded and placed in the hands of the U.S. troops. This is provided everything goes according to plan.

When U.S. forces become engaged in armed conflict, they will be heavily dependent on the supplies provided the commercial shipping logistics supply lines to fight and win. Therefore, any break in the supply lines will have dire consequences for the troops on the front lines. That is a risk the U.S. is not prepared to take. As a result, the VISA program has to come up with a risk management to deal with the potential risk that is associated with the activation. The objective of this risk management would be to identify the risk associated with VISA activation; managing that risk by mitigation or prevention. The goal of the risk management is to keep risk to a minimum in order to keep the logistic supply lines open and functional for the entire duration of the conflict(s).

There are potential risks associated with various stages of the logistic supply line and/or the VISA process. The risk drivers will then be identified. Thereafter, the various risks caused by a certain/specific driver will be identified. These risks will then be assessed to find out what the probability of the risk occurring is and what the consequences of the risk will be in the event that it occurs. Thereafter, the risk will be mitigated and the results of the mitigation will be monitored during risk monitoring stage. The purpose of the monitoring is to assess the risk mitigation steps that were taken to check whether they are effective or not. If not, then new mitigation steps will be taken to deal with the risk.

1. Risk Identification

As mentioned earlier, the sequence of events that takes place after VISA activation is as follows: (1) the military cargo is transported to the CONUS ports; (2) the cargo is loaded onto VISA participant ships; (3) the ships set sail on their commercial routes to the ports of debarkation; (4) The cargo is unloaded; (5) the cargo is the loaded on another ship (controlled by SDDC) that will take it to the point of conflict. However, for the purpose of this study, the authors have assumed that the military cargo is already at the ports awaiting ships in order to simplify the problem. Also, since U.S.-flag ships enrolled in VISA will transport cargo along their normal commercial routes; risk event (4) will not be incorporated into the analysis for further simplification. Therefore, this sequence of events can be further simplified into three parts: loading (CONUS ports), sailing, and unloading (Bremerhaven, Italy, Singapore, etc.). In addition, these events can be viewed as risk events. Table 1 shows some examples of risk that might occur after VISA activation. The authors brainstormed these examples.

Table 1. Risk Events and Risks associated with VISA activation

Risk Event (1): Loading at port of embarkation	• Ship Availability • Crane failure • Ships arriving late • Wrong type of ship • Port workers strike • War protestors/Greenpeace block harbor • Insufficient port capacity • Sabotage/Terrorism
Risk Event (2): Sailing	• Engine failure • Adverse weather conditions (rough seas) • Pirates • U.S. merchant marines crew availability
Risk Event (3): Unloading at transfer port	• Same as Risk Event (2)
Risk Event (4): Load cargo onto SDDC controlled ships.	• Availability of U.S.-flag ships • Correct type of ships available

Given the high level of on-time performance observed with commercial shipping, one may presume that under normal circumstances, the various commercial shipping companies have already incorporated buffers into their schedules to deal with normal risk. Whether those buffers are sufficient to deal with the sorts of risk exemplified in Table 1 is an open question. This question will be addressed in part, by assuming those buffers are not sufficient when the 'risk contingency' scenario is examined in Chapters IV and V.

2. Risk Analysis

One of the risks associated with the loading stage is the possibility of a container crane failure. Failure of a crane could hamper the port operations and thus delay the loading process. Therefore, the reliability of the cargo handling equipment is very important. In addition, ports have multiple numbers of cranes at different docking stations. According to Liebherr (Ref. 89), a crane manufacturer, their gantry container cranes have high reliability/availability with the Mean Time between Failure (MTBF) being less than 0.5% per annum. The ports of Los Angeles, Houston, Norfolk and Oakland use similar cranes for cargo handling. Therefore, the probability of a crane failure is very low. In addition, should one of the cranes fail, the port could use another docking station. As a result, there overall risk rating for crane failure is low risk. (Ref. 90)

The issue of labor disputes affecting port operations is a serious one. A strike at the ports of embarkation could seriously affect the loading and unloading of ships. The strike would cause the harbor to shut down and delay the loading of the ships and thus cause a disruption in the supply line. An example of this is the strike that shut down the entire U.S. west coast, from San Diego to Seattle in October 2002. (Ref. 91) This labor dispute halted all port operations and caused ships filled with import goods to lie anchored offshore. A disruption in the supply line will have significant consequences to the troops on the front lines. Therefore, the issue of a harbor strike is given a medium risk rating because it is likely to happen again sometime in the future and it will have significant consequences if it happens during VISA activation.

The vulnerabilities exposed by the September 11 terrorist attacks demonstrated the scope of the threat posed by transnational terrorist organizations. No one could have imagined that terrorists would use aircraft as missiles to bring down a building. The same analogy can be made in the case of a ship in the hand of a terrorist that is allowed to sneak in to a U.S. port. In fact, in October 2000 terrorists hinted at targeting the maritime industry by placing a boat full of explosives next to the USS Cole that lay anchored on the shore of Yemen and then blew a hole into its hull. There is no reason to think that terrorists will never do this again. Therefore, the issue of sabotage at the ports of embarkation has very serious consequences, and is likely to happen in future. As a result, sabotage has been given a high-risk rating. This risk of maritime terrorism could also affect the shipping capacity in that some commercial shipping companies could be discouraged from volunteering their ships.

A study by the Natural Resources Defense Council (NRDC) has found that sea ports are a major source of U.S. urban pollution. The study found that ten of the major U.S. seaports had increasing levels of pollution. Therefore, this will likely outrage environmental activists and cause them to protest the harbors. Furthermore, there seems to be a growing anti-war sentiment in the U.S. and in the world, which has caused many people to protest. Anti-war protesters who were protesting against commercial shipping companies that had ties to the military action in the Iraq war shut down parts of the Oakland port, one of the major west coast U.S. ports, on May 13 2003. (Ref. 92) Therefore, as long as there are people who disagree with war, pollution, etc, protests are certainly going to occur in future. These protests can cause significant disruptions in port operations as demonstrated by the Oakland port protest. Hence, protests have been given a high-risk rating.

The issue of port capacity has been given a low risk rating. The reason for this is because the VISA program uses commercial ships that already have their own established terminals at the various ports. Furthermore, since the ships will be operating on their normal commercial schedule, there will be no need for the port to handle more ships at a given time. Therefore, under VISA activation, it is unlikely that any port will need to increase its capacity beyond the current throughputs. Also, the consequences of a low throughput caused by low port capacity are moderate i.e. minor delays. The reason for this is due to the fact that if a ship is delayed at, say, the Oakland port, another one could start sailing from another port e.g. Los Angeles.

The advent of Global Positioning Satellite (GPS) technology has meant that ships can now pinpoint their exact location anywhere at sea. Also, recent improvements in weather forecasting now allow multiple days forecast for any part of the world. The National Weather Services (NWS) Ocean Prediction Center (OPC) continually monitors and analyzes maritime data then issues marine warnings, forecasts and guidance in text and graphical format for maritime users. Therefore, the GPS technology coupled with the marine warnings and forecasts allow ships to circumnavigate or prepare for any adverse weather conditions at sea be it high waves, storms, etc. Hence, the issue of adverse weather at sea has been declared a medium risk to the VISA operation. The reason for this is because it is likely there will be storms, high seas, etc at sea. The consequences, on the other hand, will be moderate because there is a great chance that the adverse weather locations will be identified thus avoided. This will cause minor delays in the delivery of the cargo.

The ships' timely arrival at port is contingent on where in the international oceans the ships are located at the time VISA is activated. The ships will therefore need time to deliver their cargo and then get back to the U.S. ports in order to start loading the military cargo. This will cause some delays in the loading and hence delivery of the military cargo. However, these ships are also involved in the daily transportation of commercial cargo that makes their processes very efficient in order to minimize cost. This means that the likelihood of ships arriving late, though possible, is remote. However, as mentioned before, the issues of adverse weather and ships equipment problems could occasionally delay the ships. The consequences of a delayed ship arrival at the port of embarkation and debarkation are significant because the nature of military operations is urgent as people's lives are at stake. Therefore, the issue of ship timely arrival has been declared a low risk.

The risk associated with engine failure has been given a medium risk rating because engine failure is unlikely to occur. The reason for this is because the commercial shipping industry is extremely competitive. Therefore, the risk of losing a ship is far greater for a commercial company because it means that they will not be able to deliver cargo usually worth hundreds of millions to its customers. This could have dire consequences for their business because a ship out of service earns no income. As a result, the commercial shipping companies are incentivized to keep their vessels in efficient operating condition. They accomplish this by performing preventative or planned maintenance on their vessels. However, as mentioned earlier, if anything can go wrong, chances are it will. Thus one cannot rule out completely, the possibility of an engine failure. Hence, if engine failure does in fact occur then its consequences will be significant because the delivery of much needed military cargo will be delayed indefinitely.

According to the International Maritime Bureau (IMB) report, pirate attacks on ships have tripled from 1993 to 2003. (Ref. 93) Indonesian waters were found to be the most dangerous, followed by Bangladesh and Nigeria. Indonesia also lies in the Asia-Pacific route that will be used by some of the commercial ships carrying military cargo. Therefore, ships that sail the Asia-Pacific route are vulnerable to piracy. As a result, the threat of piracy has been declared a high risk because it is likely to happen. Furthermore, the consequences of such an event are severe to the military because, should pirates take over the ship, the military cargo being transported could end up in the wrong hands – the hands of terrorists.

The issue of merchant marine availability has been given a medium risk rating because the ships used for VISA Stage I are U.S.-flag ships manned by U.S. merchant marines. Therefore the likelihood that merchant marines will be unavailable is unlikely. That is, as long as there are U.S.-flag ships available to transport the military cargo, there will be merchant marines to man them. However, since VISA has never been activated there is no guarantee that the U.S.-flag commercial ships will indeed volunteer their capacity to DOD in the time of war. This will, in turn, impact the number of U.S. merchant marines. Therefore, the consequences of not having merchant marines are significant because in that event the U.S. will have to entrust their sensitive military cargo on foreign nationals. That is simply not acceptable in a post-9/11 world and when the U.S. has to retain its ability to "go it alone".

The risk ratings for the port of debarkation are similar but generally higher than those at the port of embarkation. The reason for this is that the U.S. will has no effective control over protestors, striking port workers, etc in those regions. In addition, U.S. laws such as Title 46; CFR Chapter II Part 340.6 that gives DOD priority use of the U.S. ports does not apply to the ports of debarkation thus potential problems and/or delays could be aggravated.

The risks associated with risk event (4), the transfers of military cargo to local, intra-region feeder vessels are the availability of U.S.-flag ships and availability of the correct type of ship. U.S.-flag commercial ships are limited to their commercial routes because they will be carrying not only the military cargo but commercial goods as well. Therefore, it is highly unlikely that they will transport the military cargo all the way to the point of conflict. Thus the military cargo will have to be transferred to local, intra-region feeder vessels that are unlikely to be U.S.-flag. Therefore, once again, the U.S. will have to entrust their military cargo on foreign registered ships. The cargo could fall into the hands of terrorists or the enemy and thus compromise the United States' advantage in the conflict(s). As a result, the issue of availability of U.S.-flag ships has been declared a high risk factor. On the other hand, the issue of having the correct type of feeder vessel has been declared a medium risk because its consequences are significant but is unlikely to happen because of the frequency of commercial shipping transport.

3. Risk Rating Matrix

As discussed earlier in this chapter, there are two components to every risk event, the likelihood (probability) that the event will happen, and the consequences of the event happening. These two components can be used to construct a Risk Rating matrix (Figure 6).

Likelihood					
e	L	M	H	H	H
d	L	M	H	H	H
c	L	M	M	M	H
b	L	L	L	M	M
a	L	L	L	L	M
	1	2	3	4	5
	Consequences				

Key:
L (green) = Low Risk
M (yellow) = Medium Risk
H (red) = High Risk

Figure 6. Risk Rating Matrix

Legend:

Level	Probability
a	Remote
b	Unlikely
c	Likely
d	Highly Likely
e	Near Certainty

Level	Consequences
1	Minimal/None
2	Slight
3	Moderate
4	Significant
5	Unacceptable

The following Risk Rating Matrices shown below (Figures 7-10) refer to the risk ratings given to the specific risks associated with every step i.e. risk events of the VISA operation. The rationales for the risk ratings were discussed in the Risk Analysis section.

Likelihood	1	2	3	4	5
e					
d				Wrong ship type/Protests	
c				Strike	Sabotage (Terror)
b			Low Port capacity	Ship Availability	Crane failure
a				Ship is late	

Consequences

Figure 7. Risk Event (1): Loading cargo at the port of embarkation

Likelihood	1	2	3	4	5
e					
d					
c		Adverse weather			
b				Engine Failure; No Merchant Marines	
a					Pirates

Consequences

Figure 8. Risk Event (2): Sailing

Likelihood	1	2	3	4	5
e					
d		Protesters Blockade		Strikes	
c			Low Port Capacity		
b					Crane Failure
a					

Consequences

Figure 9. Risk Event (3): Unloading at port of debarkation

Likelihood	1	2	3	4	5
e					
d				U.S.-flag ship Avail.	
c					
b				Correct feeder vessel type	
a					
	1	2	3	4	5

Consequences

Figure 10. Risk Event (4): Transfer of cargo to local, intra-region feeder vessels

The U.S. Government has no choice but to deal with the risks associated with the VISA program. One way of finding out how these various risks will affect the whole military cargo transportation operation is to activate VISA program and then record any problems that arise. The data recorded could then be analyzed and then used to improve and make changes to the process. Furthermore, the information gathered could be used to mitigate any future risk that might occur. However, since the VISA has never been activated before, there is no available data or information as to how the various risks will affect the transportation process.

Therefore, the only option is to simulate the VISA activation using a computer based simulation model, in this case, Arena 8.0. The reason for this is because simulations will not only demonstrate what the outcomes or consequences of a given decision could be, but also the probability with which the outcomes will occur. (Ref. 94) All the various risk factors and sources will be quantified i.e. given probability distributions and then entered into the simulation model to see how each one affects the VISA process. The results gathered from this simulation will then be analyzed in Chapter IV to see how the various risks affected the overall transportation process.

IV. THE ARENA MODEL

A. THE ARENA MODEL FUNCTIONAL SPECIFICATION

1. Problem Formulation

In order to develop a simulation model, the client (SDDC/MSC) was approached to find their requirements. This was done at a MBA project meeting held at the SDDC in Fort Eustis, Virginia on September 16, 2004. The initial plan involved modeling the MSP participation in Stage III of the VISA Program. However, SDDC/MSC was more interested in the development of a useful tool that would assist in the operational assessment of VISA Stage I. This resulted in the re-focusing of efforts to model VISA Stage I.

In order to model Stage I, the relevant data for 126 ships that were participants in the VISA Program was collected. This data contained inter alia the ship capacity, speed etc. (See Appendix D for this data). The commercial schedule for the carriers was determined by looking at the website for each carrier and locating each VISA ship on the carrier's schedule. This data was consolidated into a useful form. (See Appendix A11 for this data). The current commercial trade routes were used for in simulation. There was no deviation from the trade routes so as to simulate the real world situation.

The scope of the project was to provide a tool that MSC/SDDC could use to analyze VISA Stage I performance in various two-theater scenarios. As the scenarios in question were classified, it became evident that the model could be adopted applied as a generic tool for later use. To this end, the analysis of data in this project is intended as a 'proof of concept' validation and not as a detailed analysis of a genuine two-theater scenario. Given the foregoing limitations and due to the relatively high number of carriers (48 in FY 2000) participating in the VISA Program, the model would be too complex if all the carriers were modeled with all their trade routes. As a result, only a few major VISA participants were selected along with their corresponding trade routes. This was seen as a representative sample to validate the model. In order to ensure that the sample was indeed representative, data on all 126 VISA ships was gathered and their corresponding trade routes were also determined. For simplicity, the model was limited to the 2 to 4 major carriers and 4 to 8 different routes they follow. Only the carriers that were most representative of the population were selected for the model.

2. Simulation Objectives

The objective of the simulation study is to provide SDDC/MSC with an operational planning tool for the Stage I of the VISA program. This simulation would aid SDDC/MSC in assessing the impact of route capacity, commercial schedules, material transfer requirements and protection level all for the case of a two-theater war scenario. The simulation would be based on representation of the actual commercial shipping schedules and operations as of the October 2004. The simulation is intended to be an operational tool that would benefit the SDDC/MSC in their planning. The simulation does not intend to replace any existing procedures/processes. However, it can provide SDDC/MSC with an operating tool that can be used to manipulate the material transfer requirements and the timelines for a various deployment scenarios. Statistical analysis shall also be performed on the output to see the level of mission accomplishment (protection level achieved in terms of the transportation of the military material) within certain constraints.

3. Boundaries

During the initiation of the project the first and major concern was where to draw the system boundary. After some discussion it was decided to draw the system boundary around the harbor of embarkation and debarkation. In other words, the intermodal activities to get the material to the port of embarkation, as well as the intermodal activities to get the material from its port of debarkation, to the combatant, have been specifically excluded from any detailed analysis. This is as the intermodal activities are beyond the scope of this study and furthermore would require as separate and more complex study. The analysis however includes a "risk contingency" case scenario. In that scenario, there is a delay module at all harbors to simulate an interrupted schedule due to factors that may include problems due to intermodal activities. This is therefore a "black box" approach for the intermodal activities.

Another boundary was set to limit the number of carriers to maximum 4. The third boundary was to limit the number of routes chosen to those that were undertaken by

US flag ships only. This limits the scope of the investigation to transport by VISA ships only. As there are many ports of interest that are not served by VISA ships, the cargo are transferred from these vessels to local intra-region vessels. These intra-region vessels then transport the cargo from the VISA port to the port nearest to operations. However, since the project was limited to VISA ships only, the intra-region vessel routes were not modeled. Nevertheless, each carrier had several different routes that they operated e.g. the APL carrier had approximately 10 routes to South East Asia, and many more to other parts of the globe. The model was limited to only one route to South East Asia for APL. This limitation was applied to other carriers – Maersk American Roll-On-Roll-Off Carrier LLC. The fourth boundary is not independent from the second boundary. Therefore, limits were established for the port of embarkation for each carrier from West CONUS and the other from East CONUS only. These ports were Los Angeles and Houston respectively for the APL carrier.

The requirement was to develop the model to handle a two-theatre war scenario. The project group chose the two ports of debarkation for the two-theatre war scenario for illustration purposes only. These choices do not imply in any way an actual war scenario ever to be undertaken or planned. On the other hand, the ports chosen were Singapore (one of the hubs for South East Asia) and the Gioia (Italy).

During the initial planning (MSP approach), Karachi was chosen as the port of debarkation. This however posed a problem in the sense that there was no direct route to Karachi using a US Flag carrier. The US Flag stopped at the hub in Singapore and the material was transferred to foreign-flag ships to Karachi. It was for this reason that Singapore was chosen as the Port of debarkation instead of Karachi (note the third boundary again).

The initial boundaries were set as follows: no intermodal activities, two-theatre war, four major carriers and two routes for each carrier, completing the definition of all performance metrics. As a result, two kinds of performance metrics were relevant. (Ref. 95) For example, metrics that measure the quality of the system as well as metrics that measure the success of the study were used to assess VISA Stage I.

4. Performance Metrics

The project group determined the following metrics were important, however, we did not verify these metrics with MSC or other clients:

- What is the most likely amount of material delivered in a given time frame based on the current trade routes and schedules for the carriers under study?
- What is the total material that can be delivered by VISA participants on a particular trade route?
- What is the protection level that can be achieved for a given period of time?
- What is the marginal benefit of adding an additional ship to a given route?
- What is the marginal cost of losing one ship form a given route?
- What is the most likely amount of material that can be delivered and what is corresponding protection level for a "risk contingency" scenario?

5. Solution Methodology

In order to perform an analysis that is suited for contingency and capacity planning, a model was developed. This model would not only be able to explore averages, but also be able to give more details about variability. The model therefore includes, but is not limited to, things like failure rates, loading/unloading rates, harbor delay and sailing times that all are attached to a particular distribution. The following was assumed in the model: uniform failure rates for the crane that loads the material, a triangular distribution for a route time and a uniform distribution for loading rates. These distributions are reasonable given the limited availability of data. The uniform distribution enabled us to input a minimum and maximum value. The triangular distribution also provided the option of having a most likely (mod) value.

The model was also developed in such a way that it "reads in" data from text files. This was done purposefully to ensure that change to input data can be easily made outside the actual model and the user does not need to know anything about simulation software.

6. System and Simulation Specification

The VISA Program was not activated before and hence no lessons learned could be obtained. It was only possible to ask questions about processes should the program be activated, and to request data to support the model. The project team was notified by a SDDC representative that some of the data could be obtained from the Internet e.g., the commercial shipping schedules. This task proved difficult as all the information contained on the websites for APL and Maersk was provided in different formats and several hours were spent to consolidate the data into a useful form that could be used in the simulation.

Upon further communication with the client, invaluable information was received. This provided the team with sufficient data as to the VISA ships and their corresponding attributes viz. name, vessels type, dry weight, fuel capacity, ship speed, square feet etc. (See Appendix D for this detail).

According to Kelton (Ref. 96) the simulation specification should generally include the simulation objectives, system description and modeling approach, and animation exactness, modeling input and output, and project deliverables. A functional specification was used as a guideline in drawing up the specification for this study. (Ref. 97)

7. Purpose of the Functional Specification

The purpose of the functional specification is to streamline the development process of the simulation. The functional specification is a transparent way of defining what is necessary to meet the user's requirements.

This functional specification firstly looks at the scheduling process, loading process, and the transportation process (ships sailing) from port of embarkation to port of debarkation and finally the return of the ship.

Secondly, the user input required to perform the simulation analysis is defined. The input consists of things like ship capacity, speed, commercial shipping schedules and material requirements.

Thirdly, the output generated by the simulation is defined. These are defined in terms of performance quality metrics. These include things such as total material delivered, transfer time and protection level achieved (percentage material delivered).

Finally the project deliverables are described; these include a CD ROM containing the Arena model and the final MBA Project report (this one).

8. Use of the Model

The model is designed to read in data from text files that can be easily changed based on different scenarios, and easily incorporate additional carriers and ships. The user cannot change the ports of embarkation and debarkation as these are predefined. However the simulation model has been designed for future students or developers to very easily modify the ports of embarkation and debarkation. The model furthermore needs very little user interface, aside from the input text files that is already populated with data. The reason for this is to make the model as autonomous as possible and user friendly. The user can also easily interpret the output but looking at an excel file instead of the built in reports that are generated by Arena that may be difficult to interpret.

9. Hardware and Software Requirements

Due to the complexity of the simulation, Arena 7.01 or higher version is necessary to perform any changes on the model. The model would run on the student version of Arena but it cannot be modified as it exceeds the limitation of the student version. The following hardware and software requirements are recommended to run Arena 7.01. (Ref. 98)

- Microsoft Windows 95 or higher (OSR-2), Windows 98, Windows ME, NT 4.0 (Service Pack 5 or later), Windows 2000 or Windows XP.
- Microsoft Internet Explorer 4.01 with Service Pack 2 or higher.
- Adobe Acrobat Reader 5.0 or later
- 128 MB RAM recommended
- Minimum Pentium processor, 300 MHz or higher
- A 1024X786 monitor resolution or higher
- Administrative privileges if using Windows NT, 2000 and XP.

However, due to the complexity of the model, the team used a high-end computer in order to have a reasonable run time. The computer used was a Pentium 4, 3.2 GHz processor with 512 MB of RAM. To achieve the shortest run time, the model was set to a batch run with no animation, the excel output file (outputdata.xls) is closed and the model was run in fast forward.

10. System Description and Modeling Approach

The "system" under study is not actually Stage 1 of the VISA Program. Only 3 of the total of 48 carriers were modeled. However, it is envisaged that all remaining (not modeled) carriers would behave in a similar manner, with the exception that their trade routes may be different.

The model will include the loading of material at the harbor, the ship setting sail according to a given schedule, the ship sailing on its commercial trade route, the arrival and unloading at the disembarkation port and the return of the ship to its port of embarkation for more material.

Finally all the material transported would be tracked over time to determine what protection level is achieved.

11. Model Timeline

The model starts off with the first ship available for the transportation of the military material that has already been delivered to the port of embarkation. If there is no military material available then the model starts off loading potential material and simulates the amount of military material that is possible to be delivered in a given time frame.

The model will be able to simulate the VISA transportation for a period of 45(forty five) days. This period can be adjusted depending on the user's requirements.

12. Ships

The three types of ships that the model initially considered were RORO (Roll On Roll Off) ships, container ships and LASH (Lighter aboard ship). The latter was however not being used to a high degree; hence it is not visible in the model. However the capability is built in. The removal of the LASH ship would not affect the VISA Program Stage I results.

13. Loading at Harbor

Variability was modeled at the harbor in two places. For example, the variability that relates to variance in loading from a variety of sources such as terrorism; worker strikes; go-slow protests; and landside congestion was modeled using a simple delay module that had a triangular distribution. The user-input was the most likely delay noted.

As a result, the variance was calculated to be approximately 50 percent of the harbor delay time. A uniform distribution was applied to the harbor rate. Two types of harbors were considered for the model viz. a modern harbor and a traditional (old) harbor. The reason these were included was that it may happen that a harbor, perhaps in a developing or third world country, does not have the latest and most efficient way of loading/unloading material. Coupled to this was also the failure rate of the crane, the modern harbor had a failure rate that was much lower than the traditional harbor. This was based on the premise that the traditional harbors had cranes that were suffering from ageing and material fatigue that resulted in the mean time between failures being shorter than for modern harbors.

14. Ship Set Sail

The ships set sail according to its commercial schedule that is determined by the carrier. The trade routes and schedule that was provided by the carriers in their websites were used in the model. A scheduled sailing was seen as a more realistic representation than a random sailing of ships, which does not happen in reality. This may be different in Stage III when the MSP ships are activated and they do not operate according to a fixed schedule (which was the initial approach). The activation of the MSP ships is however beyond the scope of this study.

15. Animation Exactness

The sailing of ships on its predefined commercial trade route from port of embarkation to debarkation and back is as exact as possible for modeling purposes. At any given point in time the position of a ship can be determined by looking at its position on the world map. This visual representation gives the user a more dynamic view of the VISA program instead of the model just running through logic like regular programming techniques.

16. Model Input

The following are the model input parameters. These are read in via text files for ease of change outside Arena.

a. Container Ship Input

- Ship type
- Container ship ID number

- Average container ship speed (in knots)
- Average container ship capacity (in TEUs)
- Route number
- Ships per month

b. RORO Ship Input

- Ship type
- RORO ship ID number
- Average RORO ship speed (in knots)
- Average RORO ship capacity (in square feet)
- Route number
- Ships per month

c. Lash Ship Input

- Ship type
- Lash ship ID number
- Average lash ship speed (in knots)
- Average lash ship capacity (in number of barges)
- Route number
- Ships per month

d. Harbor Input

- Container military material (in TEUs), RORO military material (in square feet) and lash material (in total number of barges) at each harbor of embarkation.
- Container loading rate (in containers per hour), RORO loading rate (in square feet per hour) and lash loading rate (in number of barges per hour) at all harbors.
- Harbor index for all harbors
- Distance to port of debarkation (in nautical miles) or time to port of debarkation (in days) from each port of embarkation
- Delay time
- Route (Atlantic / Pacific)

17. Output Data

The output is "written to" an excel file for ease of statistical analysis and plotting of graphs. Arena also produces its own output based on the simulation components however this is not discussed, because the system components are not analyzed. The output of Arena is however attached in Appendix E. It is attached for completeness and in the event that a developer of future student is interested.

The following are the model output parameters for all harbors (detailed output):

- Replication Number
- Container, RORO and lash military material required for delivery (in TEUs, square feet and number of barges respectively)
- Percentage container, RORO and lash military material delivered over time.
- Container, RORO and lash material delivered (in TEUs, square feet and number of barges respectively)
- Time taken for all military container, RORO and lash material to be delivered (in days)
- An overall view of the total material delivered for each war scenario (Pacific material and Atlantic material)

18. Project Deliverables

Upon completion of this project a CD will be created to with all the computer files that are necessary to run the simulation on the full academic version of Arena. The simulation is not offered as a commercial product and to be used for academic purposes only.

The files would include the following:

- Arena file (3_carriers.doe)
- Text files (read harbor info.txt, read container ship data.txt, read RO-RO ship data.txt, read lash ship data?)
- Excel file (outputdata.xls), this file includes macros and visual basic code.

19. Model Validation

The model is a limited representation of the whole VISA Stage I program. The focus of the model is thus only on US Flag carriers on the chosen routes. For this purpose, the actual data from the commercial shipping websites (see Appendix F to J) were used to determine the schedule of the ships. All VISA carriers were looked at and a reasonable representation is made of the three major carriers (APL, Maersk and American RORO Carrier, LLC). The model was validated by insuring that the commercial schedules were accurately reflected in the base scenario.

B. DETAIL MODEL DESCRIPTION

The model is hereafter is described in detail according to the named views in the model. This is done for convenience as well to provide a means to directly cross reference to the model.

1. The World Map View

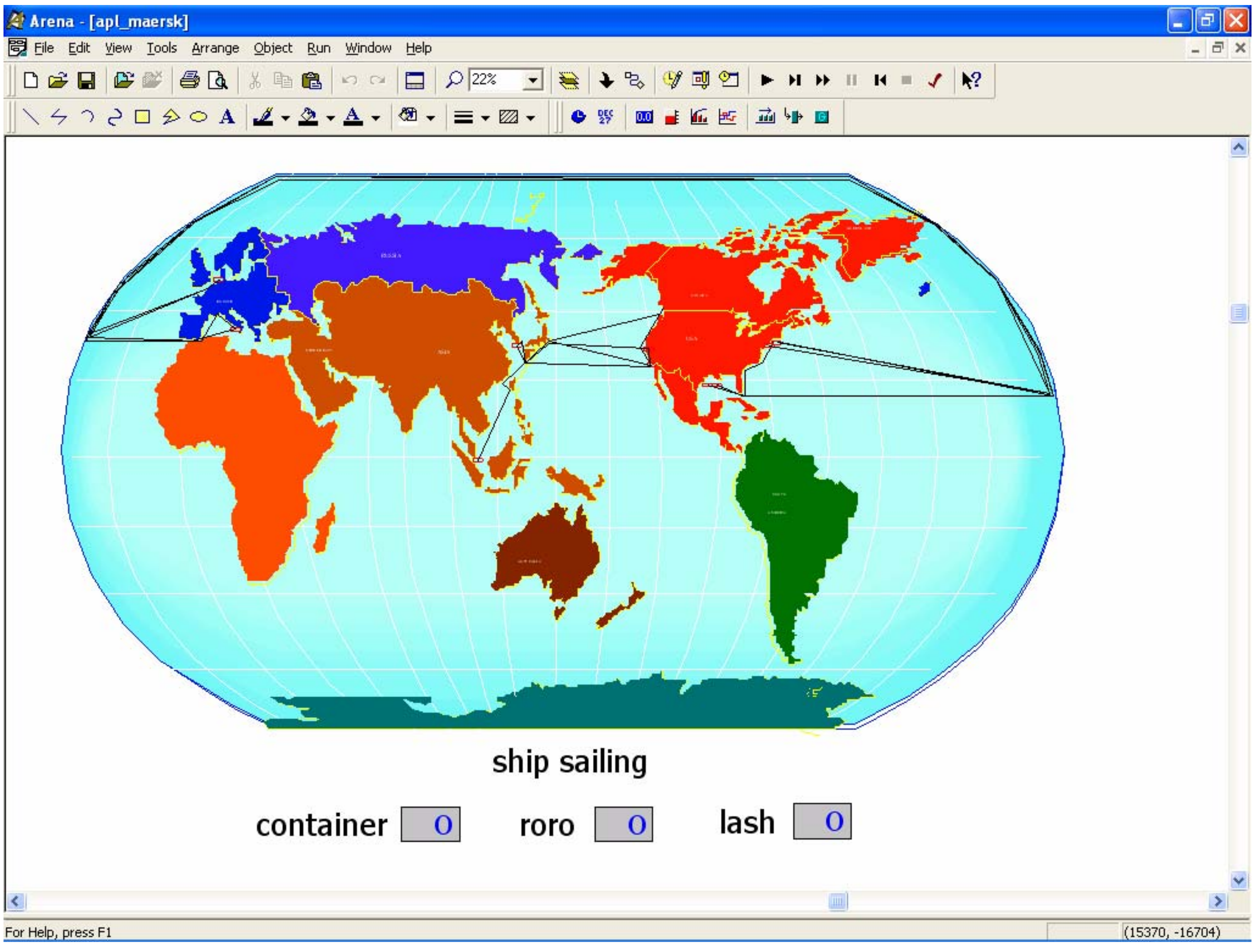

Figure 11. World map view of simulation model showing commercial trade routes

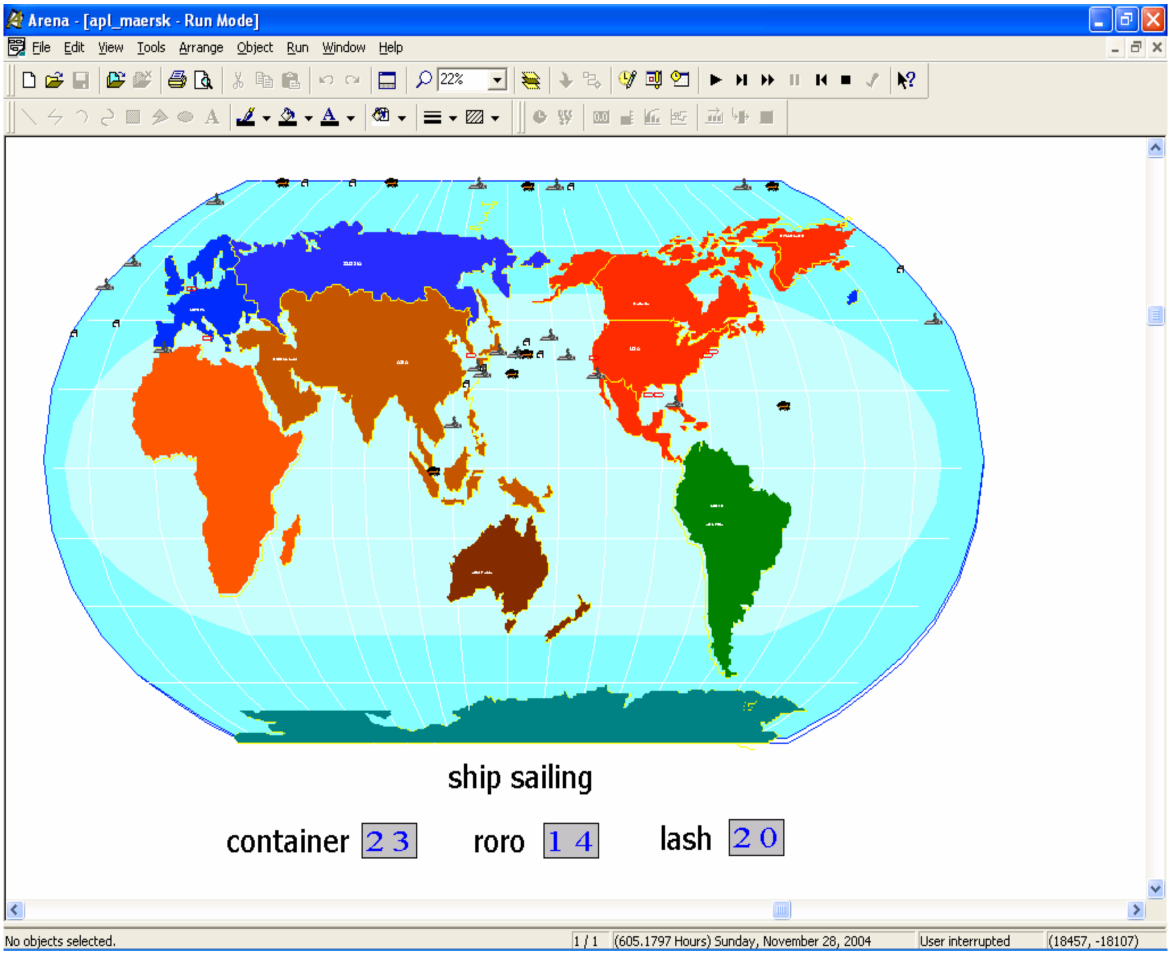

Figure 12. World map view showing Container, RORO and LASH ships on their trade route

The world map view Figure 11 shows the commercial trades routes of the 3 Carriers under study. The trade route for the APL Mediterranean Gulf Service is from Houston (East CONUS) to Gioia (Italy) and back. The trade route for the APL carrier Pacific South Service is from Los Angeles (West CONUS) to Singapore. The trade route for the Maersk Trans Atlantic Service is form Norfolk (East CONUS) to Bremerhaven (Germany) and back; the American RORO Carrier used a similar route. The trade routed for the Maersk Trans Pacific Service is from Oakland (West CONUS) to Kwangyang (Korea). The importance of the world map view is to have a visual representation of the ships sailing. Once the simulation runs the ships can be seen sailing through their various routes based on their given schedules. This animation is consistent with the logic of the simulation. In other words if the route module states that the route time is 19 days the animated ship would set sail for 19 days. These 19 days is represented in simulation time that is regular time accelerated. If the model is stopped (paused) or interrupted, the simulated position of the ships can be seen. A snapshot in time can therefore be taken and the model can resume the continuous sailing of ships for the defined run time (mission duration).

The total number of each type of ship is shown at the bottom of the world map view. Furthermore, each ship may undertake many trips. Once the ships unload the material at the port of debarkation they return for more material based on the carriers schedule for that ship.

2. The Harbor Info View

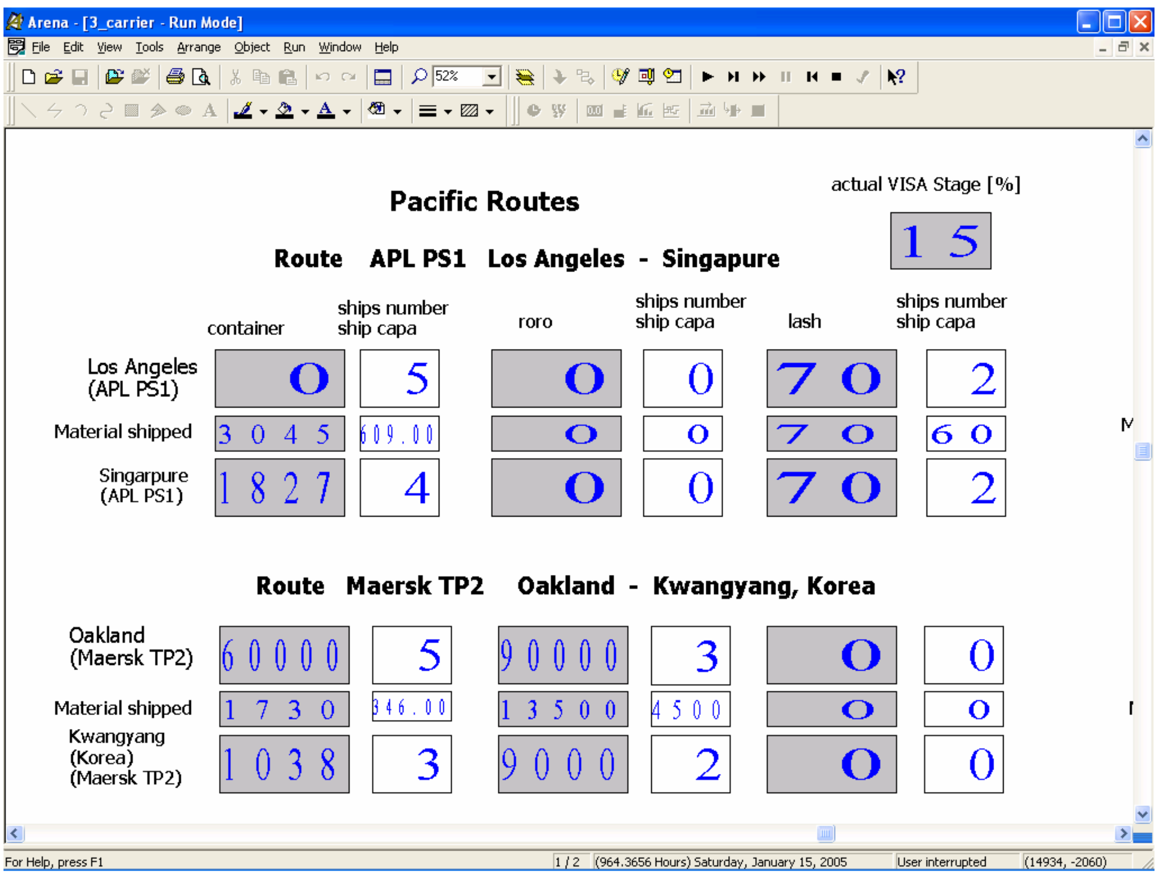

Figure 13. Harbor info view showing the Pacific Routes for the APL and Maersk carriers

Figure 13 shows a part of the Pacific trade route for the APL and the Maersk carriers. The total military material available to be transported from each harbor, the material that left the harbor of embarkation (material shipped) and the material that arrived at the harbor of debarkation are shown. The total number of ships that set sail from the harbor and those that reached the destination is also shown. The ships capacity is shown and is determined as the maximum capacity of the ship multiplied by the maximum VISA percentage. The maximum VISA capacity is shown and for Stage I this is 15% of a carrier's total capacity. It was assumed in the simulation that for the base scenario every ship of the carrier would allocate 15% of its capacity to the VISA program. This does not necessarily have to be the case in reality as a carrier may choose to allocate 100% of a particular ship's capacity to military material. However this does not pose a problem as the model is only concerned with VISA capacity not capacity in general. Also in reality, allocating 15% of each ship's capacity does relatively minimum harm in terms of upsetting commercial trade.

For this purpose, the model also simulates a "risk contingency" case scenario. Here the percentage of material loaded on each ship is a uniform distribution from 10 to 15%. The ship may leave with less than 15% material as the full complement of material may not be available at the harbor or some of the material may be damaged and not military useful. This is still in keeping with the operation of Stage I of the VISA program.

a. APL carrier Pacific South Service from Los Angeles (West CONUS) to Singapore: Container Material and Lash Material

From the Figure 13 above it can be seen that there is no (0 TEUs) of container military material available for transport from Los Angeles. The model provides us with an indication of the total material that would have been possible to transport during a given time period. This is despite the fact that there was no planned or no military material available for transport. This can aid in planning purposes. In total 3045 TEUs of potential container material were shipped from Los Angeles on the 5 ships but only 1827 have arrived at Singapore. This is because only 4 ships reached Singapore during the time period under consideration and there is one ship on the way carrying the remainder of the material.

The LASH material consisted of 70 barges for transport from Los Angeles to Singapore. Only 2 LASH ships left the Los Angeles port and both arrived at Singapore. The first LASH ship arrived with 60 barges and the second arrived with the remainder of the material (10 barges) even though the second ships capacity was 60 barges.

b. The Maersk Trans Pacific Service from Oakland (West CONUS) to Kwangyang (Korea): R-Ro Material

Here it can be seen that there is 90000 sq ft of military RORO material to be transported. The model shows that it was possible for 13500 sq ft of material to be shipped from Oakland, within the mission duration and assuming that VISA stage I was activated. It is also shown that 3 RORO ships set sail with 2 RO-RO ships arriving at the destination with 9000 sq ft of material and the balance of 4500 sq ft still on its way.

3. Pacific Routes Military Material View

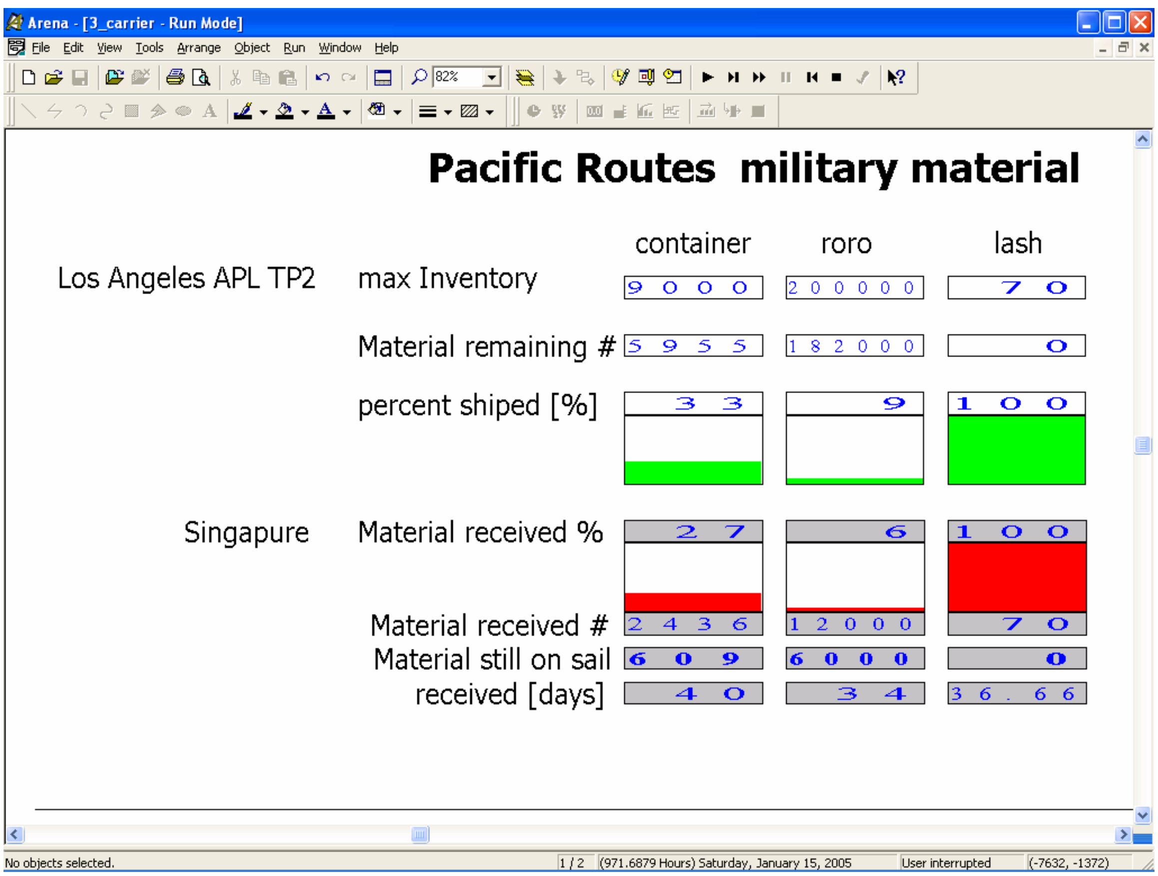

Figure 14. Pacific Routes Military Material for the APL Pacific South Service

Figure 14 shows the port of embarkation (Los Angeles) with the military material (max inventory) that to be transported by the APL carrier. The next row shows the balance of the material still to be shipped (material remaining #) and the percent shipped from the harbor. As more and more material is loaded at the harbor the percent shipped increases up to a 100% and the box fills up “linearly” until completely filled with green when there is no more military material to be shipped. As the model runs this view provides a visual representation of the material that is being shipped. There is also a time delay due to the physical sailing of ships on their routes before the material arrives at the port of debarkation. This can be seen once the model is running where the material delivered (material received #) is always lagging behind the material shipped.

At the port of debarkation (Singapore) the material received is shown for all the types of ships. Here, the material that is still on its way. As more and more material is delivered the box fills up with more and more red color. Each time material is delivered the time (received [days]) is also updated to reflect the corresponding time. The time stops updating after 100% of the military material is delivered. In fact only 33% of container material has been delivered within 40 days, even less for the RORO (9%) in 34 days. The lash ships showed 100% delivery after 36.66 days.

It should be noted that the combination of material received % and time (received [days]) gives us the protection level achieved. The percentage material delivered is continuously updated as more and more ships unload their material at the harbor of debarkation. A snapshot in time can be taken by pausing/interrupting the run and this view would give the corresponding protection level. A 100% protection level means that all military material is to be delivered. If there are more ships that are available to set sail before the simulation run expires, these ships are not counted (in simulation terms they are disposed off); even the time stops being counted further until the end of the run. The protection level in relation to time is extremely important to the combatant.

The percent material shipped and received is only applicable if there is military material available for delivery. Otherwise, the model ignores these fields. The model can therefore do one of two things (for this situation). It can either determine the time it takes to deliver the military material recorded in time [days] field or it can determine the amount of material that can be practically delivered during the time chosen for the mission. It is also worth mentioning that there may be less than 100% of the military material delivered, depending on the time period chosen to simulate the run. This is very important during planning. The total material delivered provides information about the maximum amount of military material that can be transported.

4. Read Harbor Data View

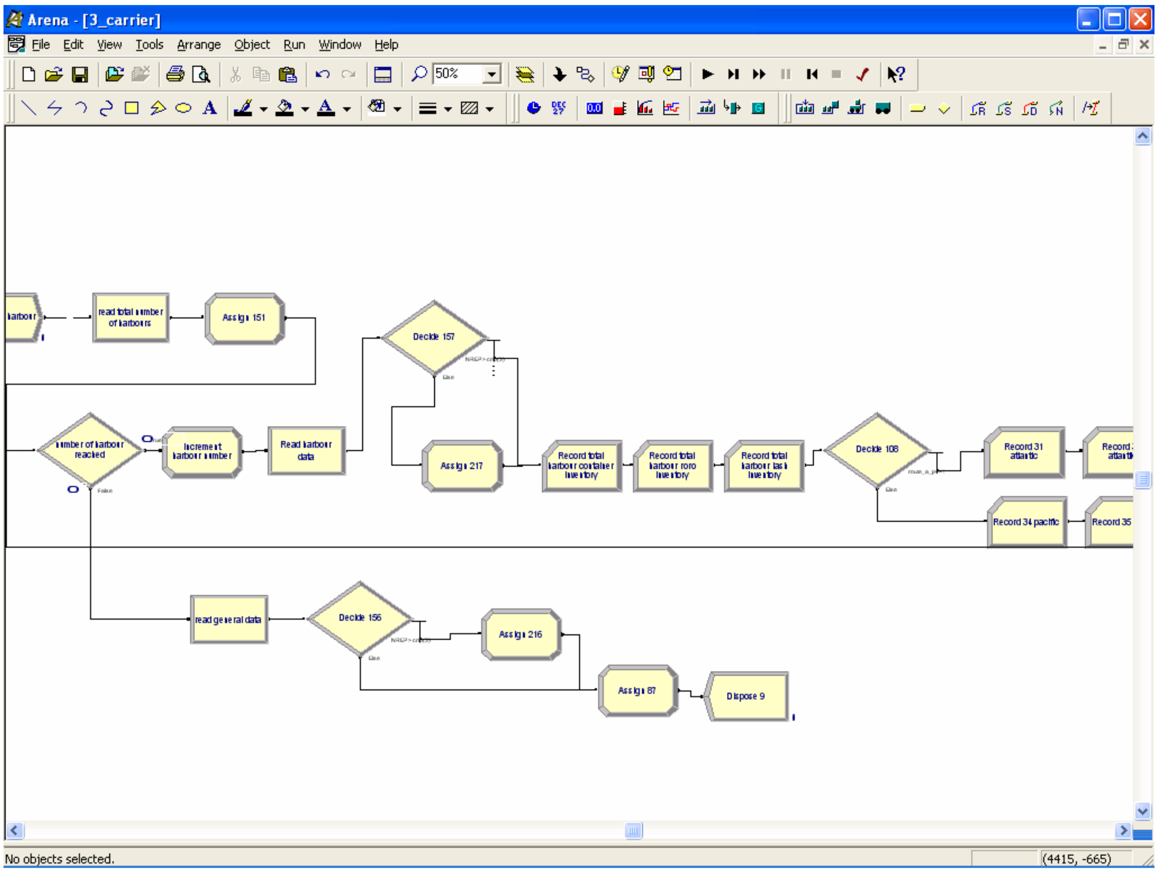

Figure 15. Read Harbor data view of simulation model

The read harbor data sub-model reads in the data for the military material to be transported by container, RORO or lash ships from each port of embarkation. The read harbor data reads in data from a text file. This read harbor data text file is shown in Appendix A. The data that is read in includes the military container, RORO and lash material at each harbor of embarkation as well as the associated load rates. The harbor index as well as the distance or route time to port of debarkation is also read in.

The reason for reading in values was so that these values can be changed outside the model by anyone who knows little about simulation. This facilitates input into the model by any user. The model cannot run without the text file as it is an integral part of the simulation.

The read harbor data module reads in data line by line sequentially from the text file. The lines with the $ sign are ignored by the read process as these lines refers to comments. This is a useful feature and there are several comments that were included in the text file to make it more meaningful. The comments also facilitated the entering of headings so as to name the record fields.

This submodel also checks which type of scenario is to be simulated. The model simulates the normal schedule first. Once completed (based on the number of replications), the read harbor data module "switches over" to the "risk contingency" scenario

5. Read Ship Data and Send Ship View

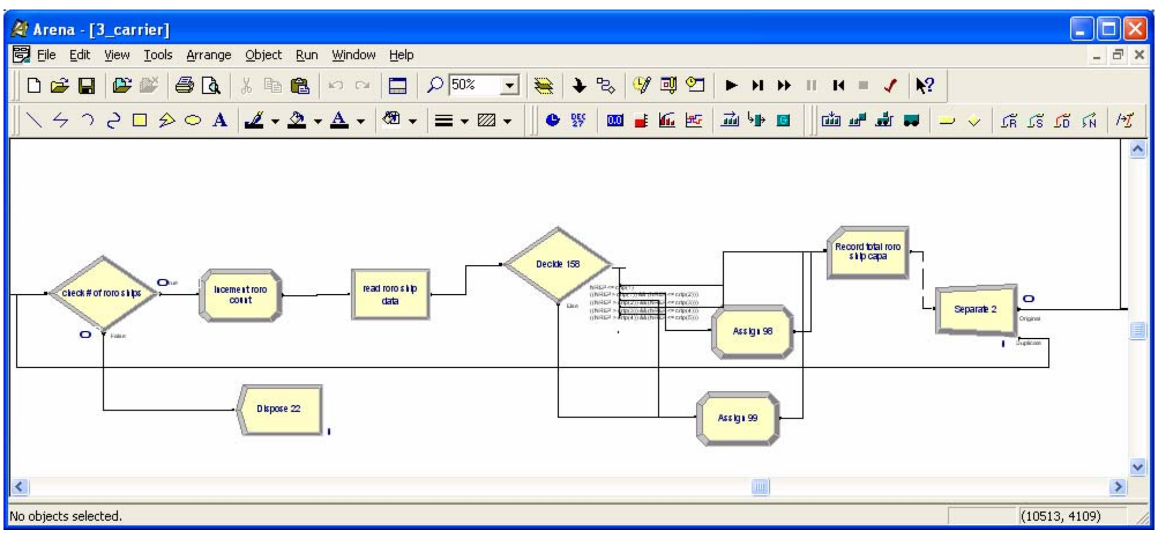

Figure 16. Read ship data and send container ship view

Figure 16 shows the read ship data and send container ship view. The data is read from a text file. See Appendix A for this text file. The data that is read includes: the container ship ID number, the container ship speed and capacity as well as the particular route for the container ship. However, the data represents the average ship for the carrier on a particular route. The model could have just as well used specific ships with their speeds and capacities. The reason for not doing so was firstly there was no major difference between the sizes, capacity and ship speed for the container ships on a particular route. The average ship represented a “grey ship” that is more representative of the long-term situation rather than looking at specific ships. The grey ship means that even though a carrier owns a particular ship, other carriers may charter that ship. Please see Appendix E for raw data of the average ships. The variability in ships capacity is an extension for future follow-on work. The carrier e.g. APL might decide based on their own discretion or due to their operational needs and maintenance requirements “pull off” a ship and replace it, then it is of no particular use to model each ship. Furthermore, if the model were exploring MSP ships then each ship would be modeled and identified uniquely without the use of average ships.

This submodel also determines for each type of scenario whether there is to be the normal (regular) number of ships or one more or one less ship if necessary. There is also an embedded sub-sub model that creates only the necessary number of ships per month.

6. Model View

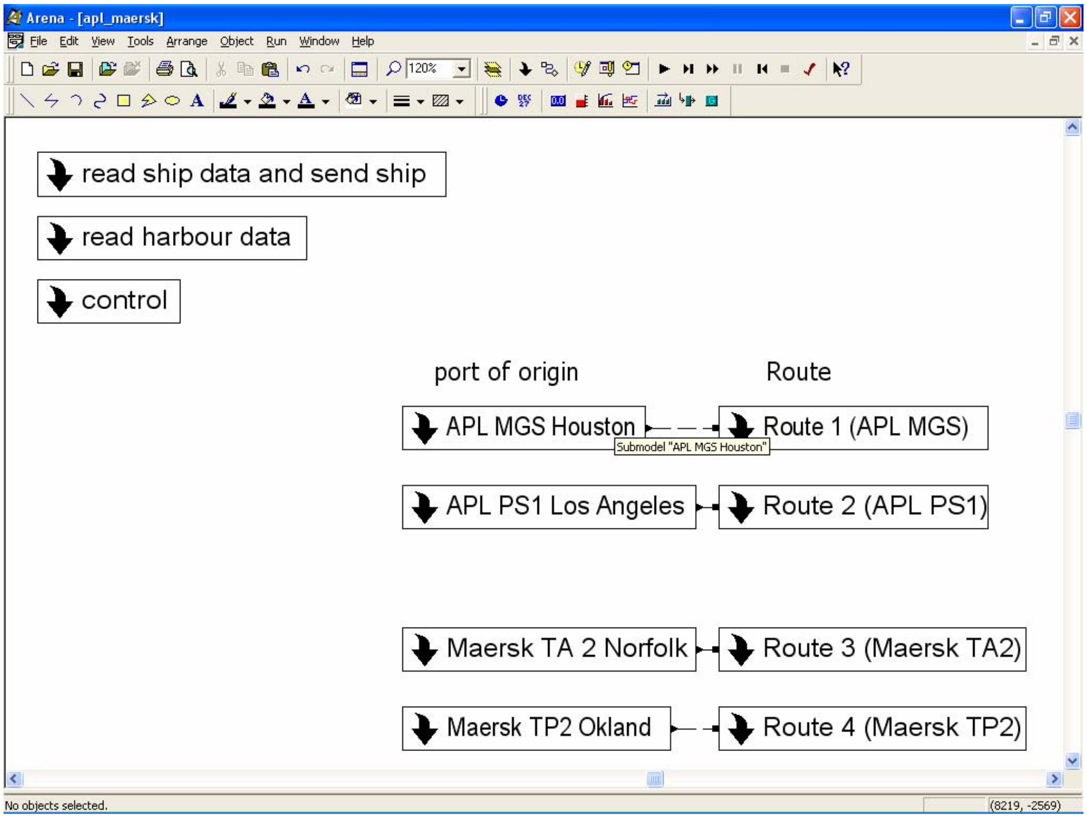

Figure 17. The model view showing sub-models

Figure 17 above shows the model with part of all the sub-models. The model was divided into sub-models based on functionality. This was also important as the model is extremely complex and had to be broken down in management pieces. The use of sub-models was one way that facilitated the development process of the relatively complex model. Once it was found the sub-model worked for a single carrier with a single route this was "duplicated" for more carriers with additional routes. Starting from the top of Figure 17, the read ship data and send ship sub-model as well as the harbor data sub-model was discussed. The control sub-model and the sub-models for the port of origin and the routing shall be discussed in the sections that follow.

7. Houston Harbor View

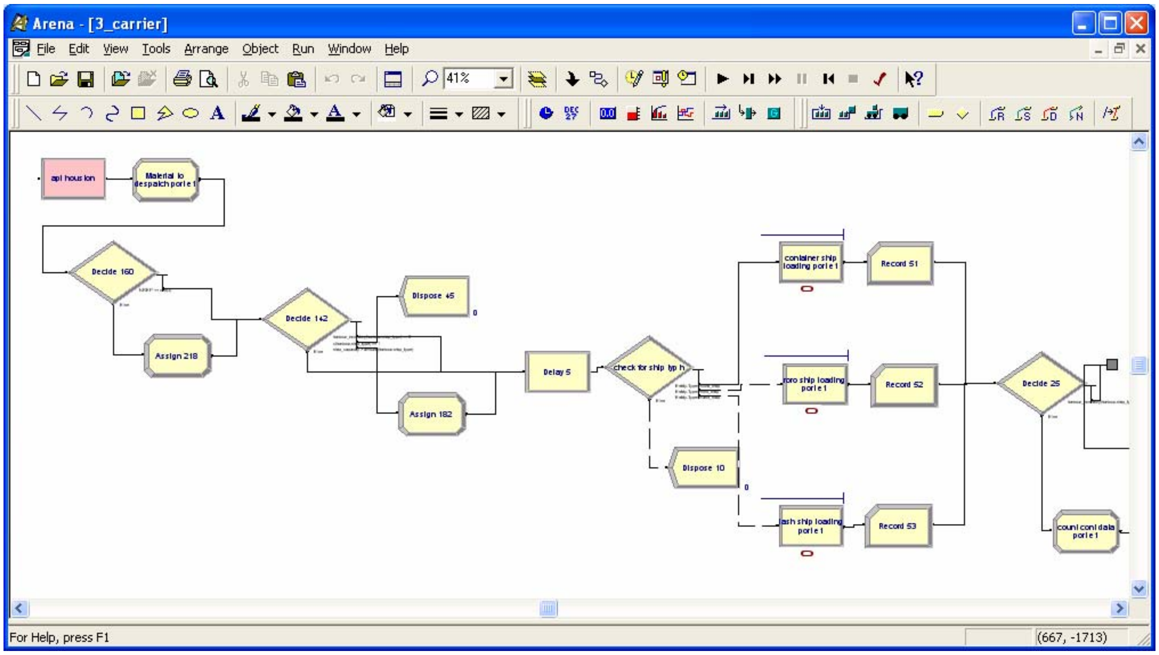

Figure 18. Part of the Houston harbor view

Here the ships load all the types of military material (container, RORO and lash). This is done at each harbor. The ships are also loaded with either military material or regular commercial cargo. The loading rate at each harbor depends on whether the harbor is modern or old. A modern harbor has twice the loading/unloading rate of an old harbor. The container loading rate variability is modeled as a uniform distribution with a minimum and maximum loading rate. This was done so as to ensure that harbors that are not well equipped in terms of facilities and infrastructure could be accommodated. The harbor at Singapore is a world-class harbor as Singapore serves as one of the hubs for South East Asia. It is envisaged that other harbors around the world may not behave similarly, even in CONUS. Once all the material is loaded, based on the VISA capacity i.e. 15% of each ships capacity, the ship is sent to the route module which routes the ship from the port of embarkation to the its port of debarkation. This is shown in the next view below.

It was mentioned earlier that the model does not look into the intermodal activities. However it was also stated that a "black box" approach was used. (See

Section A-2 for this discussion). In other words a delay time was built in every harbor for the "risk contingency" scenario. The delay time variability was modeled as a triangular distribution with ± 50% deviation from an envisaged most likely delay time. Also, the user may change the most likely delay time.

This submodel also checks whether the normal case scenario or "risk contingency" scenario is being simulated and adjusts the necessary parameters. In the normal case scenario, the ships capacity is fixed as a percentage of a given VISA stage. Under the "risk contingency" scenario the ships capacity is determined following a uniform distribution within the bounds of the VISA stage.

8. The Routing Module View

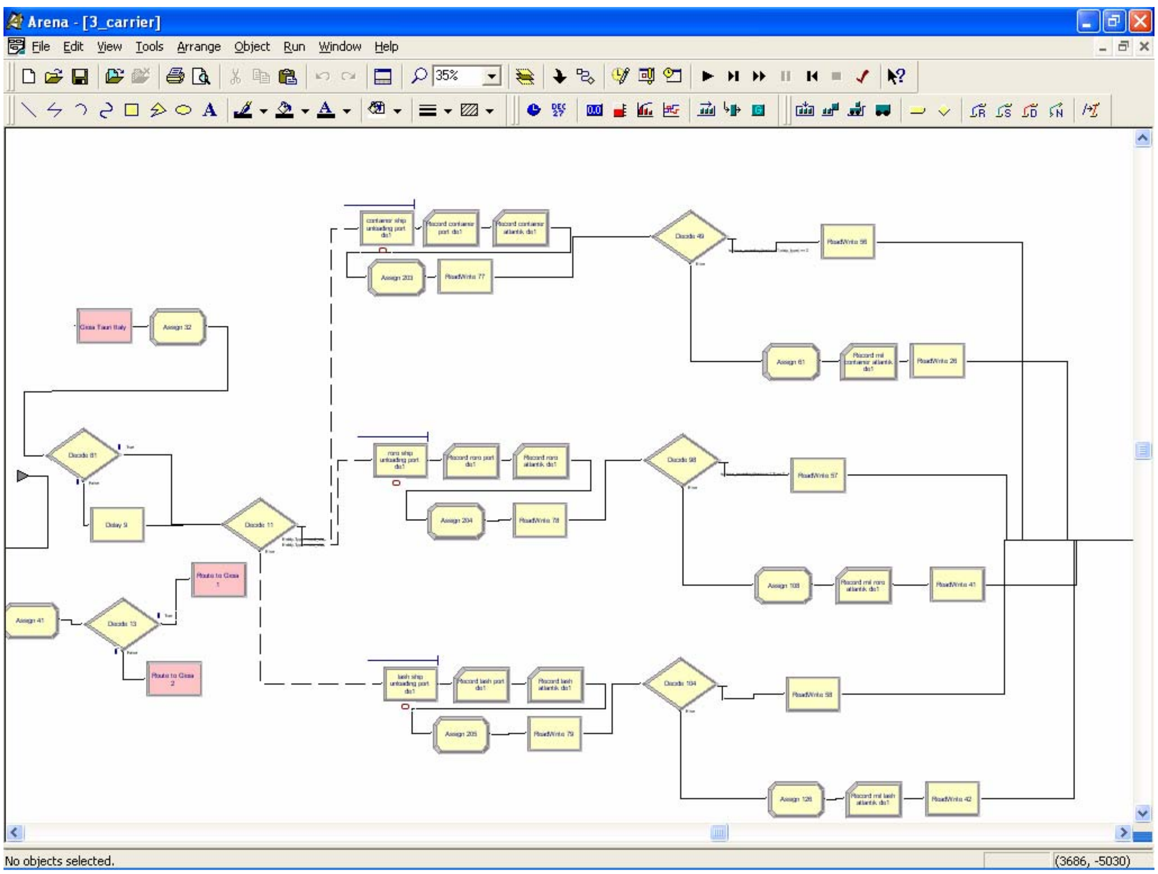

Figure 19. Part of the routing sub-model: Mediterranean Gulf Service from Houston (East CONUS) to Gioia (Italy) and back

At the harbor of debarkation the material is unloaded. There is some variability built in here, as there may be some reason that delays the unloading of the material. This may be a result of the harbor being blocked by environmentalist, or lack of unloading crew due to labor strikes or other risk factors that is discussed in Chapter III. As the material is unloaded it is counted and the results are written to an Excel file for the output analysis. See Appendix K for the output excel file and Chapter V for the output analysis. Finally the ship then returns the port of origin to start the process again and re-load the material if there is still mission time available.

This submodel also consolidates the individual harbors of debarkation based on whether the material is delivered to the Atlantic or the Pacific theatres

9. Routing Time Determination View

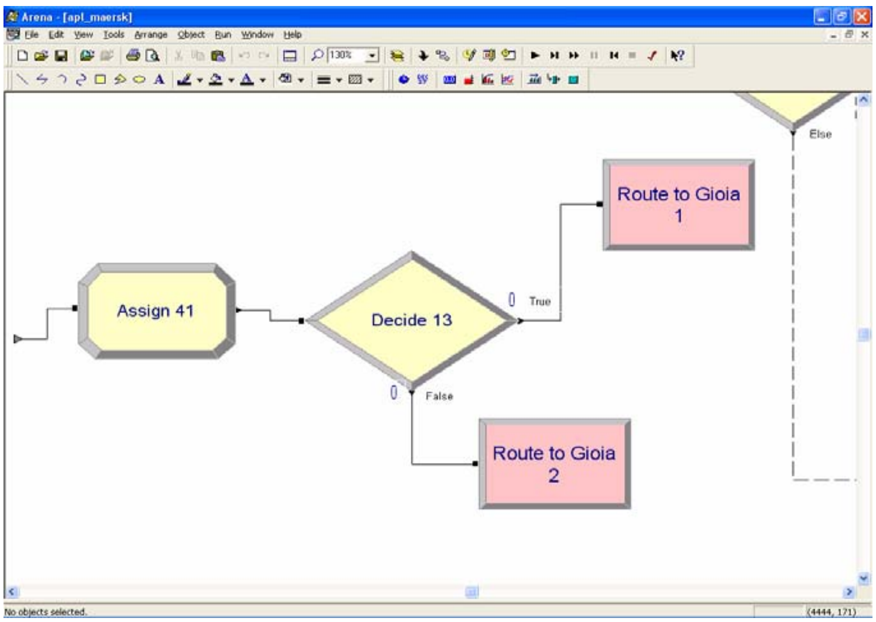

Figure 20. Part of sub-model showing the decision to choose the routing time

Here, in Figure 20, the model decides whether to use the route time that is provided by the carriers or if the route time is not provided a calculation is done to ensure to calculate the average route time based on the ship speed and the route distance.

There is very little variability built in the sailing time for the regular schedule. A triangular distribution of ± 12 hours from the scheduled route time or calculated route time is used in the model. The reason for this relative small variability is that the carriers have already "built in" risk for the schedule sailing times and the probability of a ship not arriving on time is very low. This is in keeping with good business practices. If a container ship, say is 4 days late, this would be extremely bad for future business for the carrier as commercial cargo is depending on the arrival of the goods for their sales. For the "risk contingency" scenario, the route time is ± 48 hrs from the scheduled or calculated route time. The reason for including such a wide variability was that it is envisaged that the VISA Program would be activated when there is some sort of disruption with the regular volunteer shipping. This would affect the route time amongst other things.

10. Output Data to File

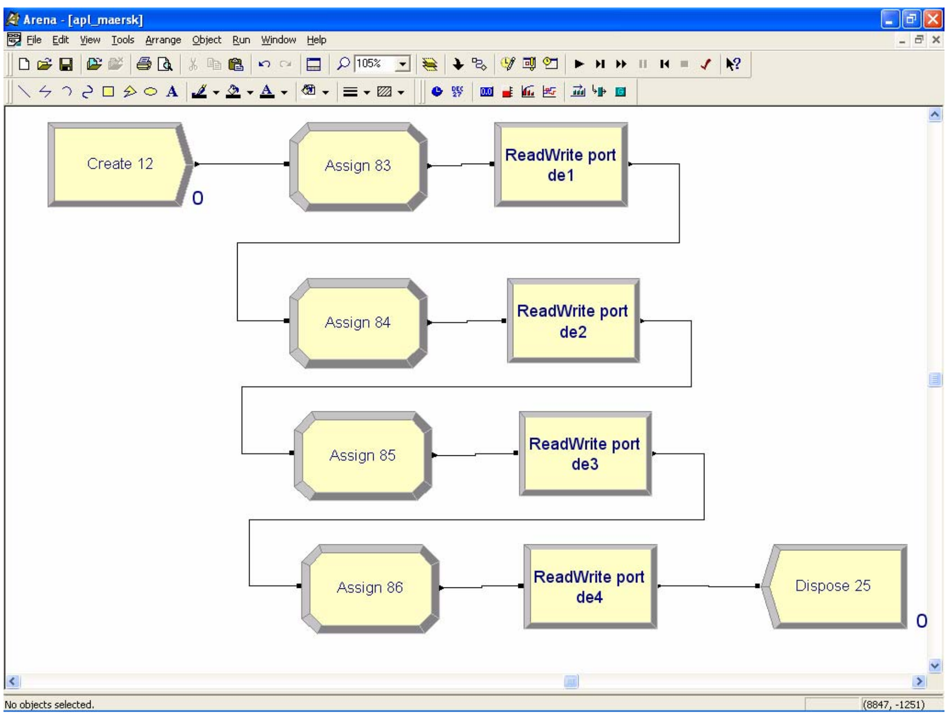

Figure 21. Output data sub-model

Here, in Figure 21, the model outputs all the data that is to be analyzed to an excel file. The explanation of the output is shown in Section A-17 of this chapter and the Excel output is shown in Appendix K. This submodel also writes the control replication length parameters to the excel file which is thereafter used by a visual basic program to analyze the data that will be discussed in the next chapter.

V. OUTPUT ANALYSIS

A. MINIMUM AND MAXIMUM OBSERVATIONS FOR TIME AND MATERIAL

The Arena simulation program generates its own output based on the system components embedded in the model. This output is useful for a manufacturing or service industry where the goals are *inter alia* process optimization, reducing wait/queue times and optimizing equipment utilization rates. Analyzing the components of the system (model) is not as useful to the military user or combatant, who is more focused on outcomes, and their contingencies.

It is for this reason that the necessary output variables were written to an excel file named output_data.xls. A very short extract of the data from this file is shown in Appendix M. The data from the aforementioned excel file was thereafter analyzed and put in a useful form. This was done by one of several means that included writing macros, writing visual basic program codes and running crystal ball software.

It is important for the combatant to have an overall view of the total material delivered at each theatre of war, as well as to have a timeline to work within. The sections that follow therefore discuss these two important parameters viz. time and material. The minimum and maximum observations for both time and material are discussed. In addition, each scenario was simulated (replicated) 100 different times. The minimum observation for time is equivalent to the earliest time a first ship offloads at the harbor of debarkation, across all 100 replications. The maximum observation for time is equivalent to the latest time a last ship offloads at the harbor of debarkation, across all 100 replications. These minimum and maximum observations for time are performed for each scenario.

The minimum observation for material is the least amount of material that is offloaded on a first delivery at the harbor of debarkation, across all 100 replications. That is, it is the smallest amount of material delivered by the first ship to reach the port of debarkation following invocation of VISA. The maximum observation for material is equivalent to the most amount of material that is offloaded at the harbor of debarkation. These minimum and maximum observations for material are performed for each scenario.

The maximum observations for time and material are related in the following way. The maximum material cannot be delivered later than the maximum time (it could have been delivered a little earlier). This means that within scenarios there may be instances where some ships arrive a little later but the total material delivered is still lower than the maximum observation for material. To summarize no ship arrives later at the harbor of debarkation or with more material than the observed maximum results.

Similarly the minimum observation for time and material are related in the following way. The minimum material cannot be delivered earlier than the minimum time (it could have been delivered a little later). This means that some of the earlier first ships that arrive may have delivered higher than the minimum material observed. To summarize no ship arrives earlier at the harbor of debarkation or with less material than the observed minimum results.

The material delivered to the two theatres will be known as the Pacific material and Atlantic material from now on. The Pacific material consists of all the material that is delivered via transpacific routes.

Table 2. Normal and Risk-Contingency Schedule: Pacific: Minimum and Maximum Observed Material and Time

Normal Schedule						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	18.87	609.00	0.00	0.00	0.00	0.00
Max	41.82	3820.00	0.00	0.00	0.00	0.00

Normal Schedule + 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	18.98	609.00	0.00	0.00	0.00	0.00
Max	43.50	4775.00	0.00	0.00	0.00	0.00

Normal Schedule - 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	18.87	609.00	0.00	0.00	0.00	0.00
Max	39.08	2865.00	0.00	0.00	0.00	0.00

Risk-Contingency Schedule						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	19.99	235.00	0.00	0.00	0.00	0.00
Max	44.99	3464.00	0.00	0.00	0.00	0.00

“Risk Contingency” + 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	19.59	232.00	0.00	0.00	0.00	0.00
Max	45.00	3862.00	0.00	0.00	0.00	0.00

“Risk Contingency” - 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	20.23	232.00	0.00	0.00	0.00	0.00
Max	44.97	2656.00	0.00	0.00	0.00	0.00

Table 2 above shows the maximum and minimum observation for material delivered and the maximum and minimum observation for time. In addition, the maximum observation for material is also equivalent to an objective that is rarely achieved. However it has some positive probability given the system constraints (simulation of the real case taking into account the variable amount of material loaded, the variable route time, the variable loading and unloading rates as well as any associated delays).

For illustration purposes only, graphs were plotted that drew a straight line through two points. The first point was the combination of minimum observations of material and time. The second point was the combination of maximum observations of material and time. These graphs are discussed in the figures below. In order to be clear that the output not only gives two points, a random pick of one actual simulation result is also plotted on the same set of axes. This is seen as the simulated schedule line.

1. Scheduled Pacific Material: Container

Figure 22 shows the container maximum observation for material delivered using the normal (regular) commercial schedule. The material includes the totals of all the material delivered to both Singapore and Kwangyang harbors. The detail view at each harbor is also available in the excel_output.xls file and hence it is not attached. It is generally more useful to look at the overall picture shown in Figure 22, but if there is a problem with the overall picture, e.g. if the material that was delivered was not meeting the requirements, then one can look deeper into the detail view.

It can be seen from Figure 22 that the minimum observed container of 609 TEUs arrived at the Pacific theatre. The minimum observed time was 18.87 days. This represents the shortest possible time to get material across for this scenario. The maximum observed time for delivery was 41.82 days. The figure also shows what would happen to the results if one additional ship were made available on the route.

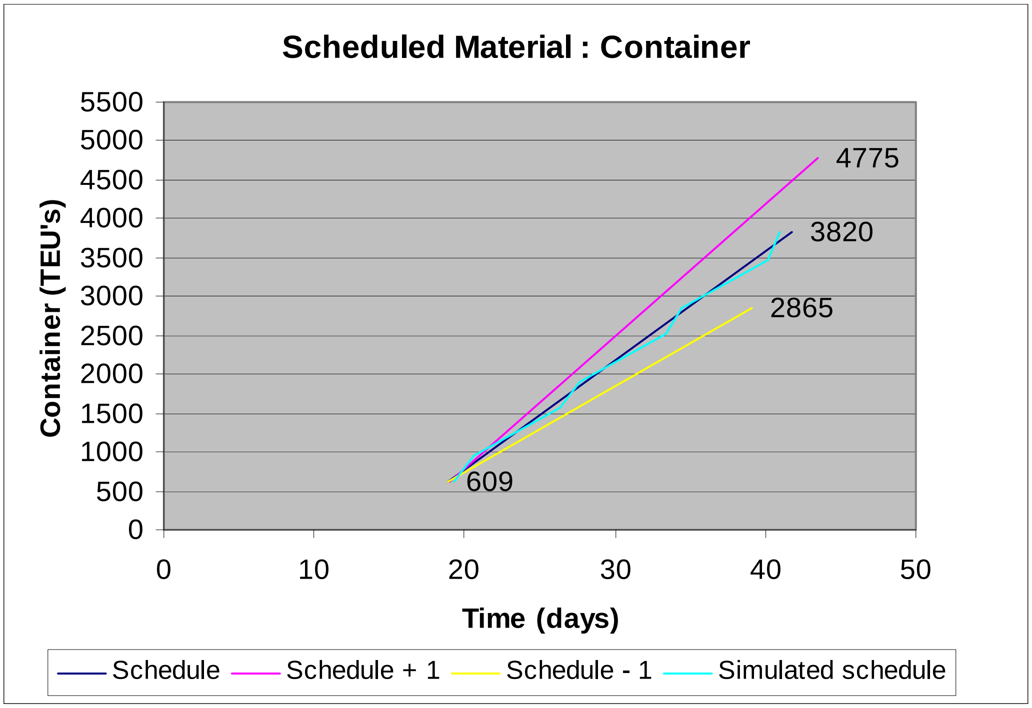

Figure 22. Scheduled container Pacific material

Figure 22 above shows that there is indeed a significant difference in the amount of material that is delivered for the different scenarios. The maximum observed material that is delivered under the regular (normal) schedule is 3820 TEUs. This occurs not later than the maximum observed time of 41.82 days. However, when one additional ship is made available the amount of maximum observed material delivered increases to 4775 TEUs, and is delivered no later than the maximum observed time of 43.50 days. This is a net benefit of 955 TEUs in maximum material. The maximum observed time is only 1.68 days more for the final delivery. This is still within the mission duration of 45 days. One can allocate a cost of the additional ship and similarly a cost benefit analysis can be performed to determine whether the additional ship is cost effective based on this marginal benefit for the observed maximum material. This cost benefit analysis falls outside the scope of this study and is an extension for future work. However, the project group also intends to develop the concept of a marginal risk reduction, which provides additional information beyond that of the marginal benefit for the observed maximum material. This marginal risk reduction might also be examined from a cost/benefit perspective, but that analysis is beyond the scope of this report.

2. Risk Contingency Pacific Material: Container

Figure 23 below shows the case when there is some disruption to the normal scheduled case. This is a result of a combination in variability in the material loaded i.e. not being a constant 15% but rather some random number between 10 and 15 % based on a uniform distribution. There is also additional variability that is built in at each harbor that includes a delay modeled as a triangular distribution. This is applies a "black box" approach to all problems associated with intermodal activities, slowdowns, landside congestion, terrorist activities, labor strikes and other activities. Finally, there is a higher risk of each ship not being on time. This is represented by the greater spread in the triangular distribution for the route time. This spread is under the normal schedule ±12 hours from the specified or calculated route time whereas for the "risk contingency" scenario it is ±48 hours from the route time.

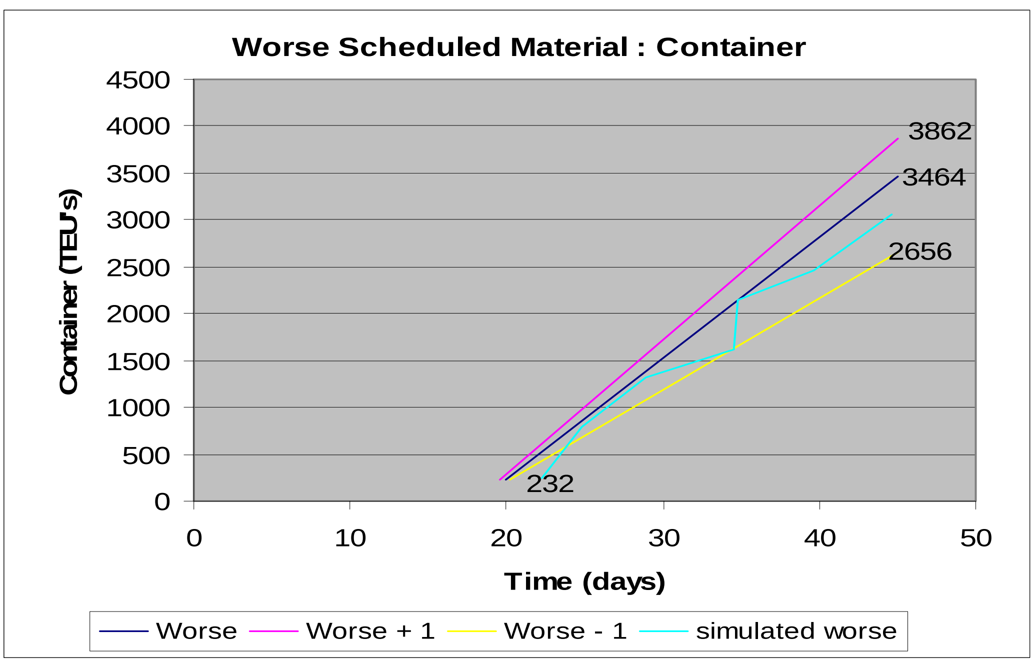

Figure 23. Risk Contingency Container: Pacific material

From Figure 23 above it can be seen that the "risk contingency" material results in overall less material being transported. The maximum observed material delivered was 3464 TEUs compared to maximum observed material of 3820 TEUs for the normal schedule scenario. Also the marginal benefit of adding an additional ship on the route is 398 TEUs of material, based on the maximum observations. It is most interesting to note that the last ship delivered its material at exactly 45 days, which is just in the nick on time. The marginal cost of losing a ship is 808 TEUs, again based on the maximum observations for material.

3. Scheduled Pacific Material: RORO

No RORO material was scheduled for the delivery to the Pacific theatre. This is because the RORO ship that is simulated only delivers to the Atlantic theatre, which will be discussed a little later.

4. Risk contingency Pacific Material: RORO

Since there is no scheduled material there is no "risk contingency" scenario.

Table 3. Normal and Risk contingency: Atlantic Minimum and Maximum Observed Material

Normal Schedule (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	12.97	498.00	14.39	25708.00	0.00	0.00
Max	36.60	3376.00	36.39	80000.00	0.00	0.00
Normal Schedule + 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	12.93	498.00	14.46	25708.00	0.00	0.00
Max	38.32	4220.00	32.43	80000.00	0.00	0.00
Normal Schedule - 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	12.92	498.00	14.47	25708.00	0.00	0.00
Max	33.85	2532.00	44.65	80000.00	0.00	0.00
"Risk Contingency" (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	14.42	235.00	16.20	17267.00	0.00	0.00
Max	44.70	3015.00	43.22	79999.00	0.00	0.00
"Risk Contingency" + 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	13.93	235.00	16.32	17228.00	0.00	0.00
Max	44.89	3832.00	38.61	79999.00	0.00	0.00
"Risk Contingency" - 1 (Minimum and Maximum material)						
	Time (Days)	**Cont**	**Time**	**RO-RO**	**Time**	**Lash**
Min	14.47	249.00	15.68	17322.00	0.00	0.00
Max	42.15	2317.00	40.57	75042.00	0.00	0.00

5. Scheduled Atlantic Material: Container

The Figure 24 below shows that the earliest the first ship arrives is 12.97 days (minimum observed time). This ship and delivers at least 498 TEUs of material (minimum observed material). The last ship (maximum observed time) arrives at 36.60 days and maximum observed material that is delivered under the regular schedule is 3376 TEUs, and when one ship is added the maximum observed material delivered increases to 4220 TEUs, and is now delivered within 38.32 days (maximum observed time). This is a marginal benefit of 844 TEUs based on maximum observed material with only 1.72 days more time for the final delivery (based on maximum observed time). This is well within the mission time of 45 days. In the case of the normal schedule there are 8.4 days remaining in the mission time after the last amount of material is delivered. However, this does not mean that there is nothing happening during this time, in fact there are ships that are still on their way. The ships still on sail can be seen from the harbor info view Figure 13. This view would give further insight into the material still on sail for the Bremerhaven and the Gioia harbors, which are the harbors under consideration for the Atlantic theatre.

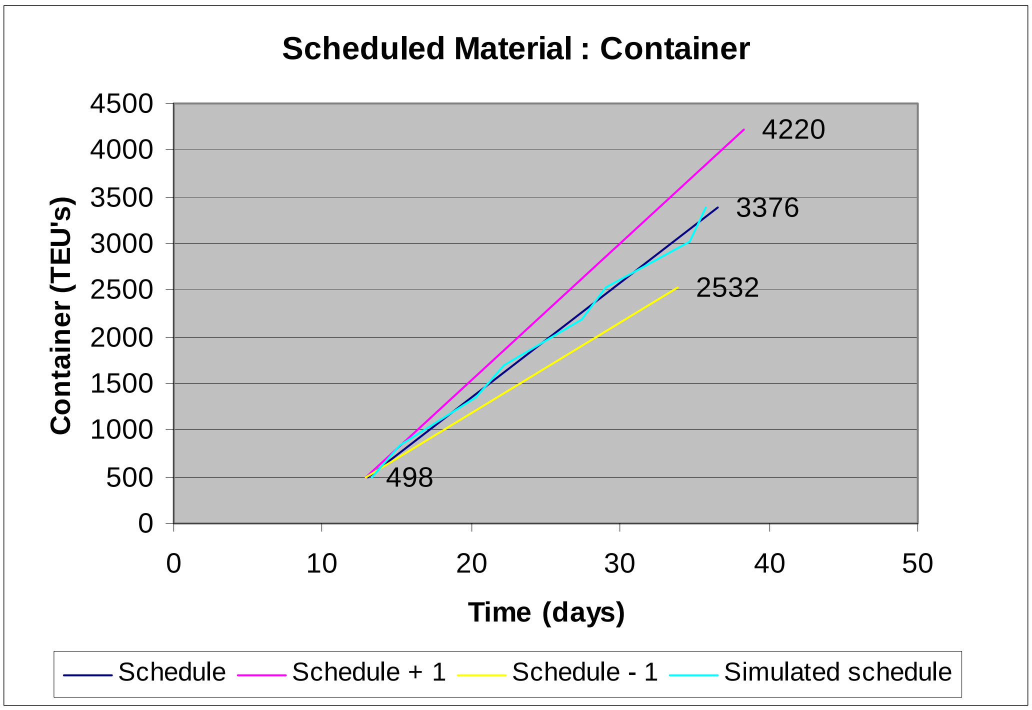

Figure 24. Scheduled Container Atlantic Material

6. Risk Contingency Atlantic Material: Container

It can be seen, from Figure 25 below, that the least amount of material that was delivered by the first ship was (235 TEUs) (minimum observed material). This occurs no earlier than 14.42 days (minimum observed time) for the risk contingency schedule scenario. The maximum observed material delivered for the risk contingency scenario is 3015 TEUs as compared to 3376 TEUs for the normal schedule scenario. Therefore, the marginal benefit of adding one more ship on the route is 817 TEUs. Furthermore, all the ships arrive just in time and with little time to spare (11 % of one whole day left (2.64 hrs) for the "risk contingency" + 1 ship scenario). On the other hand, the marginal cost of losing a ship is 302 TEUs.

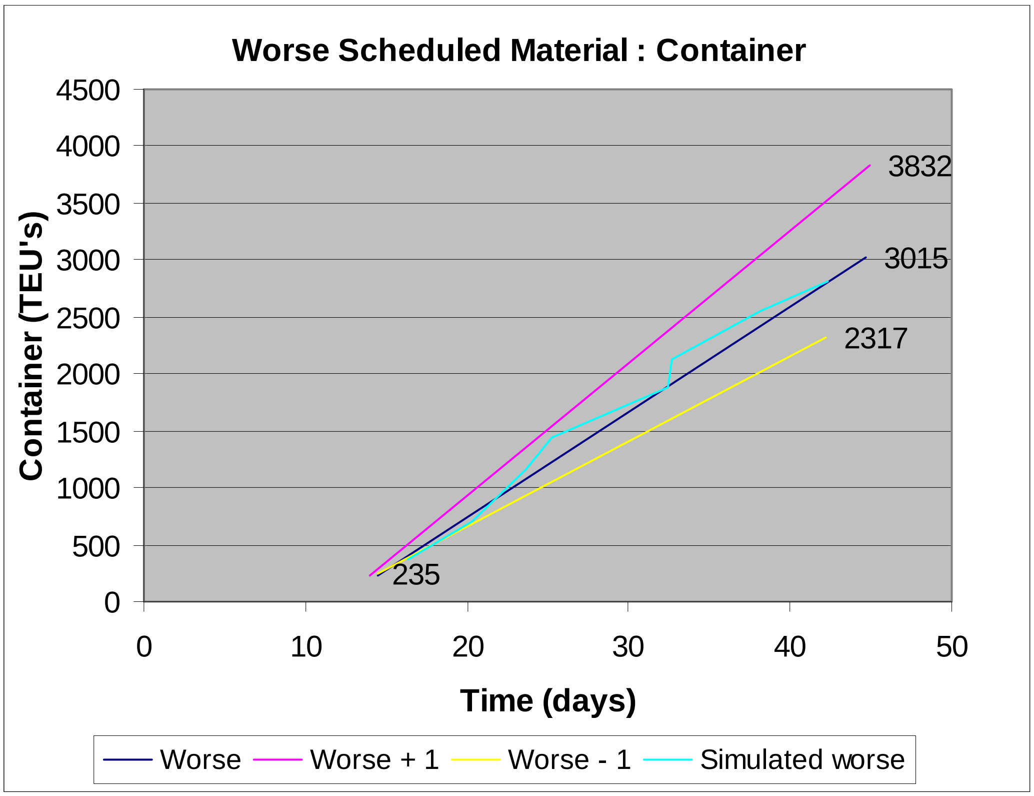

Figure 25. Risk Contingency Container Atlantic Material

7. Scheduled Atlantic Material: RORO

Figure 26 below shows the maximum observed scheduled material that can be delivered using RORO ships. Here there is no difference between the scenarios of the regular number of ships and one more or one less ship in terms of maximum possible material delivered. The reason for the not so significant benefit for one more ship is that the current number of ships is extremely low; in fact there is only 1 ship that set sails per week for the regular schedule. Adding another ship effectively decreases the observed maximum time for the delivery from 36.39 days to 32.43 days a net benefit of 3.96 days.

There is also a “hidden” benefit that cannot be seen here but may be seen from the harbor info view Figure 13. However this was unfortunately not captured to report here but logic states that there is material on its way that is a very short while away from delivery. Losing one ship increases the maximum observed time for delivery of 80000 sq ft of material to 44.65 days. The final delivery takes 8.26days longer than the normal schedule and just about makes it for delivery before the mission time expires.

The random pick of the simulated run is mostly outside the bounds of the lines plotted. This is true, for all points except for the start point from where the simulated graph is plotted to the end point, which are always within the maximum and minimum observations.

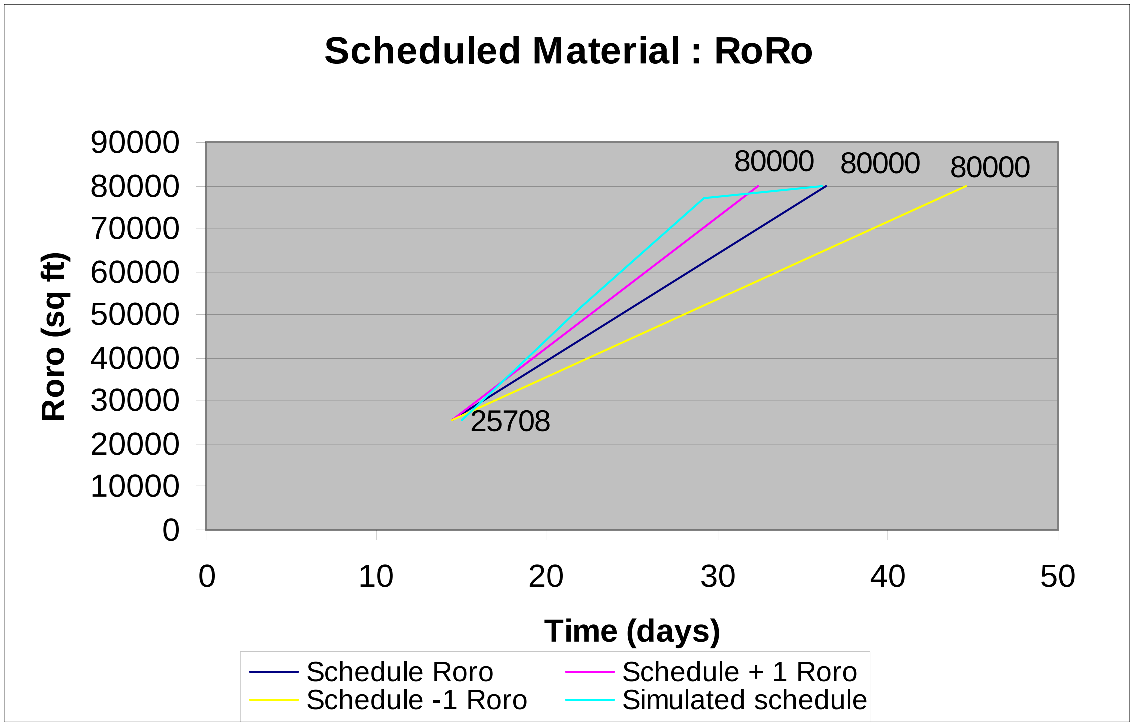

Figure 26. Scheduled Atlantic Material: RORO

8. Risk Contingency Atlantic Material: RORO

The Figure 27 below shows that the marginal benefit is not very significant for adding one more ship in the “risk contingency” material case. There is no benefit visible in material delivered but there is a benefit of 5.1 days. The marginal cost of losing one ship from the route is 4957 sq ft. less material delivered.

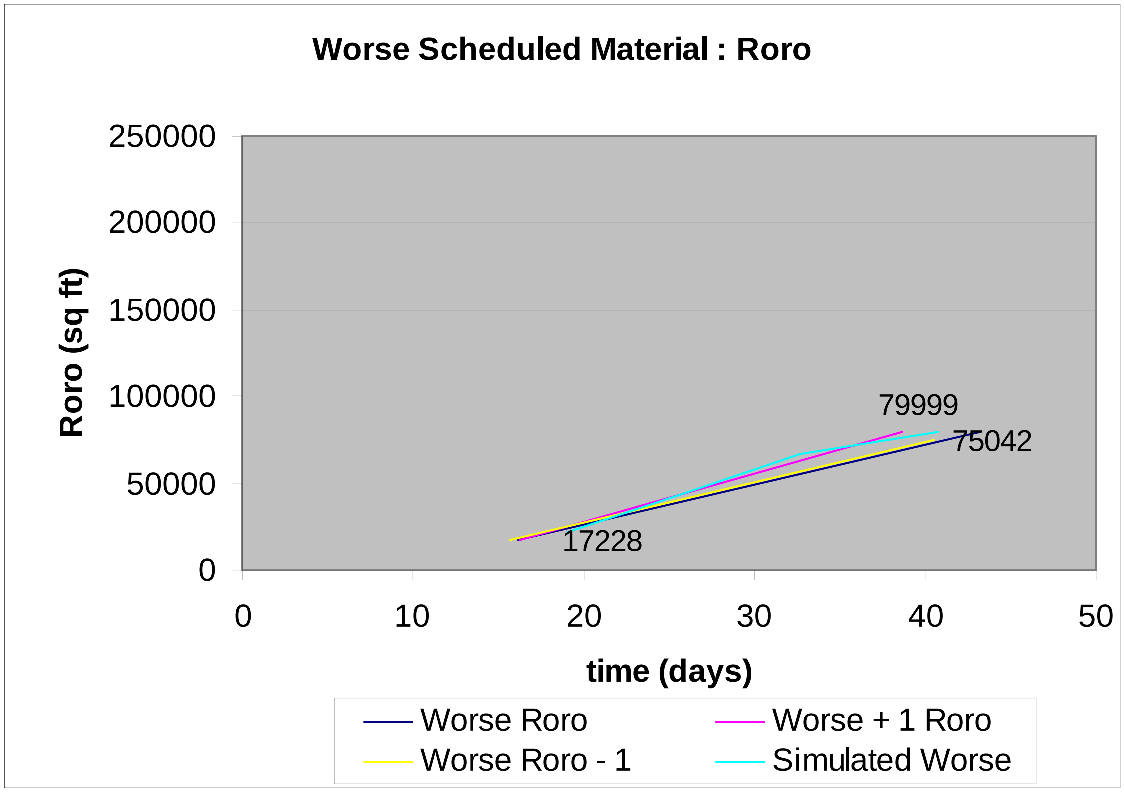

Figure 27. Risk contingency Atlantic Material: RORO

B. STATISTICAL ANALYSIS OF OUTPUT

This statistical analysis looks at the "risk contingency" scenarios already discussed in the preceding section. To reiterate the previous section looks at maximum and minimum observed material and observed time. Here there is no time parameter that is investigated, only the material is investigated. Furthermore, instead of the maximum and minimum observed material, the 5th percentile and 95th percentile of total material delivered were also studied. Furthermore, the same raw data that was used in Section A (not shown) is used in this analysis as well.

In order for the output to be utilized for contingency planning by a pragmatic combatant whose major focus is on risk, it is very important to provide information that is statistically sound.

The points of interest for the combatant were chosen as the 5th and 95th percentile. This means that 90% of the time the total material delivered fell in the range between the 5th and 95th percentile. Three methods that may be used to determine the 5th and 95th percentile are elucidated below.

1. Method I: Direct from Sample Data

The sample output data that consists of the total material delivered for all 100 replications were arranged in ascending order. The 5th and 95th data point for each scenario was thereafter selected and these observed data points represent the 5th and 95th percentiles. This method however does not tell us much about the confidence of the estimates. The results of this observed 5th and 95th percentile are reported in Table 4 below.

2. Method II: Fit an Analytical Distribution to the Data

If it is assumed that there is an underlying analytical distribution that fits the data then one can read off the 5th and 95th percentile from the analytical distribution. This is shown below for the risk contingency Atlantic container total material.

To facilitate this analysis the Crystal Ball® software which is an “add-in” to Excel® was used to fit an analytical distribution to the sample output data (total material delivered). Figure 28 shows that the 5th and 95th percentiles are 2584 and 2972 TEUs respectively. This is based on the Weibull distribution that was the best fit to the sample data according to the Anderson-Darling goodness of fit test reported by Crystal Ball. The goodness of fit test statistic revealed that the analytical distribution did not fit the data well; however these results are reported below to show the concept only.

Atlantic Material
Assumption: Risk Contingency Container

Weibull distribution with parameters:

5% - tile	2584.43
50% - tile	2788.98
95% - tile	2972.24

Selected range is from 2341.17 to +Infinity

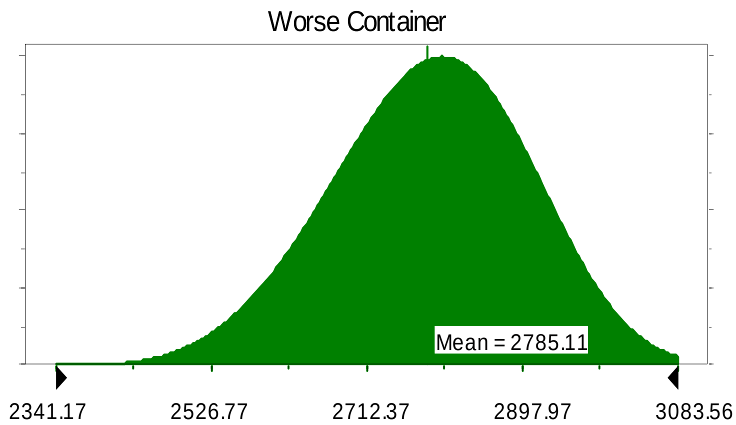

Figure 28. Risk contingency Atlantic Container Material: Weibull Distribution with 5, 50 and 90 percentile

3. Method III: The Bootstrap Method

The Bootstrap method is a more systematic way of determining the 5th and 95th percentile. Bootstrapping is a way to estimate parameters from a sample. This is a more involved process and the full description of the method falls outside the scope of the study. The Bootstrap however allows one to get a confidence interval around the estimate. Please see Efron (Ref. 99) for an explanation of how the confidence intervals of a Bootstrap may be calculated. The Bootstrap analysis for the simulation sample output for each scenario is reported in Table 4 below.

Table 4. Observed Bootstrap Estimate and Confidence Interval for 5^{th} and 95^{th} Percentile

	5th Percentile				95th Percentile			
	Observed	Bootstrap estimate	90% Confidence Interval for Estimate		Observed	bootstrap estimate	90% Confidence Interval for Estimate	
Atlantic	2565	2569	2548	2580	2979	2977	2961	2979
Plus One	3288	3292	3287	3301	3706	3702	3674	3748
Minus One	1978	1984	1968	2008	2278	2271	2262	2280
Pacific	2206	2198	2138	2215	3319	3298	3194	3332
Plus One	2945	2946	2921	2955	3728	3728	3706	3770
Minus One	1876	1905	1867	1928	2599	2582	2542	2601

The 5th and 95th percentiles for the best distribution fit using the Bootstrap method are reported above in Table 4. This means that, across simulation runs, 90% of the time the estimated total delivery of material would fall somewhere in between these values. This gives the combatant more information to work with. In addition, the 5th percentile was chosen because it was assumed that the combatant was prepared to accept a 5% level of risk. There is also a 90% confidence interval that is built around both the 5th and 95th percentile so as not to report just a point estimate like the previous two methods. This confidence interval is especially important for contingencies were the level of acceptable risk has to be quantified as best as possible.

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VI. CONCLUSIONS

A. RESEARCH QUESTIONS ANALYSIS

At the time of the simulation analysis for this project, 126 vessels comprised the VISA program. In this regard, the initial undertaking was to identify what vessel routes were available for VISA carriers. In the end, approximately 22 percent of the VISA capacity that was useful to the simulation was identified. Moreover, there was no attempt to encode every ship that was identified as belonging to the VISA program. Only container and RO/RO ships participating in the VISA program were considered. In other words, the type of vessels used in the model was restricted to U.S.-flag container and RO/RO ships on a given commercial route. Additionally, the estimates derived for the output analysis in Chapter V did not include all VISA ships, but are listed in Appendix D and could be incorporated in future extension work. This would be in keeping with the original scope of the project, which was to provide a tool that demonstrated proof of concept. To this end, the brief analysis that follows is provided as answers to the research questions outlined in the introductory paragraph:

1. What is the Material that Is Possible to Be Transported During Stage 1 Of VISA Activation Using the Normal Commercial Trade Routes and Schedules?

This question could not be answered because of data constraints. Specifically, the unclassified nature of the project prevented the inclusion of current, relevant and accurate data contained in the various Mobility Requirements Study/Bottom-Up Review documents.

2. What is the Marginal Benefit of Adding One More Ship to the Existing the Commercial Trade Route and Similarly What Is the Marginal Cost of Losing One Ship from the Trade Route?

Marginal benefit within the context of VISA/sealift asks what the value of an additional ship is. In general terms, the amount of material that can be delivered under given risk conditions would decrease with the addition of one ship. This would be analogous to a probability distribution where the addition of a ship represented a shift in the curve that indicated the following:

- All things being equal (*ceteris paribus)*; in a given time frame more material can be delivered on average, and any given amount of material can be delivered with less risk.
- Given the same level of risk, more materiel can be delivered in the same time frame.
- Given the same level of risk, the same materiel can be delivered in a shorter time frame.

3. What Amount of Material Can Be Transported, Given a Specific Vessel Capacity and Assuming a "Risk Contingency" Scenario in a Given Timeframe?

Any "risk contingency" scenario will depend on the level of variability caused by simulated risk events. In other words, as the likelihood of risk events capable of impacting shipping increases; the variability also increases. The output analysis produced in this simulation project showed that the addition of risk as seen in the 5^{th} percentile and 95^{th} percentile analysis of Chapter V decreased the amount of materiel that could be transported.

As already noted, the classified nature of the data in the various Mobility Requirements Study documents prevented an accurate analysis of actual conditions. Hence the generalization of these specific numbers to actual two-theater scenarios is not possible. However, there is no reason why the relative (percentage) reduction in average material delivered from the base case to the risk-contingency case should not represent a plausible estimate of the average (percentage) mission degradation from the risk factors modeled.

4. What Are the Risks Involved after Activation of the VISA Program?

In addressing the risk events that may occur after VISA is activated, scenarios such as unforeseen labor disputes; ship mechanical failures; shortfalls in U.S. mariner numbers and experience gaps can all impact the execution of DOD sealift requirements. Chapter three outlined a more detailed discussion of risk-related events and scenarios that are relevant to VISA. The primary findings relevant to risk are discussed in more detail in Section B of this chapter.

5. How Will These Risks Impact the DOD Sealift Capability i.e. the Time it Takes to Deliver the Materiel?

Although the statistical analysis of the time is not performed in this study, the final material that is delivered during a chosen time frame is analyzed. Considering that the occurrence of risk events would effectively lengthen unit materiel and equipment transportation times; one can conclude that DOD sealift capability would be degraded under these circumstances.

B. RISK ASSESSMENT IN VISA

1. Risk

Risk was defined as any uncertainty that affects systems in an unknown manner whereby its consequences are also unknown. Furthermore, risk is seen as the probability of something bad happening. Therefore, to deal with the potential risk, companies began employing risk management and risk assessment methods to help mitigate the risk. Insurance companies were the first to use risk management and soon other areas of business followed suit. In the insurance industry, risk management was used to offer viable economic reasons for firm managers to encourage them to engage themselves with both expected profit and distribution of firm returns.

2. Risk Management in Logistics and Mobility

The purpose of risk management in logistics and mobility is to mitigate the risks associated with the transportation of military cargo. The risk associated with the transportation of military cargo is the probability of the material not arriving on time. The consequence of this risk would be a loss of competitive advantage on the battlefield for the U.S. and hence loss of life. This is a risk the U.S. is not willing to take. Therefore, to mitigate this risk, USTRANSCOM aims to decrease the probability that the material will not reach its destination timely. However, to mitigate this risk, risk assessment was conducted to identify and then analyze the risk.

3. Risk Assessment in VISA

This study concentrated on the risks associated with the VISA program, in particular after activation of the programs. For the purpose of this study, the risk assessment in VISA process was simplified into three stages viz. loading at CONUS, sailing of the ship, and then unloading at the transfer port. These stages were then classified as risk events. Thereafter, the authors brainstormed various risks associated with the risk events. The identified risk were then analyzed and given risk ratings based on their probability and consequences. The identified risks were given probability distributions and thereafter used as input for the Arena simulation model. However, not all risk elements were included in the model assumptions. For example, balking was discussed in Chapter II, but was excluded from the simulation analysis. Despite the foregoing comments on risk, it is worth mentioning that the probability that VISA will be activated is remote.

Risk was defined and discussed in detail in Chapter III. For example, harbor blockades, arrival delays, in-country riots, labor disputes and slowdowns, port congestion, terrorist activities, ship mechanical failure and intermodal-related problems are probable risk-oriented events that could occur and reduce DOD's overall sealift capability. However, the likelihood of experiencing a combination of these events is remote or extremely low. This conclusion is supported by "risk contingency" considerations – delay time and failure rates that were incorporated into the simulation model inputs. Specifically, the variable nature of delay time, failure rates, and ship capacity under "risk contingency" conditions are representative of variability. These input events were modeled in the project simulation to simulate risk and create a distribution. However, because the "risk contingency" scenario described in the foregoing paragraph is the likelihood of occurrence of these inputs; then it can be said that this probability would be very remote. It therefore, can be said that a risk contingency scenario would also be a remote probability. In this regard, the conclusion that can be reached is that the likelihood of a real-world scenario that is close to a simulated risk contingency condition is very small. This analogous to the point made previously, where the actual risk in regard to transportation capacity is small and the statement that an activation of the VISA program is marginal.

C. EXTENSIONS

In conclusion, several additional points bear mentioning. First, considering the level of planning and coordination that takes place among representatives from DOD (USTRANSCOM), MARAD and the commercial carrier industry; what is the likelihood that VISA would be activated during a two major theater war scenario? Based on the research conducted for this project and the results of the simulation model, the probability of activation in the event of a Desert Shield/Desert Storm level contingency seems remote. This assertion can be made because VISA activation in Stage I would coincide with the strongest elements of DOD's organic mobility assets and capability. In other words, during the initial stage of a contingency the lift assets that are likely to be employed to transport troops, Army brigade sets and high-demand military equipment to the operational theater will come from organic airlift, prepositioned LMSR vessels and host-nation prepositioned stocks as applicable. In the event that organic military capacity was insufficient to meet the needs of war-fighters, the response by military planners and MSC logisticians would be to use ships of the FSS variety along with mobilization of the RRF. The next logical step would be the solicitation and charter of U.S.-flag and foreign flag volunteers to fill any DOD capacity shortfall. It is only after these sealift assets are totally exhausted that VISA can conceivably be activated. In fact, there is an intermediate step on the path towards activation of VISA; the NDRF that are under the custody of MARAD and have an activation window that ranges between 20 and 120 days. Second, the communication and coordination achieved through JPAG decision forums provides timely and relevant information to all stakeholders involved with the VISA process. This serves to reduce the inherent risks that may trigger VISA activation. Again, the likelihood of VISA activation is low considering the availability or adequacy of commercial U.S.-flag, foreign flag and effectively U.S.-controlled (EUSC) vessels. A 1997 Congressional Budget Office (CBO) study reached a similar conclusion by asserting that adequate capacity was available in the commercial market to deliver sustainment materiel. (Ref. 100)

In this regard, the key benefits that VISA offers DOD may not be access to capacity; but the advantages that are achieved through joint planning; the access to the modern and global intermodal infrastructure of commercial carriers; the risk reduction benefits or assuredness that is achieved by retaining a U.S.-flag merchant marine capability; retaining of the U.S. citizen mariner pool with the experience and relevant skill sets to function in a contingency environment.

D. RECOMMENDATIONS FOR FUTURE RESEARCH

The value of the simulation modeling undertaken in this project could have been maximized with the inclusion of cost benefit analysis to prove the usefulness of the VISA program. However, this option was beyond the scope of this project because most of the data required to make definitive conclusions was classified. To this end, future thesis research to assess the value of VISA should be undertaken in a classified realm. For example, data related to the number of Army divisions and the capacity they represent can be extracted from the current Mobility Requirements Study Bottom-Up Review to predict the relative success of the DOD sealift process.

APPENDIX A: HARBOR DATA TEXT FILE

```
$This file contains the routes / harbor data
$ Number of total Ports (harbors) embarkation and debarkation
$
        10
$
$ Amount to be moved via container ship, RORO, and LASH and max capacity from
each port if available and of interest
$ If no data for military material (cont / roro / lash) is available type "0"!!
$
$       Ports of embarkation and debarkation / routes
$
$ Cont / cont per hr / RORO (sqft) / roro per hr / LASH (# of barges) / barg per hr /
harbor index / distance  / days / delay_time / route
$
$       Route APL MGS (Route 1)
 0      240     0       4000    0       2       1       4500    15      48      1
        $Houston / USA                  port e1
 0      200     0       4000    0       2       2       4500    18      96      1       $Gioia
Tauri / Italy   port de1
$
$       Route APL PS1 (Route 2)
 0      240     0       3000    0       3       3       6000    19      48      2       $Los
Angeles / USA           port e2
 0      500     0       3000    0       4       4       5000    19      96      2
        $Singapure              port de2
$
$       Route Maersk TA 2 (Route 3)
 0      240     0       2500    0       2       5       0       13      48      1
        $Norfolk /USA                   port e3
 0      300     0       3000    0       1       6       0       22      72      1
        $Bremerhaven / GER port de3
$
$       Route Maersk TP2 (Route 4)
 0      240     0       2500    0       2       7       0       20      48      2
        $Oakland / USA          port e4
 0      300     0       2500    0       2       8       0       14      96      2
        $Kwangyang / Korea  port de4
$
$       Route American RoRo Carriers (route 5)
  0     240     0       3000    0       2       9       0       14      48      1
        $Charleston / USA port e5
```

```
 0      0      0      3000   0      2      10     0      14     72     1
        $Bremerhaven
$
$ number of general data to be read
$       general data / variables:
$
$       visa / ship plus per month / ship minus per month / delay time plus [%]
$
        15          1                1               50
$
$
```

$ Visa Stage in % (e.g. 15 % = 15)
$
$ ship plus (internal days will be subtracted from normal schedule time) => more ships on route per time frame means shorter schedule time (every 5 days instead 7 days a ship sail) input as ships per month!!
$
$ ship minus (internal days will be added to normal schedule time) => more ship on route per time frame; input as ships per month
$
$ distance in nautical miles means distance to next harbor on route (normal route is a circle with two harbors)
$ THIS IS NOT THE real world of carrier practice but a approximation we used.
$
$ days means sailing-days to the next harbor on that route (normally to harbor of debarkation and back to harbor of embarkation.
$
$ delay_time means possible delay in front of harbor entry due to different reasons (no loading / unloading facility available or closed harbor and others); input in hours
$
$ harbor index is given by Arena intern in sequence of reading the harbor data!!
$
$ delay time plus [input in %] is used to set up the max point for the delay module in front of each harbor; equal for each harbor; however, because delay time * delay time plus % = max delay for TRIA distribution each harbor is unique
$
$ route info for counting Atlantic and pacific total route material 1=Atlantic / 2=pacific
$ END

APPENDIX B: CONTAINER SHIP DATA TEXT FILE

```
$  input file for container ship data
$
$ number of container ships
$
        4
$
$ container ship data
$
$ ship type / container ship ID number  /  container ship speed  /  container ship capacity /
Route / ship per month
$
 1      1       20.7    2306    1       4.28    $ avg ship APL MGS
 1      2       24.2    4060    2       4.28    $ avg ship APL PS1
$
$
$
 1      4       20      3320    3       4.28    $ avg ship Maersk TA2
 1      3       20.7    2306    4       4.28    $ avg ship Maersk TP2
$
$
$ route means the specific route on which the ship is used through the carrier
$
$ 1 = APL Mediterranean Gulf Service (MGS)
$ 2 = APL Pacific South 1 Service (PS1)
$ 3 = Maersk Transatlantic (TA2)
$ 4 = Maersk Transpacific II (TP2)
$
$ ships per month is intern handled as schedule time is: ship sails every "x" days; e.g.
every 7 days one ship
$       means 4.28 ships per month for input through data file!!!! important
$
$       end
```

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APPENDIX C: RO-RO SHIP DATA TEXT FILE

```
$  input file for roro ship data
$  number of roro ships
$
           1
$
$  roro ships data (capacity in sqft)
$
$ ship type / roro ship id  /  roro ship speed  /  roro ship capacity  /  route / ships per month
$
$ 2      1       19      30000        1       2
$ 2      2       19      40000        2       2
$ 2      3       19      160000       3       4.28
$ 2      4       19      30000        4       4.28
  2      5       18      171385       5       4.28
$
$ route means the specific route on which the ship is used through the carrier
$
$ 1 = APL Atlantic MGS - port of origin is Houston
$ 2 = APL pacific PS1 - port of origin is Los Angeles
$ 3 = Maersk Transatlantic (TA2) and American RoRo Carrier
$ 4 = Maersk Transpacific II (TP2)
$ 5 = American RoRo Carrier Inc Atlantic route
$
$ ships per month is intern handled as schedule time is: ship sails every "x" days; e.g. every 7 days one ship
$         means 4.28 ships per month for input through data file!!!! important
$
$
$
$         end
```

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APPENDIX D: THE VISA SHIP DATA

	VOLUNTARY INTERMODAL SEALIFT AGREEMENT DRY CARGO VESSELS																	
	WITH BASIC VESSEL CHARACTERISTICS/1																	
					BY TYPE AND NAME													
IMO	SHIP NAME	PGMS			VSSL	NISC	SQ FT	SPD (kts)	LOA (m)	BEAM (m)	DRFT (m)	DWT	FUEL	FUEL	TEUS	TEUS	BALE	MEAS
NUMBER		/2			TYPE								CAP	CONS		MT/3		TONS
		V	M	J														
		S	S	A														
		A	P															
********	********************************	*******			**********	*******	*******	*****	******	******	******	********	******	******	******	*********	********	*********
7515339	ADVANTAGE	Y			BB/5	M44905		17.5	170	26.4	11.5	27740	1885	43	726	16582		30603
6916873	CLEVELAND	Y			BB	M31055		21	184.4	24.99	10.67	22210	1680	85	332	7583		26195
9010498	COASTAL NAVIGATOR/10	Y		Y	BB	N53755		12	59	12.6	5.5	1406	759	8				35000
5408491	COASTAL TRADER/10	Y		Y	BB	M32482		10.5	78.34	13.42	4.04	2235	398	6.5				56000
7529914	NOBLE STAR	Y			BB	M47479		17.5	171.41	25.4	10.55	27135	2900	43	660	15074		27135
6909911	WILSON	Y			BB	M30603		21	184.4	24.99	10.67	22210	1680	85	332	7583		26195
	TOTAL BREAKBULK VESSELS				6													
7821154	CYNTHIA FAGAN/6	Y			BULK	M56876	43000	16.75	186.49	28.35	10.75	36414	2802	37				40095
7225855	JUDY LITRICO	Y		Y	BULK	M37952	34000	14	158.38	23.47	9.75	30463	2737	33				
9278753	LIBERTY EAGLE	Y			BULK	M95546	30000	15.3	189.99	32.26	12.25	50600	2467	38				
9228136	LIBERTY GLORY	Y			BULK	N94733	30000	15.3	189.99	32.26	11.92	50601	2467	38				
9228148	LIBERTY GRACE	Y			BULK	N94734	30000	15.3	189.99	32.26	11.92	50601	2467	38				
8300901	LIBERTY SEA	Y			BULK	M62383	57000	15	225	32.2	13.12	63739	2939	33				
8500549	LIBERTY SPIRIT	Y			BULK	M01139	57000	15.8	225.03	32.31	13.11	64152	2939	45				
8510647	LIBERTY STAR	Y			BULK	M02888	57000	17	225	32.21	13.1	64152	1570	34				
8500551	LIBERTY SUN	Y			BULK	M02893	57000	17	225	32.26	13.1	64059	2120	34				
8311089	LIBERTY WAVE	Y			BULK	M62779	57000	15	225	32.2	13.12	63463	2507	34				
7929308	SHEILA MCDEVITT	Y		Y	BULK	M56601	43000	15	187.74	28.4	10.76	37244	2887	36				
	TOTAL BULK CARRIERS				11													
9074389	APL CHINA	Y	Y		CNTNR	N61937		24.5	276.3	40	14	66630	6688	183	3900	89076		
9074535	APL KOREA	Y	Y		CNTNR	N61950		24.5	276.3	40	14	66630	6688	183	3900	89076		
9077276	APL PHILIPPINES	Y	Y		CNTNR	N62416		24.5	276.3	40	14	66630	6688	183	3900	89076		
9074547	APL SINGAPORE	Y	Y		CNTNR	N61951		24.5	276.3	40	14	66630	6688	183	3900	89076		

9077123	APL THAILAND	Y	Y		CNTNR	N62401		24.5	276.3	40	14	66630	6688	183	3900	89076		
7635933	ARGONAUT	Y			CNTNR	M52638		20	185.92	23.77	8.23	16205	2299	250	1086	24804		
8912857	ASCENSION/10	Y			CNTNR	N51974		12.5	97.8	17.3	5.62	4124	90	12	270	6167		
8200711	CHESAPEAKE BAY	Y	Y		CNTNR	M00010		18	206	32.21	11.5	36004	4082	163	2409	55022		
7114185	CHIEF GADAO	Y		Y	CNTNR	M35121		21.3	240.09	30.48	10.67	37346	9272	138	1981	45246		
7119678	COASTAL VENTURE/10	Y		Y	CNTNR	M35754		13	71.81	12.91	3.499	1390	166	5.5	82	1873		
8200709	DELAWARE BAY	Y	Y		CNTNR	M64888		18	206	32.21	11.5	36004	4082	163	2409	55022		
9007817	ENDEAVOR	Y	Y		CNTNR	N53506		18	181.44	31.4	10.3	35012	2284	53	1834	41889		
9007829	ENDURANCE	Y	Y		CNTNR	N53507		18	181.4	31.4	10.3	35012	2629	53	1834	41889		
9007831	ENTERPRISE	Y	Y		CNTNR	N53508		18	181.4	31.4	10.3	35012	2629	53	1834	41889		
7125316	EWA	Y		Y	CNTNR	M35880		21	249.92	30.48	10.67	38656	9272	138	2015	46023		
7710733	GEYSIR/10	Y			CNTNR	M56200		13.75	90.07	13.72	4.53	2786	241	9	141	3220		
8419142	HORIZON ANCHORAGE	Y		Y	CNTNR	M04986		20	216.4	23.77	9.14	20668	2012	69	1582	36133		
6812211	HORIZON CHALLENGER	Y		Y	CNTNR	M29114		21	213.65	27.43	9.75	22493	3415	137	1364	31154		
7224306	HORIZON CONSUMER	Y		Y	CNTNR	M37721		22	219.45	28.95	9.45	25730	6751	270	1468	33529		
6905252	HORIZON CRUSADER	Y		Y	CNTNR	M30008		21	213.65	27.43	9.75	20904	3510	140	1354	30925		
6820579	HORIZON DISCOVERY	Y		Y	CNTNR	M29197		21	213.65	27.43	9.75	22013	3510	140	1382	31565		
7617905	HORIZON ENTERPRISE	Y			CNTNR	M56342		21	247.79	27.43	8.84	31477	4977	199	1863	42551		
7218462	HORIZON EXPEDITION	Y		Y	CNTNR	M37711		22.5	203.69	27.49	11.13	19845	4411	137	1254	28641		
7233278	HORIZON HAWAII	Y		Y	CNTNR	M37169		22.5	203.69	27.49	10.69	19842	4411	137	1254	28641		
8419166	HORIZON KODIAK	Y		Y	CNTNR	M05765		20	216.4	23.77	9.14	20668	2012	69	1582	36133		
7116315	HORIZON NAVIGATOR	Y		Y	CNTNR	M33359		21	247.79	27.43	11.14	31303	4439	178	1848	42208		
7617890	HORIZON PACIFIC	Y			CNTNR	M47910		21	247.79	27.43	8.84	31268	4977	199	1863	42551		
7366312	HORIZON PRODUCER	Y		Y	CNTNR	M39765		22	219.45	28.95	9.45	25730	6751	270	1468	33529		
7729461	HORIZON RELIANCE	Y			CNTNR	M55928		21	272.17	30.48	11.58	46631	5740	230	2097	47895		
7729459	HORIZON SPIRIT	Y			CNTNR	M5816		21	272.17	30.48	11.58	41165	5740	230	1650	37686		
8419154	HORIZON TACOMA	Y		Y	CNTNR	M05275		20	216.4	23.77	9.14	20668	2012	69	1582	36133		
7326233	HORIZON TRADER	Y		Y	CNTNR	M38859		21	247.79	27.43	10.06	31657	4510	180	1848	42208		
7802718	KAUAI	Y		Y	CNTNR	M56214		20	219.45	28.95	10.36	26350	6818	110	1626	37138		
7105471	LIHUE	Y		Y	CNTNR	M33964		21.3	249.92	30.48	10.67	38656	1130	138	1979	45200		
8413239	LYKES DISCOVERER	Y	Y		CNTNR	M04479		21	259.99	32.2	10.29	44966	3304	78	2698	61622		
8413277	LYKES EXPLORER	Y	Y		CNTNR	M04131		21	259.99	32.2	10.29	44966	3304	78	2698	61622		
8415952	LYKES LIBERATOR	Y	Y		CNTNR	M04507		21	259.99	32.2	10.29	44966	3304	78	2698	61622		
8905969	LYKES MOTIVATOR	Y	Y		CNTNR	N51469		21.7	242.25	32.2	11.7	43714	3676	97	2500	57100		
8413289	LYKES NAVIGATOR	Y	Y		CNTNR	M04444		21	259.01	32.2	10.29	44966	3304	78	2698	61622		
9155133	MAERSK CAROLINA	Y	Y		CNTNR	N73744		24.2	292.07	32.25	13.5	62228	5580	223	3084	70438		
9155119	MAERSK GEORGIA	Y	Y		CNTNR	N73742		24.2	292.09	32.25	13.5	62242	5580	223	3084	70438		
9155121	MAERSK MISSOURI	Y	Y		CNTNR	N73743		24.2	292.07	32.5	13.5	62226	5580	223	3084	70438		
9235531	MAERSK VIRGINIA	Y	Y		CNTNR	N95638		24.2	292.07	32.25	13.5	61150	5580	223	3084	70438		
7907996	MAHI	Y			CNTNR	M60277		23.3	262.12	32.31	10.67	30825	5296	212	2824	64500		
7907984	MANOA	Y			CNTNR	M59887		23.3	262.12	32.31	10.67	30825	5296	212	2824	64500		
9244130	MANUKAI	Y		Y	CNTNR	M31227		19	219.75	28.95	10.36	30000	7010	108	1726	39422		
7602338	MAUI	Y		Y	CNTNR	M46841		20	219.45	28.95	10.36	26665	6818	110	1626	37138		
9268538	MAUNAWILI	Y		Y	CNTNR	M92580		19	210.2	28.95	11	30000	7010	108	1726	39422		

7908005	MOKIHANA	Y			CNTNR	M60972		23.3	262.12	32.31	10.67	30825	5296	212	2824	64500		
8616934	PRESIDENT ADAMS	Y	Y		CNTNR	M07075		24	275.11	39.4	12.5	53615	3320	152	3600	82224		
8710704	PRESIDENT GRANT	Y			CNTNR	M07496		23.6	275.8	32.2	12.5	51437	6146	123	3000	68520		
8616300	PRESIDENT JACKSON	Y	Y		CNTNR	M07077		24.3	275.11	38.48	12.4	53615	3320	153	3600	82224		
8616922	PRESIDENT POLK	Y	Y		CNTNR	M06942		24.3	275.11	38.48	12.5	53615	3320	152	3600	82224		
8616283	PRESIDENT TRUMAN	Y	Y		CNTNR	M06519		24.3	275.2	39.4	12.5	53615	3320	152	3600	82224		
8802909	PRESIDENT WILSON	Y			CNTNR	M08637		23.6	275.08	32.3	12.5	51437	6146	123	3000	68520		
9002037	R.J. PFEIFFER	Y		Y	CNTNR	N52972		22.5	217.47	32.26	11.6	28555	2309	2229	2229	50910		
8212647	SEA-LAND ACHIEVER	Y	Y		CNTNR	M63322		19.1	289.52	32.3	12.7	58943	7321	70	3606	82361		
8212685	SEA-LAND ATLANTIC	Y	Y		CNTNR	M64273		19.1	289.55	32.31	11.58	58943	6370	74	3606	82361		
8212702	SEA-LAND COMMITMENT	Y	Y		CNTNR	M64486		19.1	289.52	32.22	11.67	58943	7321	80	3606	82361		
7820966	SEA-LAND DEFENDER	Y	Y		CNTNR	M54907		20.7	257.49	30.78	10.06	30379	3477	76	2306	52669		
7820904	SEA-LAND DEVELOPER	Y			CNTNR	M55329		20.7	257.51	30.78	10.06	30296	3477	76	2306	52669		
7820849	SEA-LAND ENDURANCE	Y	Y		CNTNR	M56391		20.7	257.49	30.78	10.06	30224	3477	76	2306	52669		
7820930	SEA-LAND EXPLORER	Y	Y		CNTNR	M55235		20.7	257.49	30.78	10.06	30298	3477	76	2306	52669		
7820978	SEA-LAND EXPRESS	Y			CNTNR	M55390		20.7	257.49	30.78	10.06	30422	3477	76	2306	52669		
8212611	SEA-LAND FLORIDA	Y	Y		CNTNR	M62755		19.1	289.52	32.22	121.68	58943	7321	74	3606	82361		
7820942	SEA-LAND INDEPENDENCE	Y			CNTNR	M55811		20.7	257.85	30.78	10.06	33939	3477	76	2306	52669		
7820851	SEA-LAND INNOVATOR	Y	Y		CNTNR	M56523		20.7	257.48	30.78	10.06	30350	3477	76	2306	52669		
8212659	SEA-LAND INTEGRITY	Y	Y		CNTNR	M63696		19.1	289.55	32.31	11.58	58943	6370	73	3606	82361		
7820928	SEA-LAND LIBERATOR	Y	Y		CNTNR	M54781		20.7	257.85	30.78	10.06	30416	3477	76	2306	52669		
8212623	SEA-LAND MOTIVATOR	Y	Y		CNTNR	M62754		21	261.02	32.22	11.6	58943	7321	74	2890	66008		
7820899	SEA-LAND PATRIOT	Y	Y		CNTNR	M54540		20.7	257.85	30.78	10.06	30234	3477	76	2306	52669		
8212726	SEA-LAND PERFORMANCE	Y	Y		CNTNR	M64850		19.1	289.55	32.31	11.58	58869	6370	73	3606	82361		
8212661	SEA-LAND PRIDE	Y	Y		CNTNR	M63688		21	261.02	32.22	11.6	58943	7321	75	2890	66008		
8212697	SEA-LAND QUALITY	Y	Y		CNTNR	M64248		19.1	289.55	32.31	11.58	58869	6370	73	3606	82361		
7820916	SEA-LAND VOYAGER	Y			CNTNR	M55960		20.7	257.48	30.78	10.06	30390	3477	76	2306	52669		
8813025	STRONG PATRIOT/10	Y			CNTNR	M10278		14	91	16.21	4.25	3100	418	10	170	3883		
	TOTAL CONTAINERSHIPS				76													
7504627	BUFFALO SOLDIER/7	Y			CNTRRBB	M47525	143064	19	204.15	26.51	10.74	27438	3008	120	1063	24279		18988
	TOTAL CNTNR-RO/RO-BB				1													
8322789	LTC CALVIN P. TITUS	Y			CNTRO/RO	M64759		17.8	198.6	32.21	10.99	33625	2200	65	2101	47987		
7321087	LURLINE/8	Y		Y	CNTRO/RO	M38565	96400	25	251.9	28.05	9.4	22030	3205	128	1379	31496		
7361233	MAERSK ALASKA	Y			CNTRO/RO	M43216		21	239.28	30.56	11.52	29914	88	4.25	1413	32273		
7361180	MAERSK ARIZONA	Y			CNTRO/RO	M42383		21	239.28	30.56	11.52	29839	88	2.25	1413	32273		
7334204	MATSONIA/8	Y		Y	CNTRO/RO	M38964	102500	25	213.4	32	12	13860	3270	131	1712	39102		
8320547	SP5 ERIC G. GIBSON(MSC)	Y			CNTRO/RO	M63556		17.8	198.86	32.2	10.99	33625	2646	69	2101	47987		
8300200	VIRGINIAN	Y			CNTRO/RO	M62490	80697	16.5	156.06	32.01	9.02	20375	2140	48				
	TOTAL CONTAINER-RO/RO				7													

9213935	INDUSTRIAL CHALLENGER/7	Y			HVYLFT	N92162	33119	16.5	119.8	20	7.4	8661	738	25	350	7994		7224
	TOTAL HEAVY LIFT				1													
7634343	JANIS GUZZLE/MARIE FLOOD	Y		Y	ITB	N29500	40000	15.4	164.59	25.9	9.75	34500	815	23				
7236024	BETTY WOOD/PAT CANTRELL	Y		Y	ITB	N22884	30000	12	206.7	25.1	9.75	33600	386	26				
7532741	BARBARA KESSEL/GAYLE EUSTACE	Y		Y	ITB	N28304	21000	12.5	191.4	22.9	8.46	33281	684	23				
7303853	SHARON DEHART/DORIS GUENTHER	Y		Y	ITB	M49309	20000	19.2	167	23.16	8.5	23000	196	16				
	TOTAL ITB				4													
8227460	ATLANTIC FOREST	Y	Y		LASH	M62023		20	262.93	32.21	11.65	47320			1148	26220		
	TOTAL LASH				1													
7367445	EL MORRO/8	Y		Y	LOLO	M40051	104822	21.5	241.03	28.05	9.18	14897	3206	128	687	15691		
7506015	EL YUNQUE/8	Y		Y	LOLO	M46183	104822	25	241.03	27.97	9.02	14472	3206	128	687	15691		
9129706	FREEDOM	Y	Y		RO-RO	M69400	222802	18.8	190.05	32.26	10.2	19884	2528	46				
7420493	GREAT LAND	Y		Y	RO/RO	M42438	205901	25	241.09	28.04	9.14	11500	3093	124				
9073701	GREEN COVE	Y	Y		RO/RO	N61876	131998	19	178.8	32.3	9.14	13277	2763	111				
9181376	GREEN DALE	Y	Y		RO/RO	N78110	131998	19	178.8	32.3	9.14	14930	2744	110				
8607749	GREEN LAKE	Y	Y		RO/RO	N74472	150828	19	199.8	32.3	9.14	22799	2941	61				
9056296	GREEN POINT	Y	Y		RO/RO	N58916	128328	18	199.8	32.3	9.7	14930	2263	44				
7518563	INDEPENDENCE(ex TELLUS)	Y			RO/RO	M47152	134312	19.8	194.52	32.01	9.7	18890	3653	75				
8320779	LIBERTY (ex FAUST)	Y	Y		RO/RO	M00244	135324	19.5	199.02	32.26	11.66	28055	4228	52				
7717171	MAERSK CONSTELLATION	Y			RO/RO	M55474	33000	18.5	182	27.49	11.85	21213	2708	30				
9232278	MIDNIGHT SUN	Y		Y	RO/RO	N95347	300165	24	255.72	35.96	8.99	27835	3084	123				
9232280	NORTH STAR	Y		Y	RO/RO	M47479	300165	24	171.4	25.4	10.6	27835	3407	136				
7395351	NORTHERN LIGHTS	Y		Y	RO/RO	M41585	205901	25	240.78	28.05	8.53	11500	3194	128				
8606056	OVERSEAS JOYCE	Y	Y		RO/RO	M05052	100965	18.5	190.51	32.26	8.9	16141	2841	114				
8602775	PATRIOT(ex FIDELIO)	Y	Y		RO/RO	M03816	155947	18	190.05	32.26	8.92	15436	1842	35				
9080297	RESOLVE (ex TANABATA)	Y			RO/RO	M62723	215709	19.4	189.8	32.26	10.19	19768	2212	48				
7614915	WESTWARD VENTURE	Y		Y	RO/RO	M47131	205901	25	240.99	31.99	9.14	11500	3615	145				
					18													
7634331	STRONG/AMERICAN	Y			TUGBRG	N60171	90000	15.5	211.6	25.1		7100						
	TOTAL TUG/BARGE DRY				1													
							TOTAL VISA:			126								

	TOTAL MSP: 47
	TOTAL JONES ACT: 38
1	LOA, BEAM AND DRAFT ARE EXPRESSED IN METERS, FUEL CAPACITY IN METRIC TONS AND FUEL CONSUMPTION IN METRIC TONS PER DAY.
2	THE "Y" IN A CELL INDICATES VESSEL PARTICIPATION IN A PROGRAM. "VSA" STANDS FOR THE VOLUNTARY INTERMODAL SEALIFT AGREEMENT (VISA)
	PROGRAM. CURRENTLY, THERE ARE 126 VESSELS IN THE PROGRAM. "MSP" STANDS FOR THE MARITIME SECURITY PROGRAM. CURRENTLY, THERE ARE 47
	VESSELS IN THE PROGRAM. "JA" STANDS FOR JONES ACT AND A "Y" INDICATES VESSELS PARTICIPATING IN CONTIGUOUS AND NON-CONTIGUOUS DOMESTIC
	TRADE.
	AN "MSC" NEXT TO A VESSEL'S NAME STANDS FOR THE MILITARY SEALIFT COMMAND AND INDICATES THAT THE VESSEL IS UNDER CHARTER TO MSC.
	PLEASE NOTE: FOR VESSELS PARTICIPATING IN THE VISA PROGRAM, SQUARE FOOTAGE, TEUS AND BALE CUBIC CAPACITY REPRESENT THE VESSEL OWNER'S
	ESTIMATE OF MILITARILY USEFUL CAPACITY.
3	IN CALCULATING THE MEASUREMENT TON CAPACITY OF TEU CONTAINERS, THE RATIOS OF 25.87 CUBIC METERS PER TEU AND 35.315 CUBIC FEET PER METER
	WERE USED.
4	IF A VESSEL WAS REBUILT, THE YEAR REBUILT IS SHOWN.
5	FOR THE BREAKBULK VESSELS, THE TEU CAPACITY AND BALE CUBIC CAPACITY ARE MUTUALLY EXCLUSIVE.
6	FOR THE BULK CARRIER CYNTHIA FAGAN THE SQUARE FOOTAGE AND MEASUREMENT TON CAPACITY ARE MUTUALLY EXCLUSIVE.
7	THE SQUARE FOOTAGE, TEU AND MEASUREMENT TON CAPACITIES ARE MUTUALLY EXCLUSIVE.
8	THE SQUARE FOOTAGE AND TEU CAPACITY ARE ADDITIVE.
9	THE PRIDE OF ALOHA CURRENTLY HAS 1001 CABINS AND A PASSENGER CAPACITY OF 2450. THE COMMERCIAL CREW SIZE IS 847.
10	THESE VESSELS ARE NOT "MILITARILY USEFUL" ACCORDING TO THE STRICT DEFINITION OF THE PHRASE, HOWEVER, THEY PARTICIPATE IN THE VISA
	PROGRAM AND, THEREFORE, ARE TREATED AS AN EXCEPTION.

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APPENDIX E: VISA CARRIER DATA FOR SPECIFIED ROUTES

carrier	route Asia	route Middle East	ships	Type	capa TEU's / sqft	ship speed		comments
APL	PS1		APL Japan	cont	5108	24?	no VISA ?	on avg all 7 days
	Pacific South 1		Pres Jackson	cont	3600	24.3		Seattle - Vancouver - **Los Angeles** - Yokohama -
			APL Kennedy	cont	4848	24?	no VISA?	Yantian - Hong Kong - Kaohsiung - **Singapure**
			Pres Adams	cont	3600	24.3		Los A - Singa - Los A each 19 days sail
			Pres Polk	cont	3600	24.3		2 days loading each Sing and Los A
			Pres Truman	cont	3600	24.3		total round 36 - 38 days
APL		MGS	SL Liberator	cont	2306	20.7		on avg all 7 days
	Mediterranean Golf Service		SL Independence	cont	2306	20.7		New York - Charlston - Miami - **Houston** - **Gioia Tauro** - Genoa - Algeciras
			SL Voyager	cont	2306	20.7		
			SL Mariner	cont	2306	20.7?	no VISA?	Houston - Gioia T 15 days / Gio - Hou 18 days
			SL Developer	cont	2306	20.7		2 days loading HOU / 1 day Gioia
								total round in 35 days
Maersk	TP2		SL Patriot	cont	2306	20.7		on avg all 7 days one ship
	Transpacific II		SL Explorer	cont	2306	20.7		Los Angeles - **Oakland** - Yokohama - Nagoya - Busan - Xingang - Quingdao - **Kwangyang**
			SL Defender	cont	2306	20.7		
			SL Endurance	cont	2306	20.7		Oak - Kwang 20 days / Kwang - Oak 14 days
			SL Innovator	cont	2306	20.7		Oak and Kwang each loading 1 day
Maersk		TA2	SL Integrity	cont	3606	19.1		on avg all 7 days
	Transatlantic2		SL Pride	cont	2890	21		Houston - Charlston - **Norfolk** - Rotterdam - Felixstowe - **Bremerhaven**
			SL Florida	cont	3606	19.1		
			SL Motivator	cont	2890	21		Nor - Bre in 13 days / Bre - Nor in 22 days
			SL Achiever	cont	3606	19.1		Nor and Bre each loading 1 day
A RoRo C		Atlantic	Liberty	sqft	135,324	19		on avg all 7 days one ship
RoRo	Transatlantic		Patriot	sqft	155,947	17		Antwerp - **Bremerhaven** - Southampton Brunswick - **Charlston** - Baltimore
			Freedom	sqft	222,802	18		
								each trip 14 days
								each harbor 2 days (Char / Brem)

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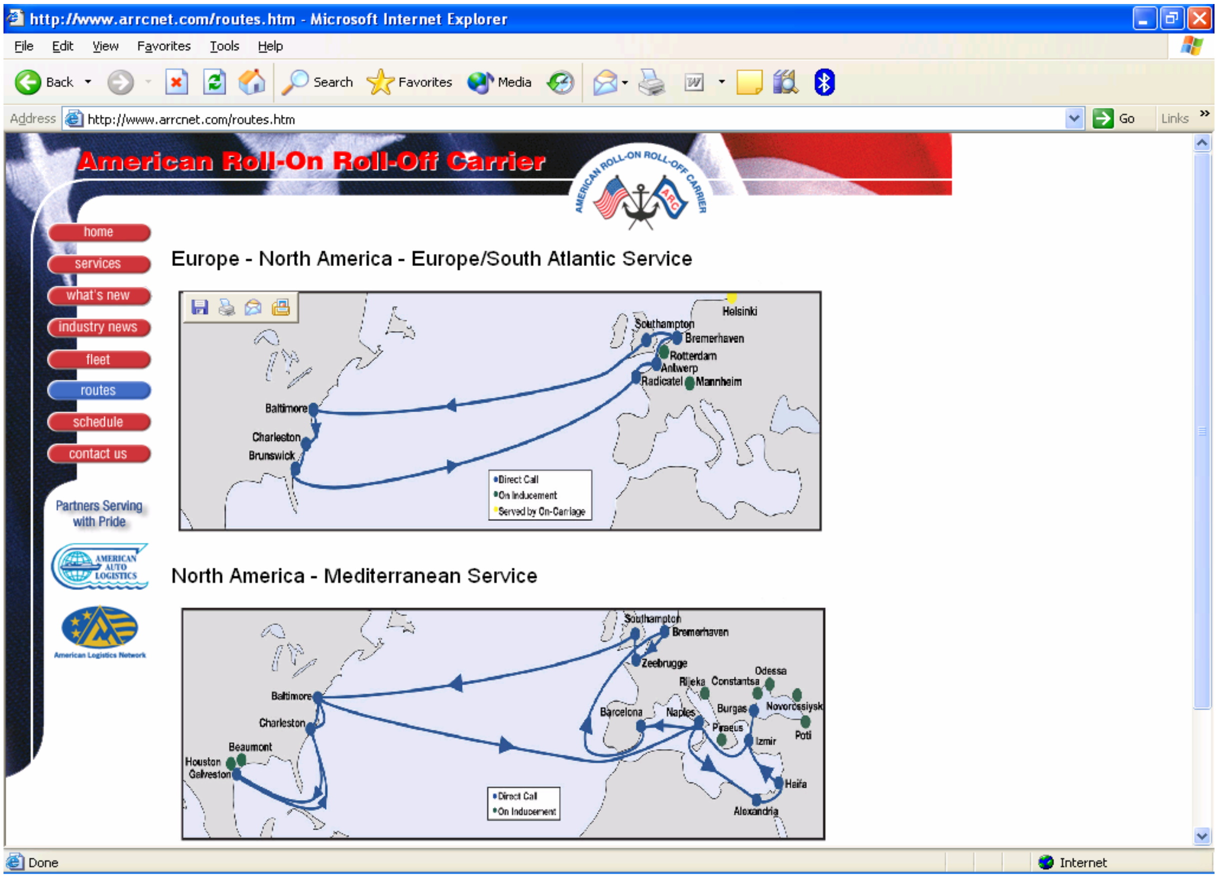
APPENDIX F: RO-RO ATLANTIC ROUTES



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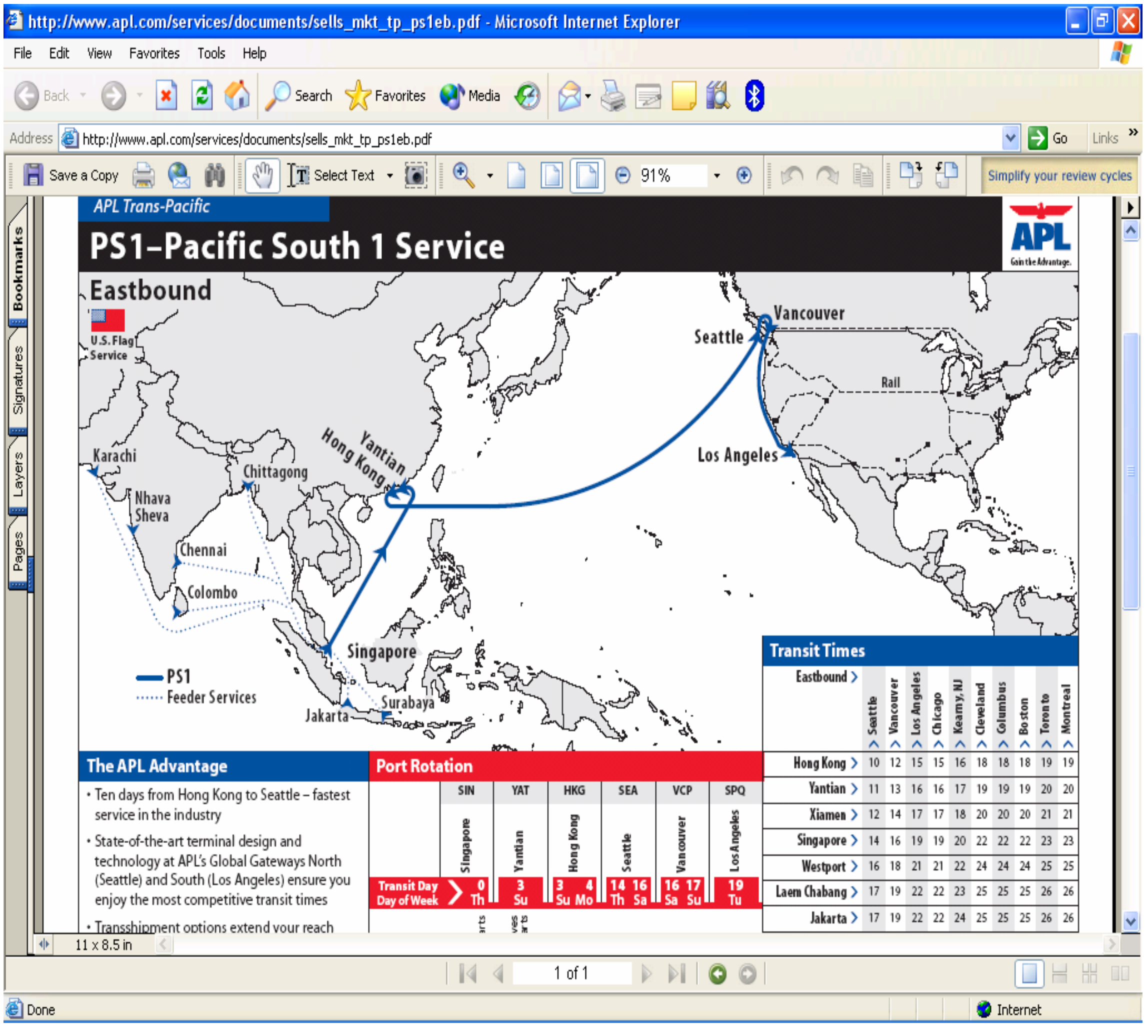
APPENDIX G: ATLANTIC ROUTE



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APPENDIX H: APL PACIFIC SCHEDULE

Mexico to Asia

Frame	47		48	49		50
Vessel	APL Argentina	APL Quetzal	TMM Monterrey	TMM Aguascalien	APL Guadalajara	Lykes Provider
Voyage	ARN-002	QZZ-049	MTE-016	AGC-014	GDL-048	LPV-016
Departs / **Service**	**MAX**	**MCX**	**MAX**	**MAX**	**MCX**	**MAX**
Altamira	We 17 Nov	Su 14 Nov	Fr 26 Nov	We 01 Dec	We 24 Nov	We 08 Dec
Ensenada	**Mo 15 Nov**	— —	**We 24 Nov**	**Mo 29 Nov**	— —	**Mo 06 Dec**
Guadalajara	We 17 Nov	Su 14 Nov	Fr 26 Nov	We 01 Dec	We 24 Nov	We 08 Dec
Manzanillo, MEXICO	**Th 18 Nov**	**Mo 15 Nov**	**Th 18 Nov**	**Th 02 Dec**	**Th 25 Nov**	**Th 09 Dec**
Mexico City	We 17 Nov	Su 14 Nov	Fr 26 Nov	We 01 Dec	We 24 Nov	We 08 Dec
Monterrey	Tu 16 Nov	Sa 13 Nov	Th 25 Nov	Tu 30 Nov	Tu 23 Nov	Tu 07 Dec
Tampico	Tu 16 Nov	Sa 13 Nov	Th 25 Nov	Tu 30 Nov	Tu 23 Nov	Tu 07 Dec
Tijuana	Mo 15 Nov	— —	We 24 Nov	Mo 29 Nov	— —	Mo 06 Dec
Veracruz	We 17 Nov	— —	Fr 26 Nov	We 01 Dec	— —	We 08 Dec
Arrives						
Chiwan	**Tu 07 Dec**	— —	**Tu 14 Dec**	**Tu 21 Dec**	— —	**Tu 28 Dec**
Dalian	Fr 17 Dec	— —	Fr 24 Dec	Fr 31 Dec	— —	Fr 07 Jan
Hakata	Su 05 Dec	— —	Su 12 Dec	Su 19 Dec	— —	Su 26 Dec
Ho Chi Minh City	Fr 10 Dec	— —	Fr 17 Dec	Fr 24 Dec	— —	Fr 31 Dec
Hong Kong	**We 08 Dec**	— —	**We 15 Dec**	**We 22 Dec**	— —	**We 29 Dec**
Jakarta	Sa 18 Dec	— —	Sa 25 Dec	Sa 01 Jan	— —	Sa 08 Jan
Kaohsiung	**Mo 06 Dec**	— —	**Mo 13 Dec**	**Mo 20 Dec**	— —	**Mo 27 Dec**
Karachi	Tu 28 Dec	— —	Tu 04 Jan	Tu 11 Jan	— —	Tu 18 Jan
Kobe	**Fr 03 Dec**	— —	**Fr 10 Dec**	**Fr 17 Dec**	— —	**Fr 24 Dec**
Kwangyang	Th 16 Dec	— —	Th 23 Dec	Th 30 Dec	— —	Th 06 Jan
Laem Chabang	Su 12 Dec	— —	Su 19 Dec	Su 26 Dec	— —	Su 02 Jan
Manila	Th 09 Dec	— —	Th 16 Dec	Th 23 Dec	— —	Th 30 Dec
Nagoya	Fr 03 Dec	— —	Fr 10 Dec	Fr 17 Dec	— —	Fr 24 Dec
Penang	Sa 18 Dec	— —	Sa 25 Dec	Sa 01 Jan	— —	Sa 08 Jan
Port Kelang	Fr 17 Dec	Fr 17 Dec	Fr 24 Dec	Fr 31 Dec	Fr 31 Dec	Fr 07 Jan
Pusan	**Tu 14 Dec**	— —	**Tu 21 Dec**	**Tu 28 Dec**	— —	**Tu 04 Jan**
Qingdao	Tu 14 Dec	— —	Tu 21 Dec	Tu 28 Dec	— —	Tu 04 Jan
Shanghai	**Su 12 Dec**	— —	**Su 19 Dec**	**Su 26 Dec**	— —	**Su 02 Jan**
Singapore	Tu 14 Dec	— —	Tu 21 Dec	Tu 28 Dec	— —	Tu 04 Jan
Tokyo	Fr 03 Dec	— —	Fr 10 Dec	Fr 17 Dec	— —	Fr 24 Dec
Xiamen	— —	— —	We 15 Dec	Fr 24 Dec	— —	Sa 01 Jan
Yantian	We 08 Dec	— —	We 15 Dec	We 22 Dec	— —	We 29 Dec

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APPENDIX I: MEDITERRANEAN GULF SERVICE

APL Trans-Atlantic

MGS–Mediterranean Gulf Service

APL Gain the Advantage.

Transit Times

Eastbound >	Gioia Tauro	Genoa	Algeciras
Charleston >	11	13	16
Houston >	15	17	20
Miami >	18	20	23
New York >	21	23	26

Port Rotation

	ME3	MM7	ULT	KCS	GQT	GV7	AGL
	New York	Miami	Houston	Charleston	Gioia Tauro	Genoa	Algedras
Transit Day	0	3	5 6	9 10	21 22	23 24	26
Day of Week	Sa	Tu	Th Fr	Mo Tu	Sa Su	Mo Tu	Th
	Departs	Arrives Departs					

The APL Advantage

- Industry's fastest transits between key U.S. East Coast and Gulf ports
- Market's only direct service connecting Miami to Gioia Tauro
- Direct service from New York to Italy and Spain
- Reach your markets faster and improve your inventory turn times
- Reefer and special equipment services available

For sailing schedules, shipment booking, and tracing, visit *www.apl.com.*

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APPENDIX J: SHIP SPECIFICATION TABLE (RORO)

http://www.arrcnet.com/fleet_patriot.htm - Microsoft Internet Explorer

Deck 4 is lifted to create the higher deck height option on deck 5.

Deck 10 is lifted to create the higher deck height option on deck 11.

NOTE: Lifted decks are unavailable for cargo when in the lifted position.

LOADING PARTICULARS

				Max Deck Area			Max Ro-Ro Height			Military	Max HSV
	Metric Units			English Units			English Units			Strong-deck	
	Height	Load	Area	Height	Load	Area	Height	Load	Area	Area	
Deck No.	m	(mt/m2)	m2	Ft	(lb/ft2)	Ft2	Ft	(lb/ft2)	Ft2	Ft2	
1	1.65	0.18	5,227	5.41	36.9	56,263	5.41	36.9	56,263		
2	2.30	0.40	5,292	7.55	81.9	56,963	7.55	81.9	56,963		56,963
3	2.30	0.40	5,384	7.55	81.9	57,953	7.55	81.9	57,953		57,953
4 (L)	1.65	0.18	5,384	5.41	36.9	57,953	-	Liftable deck			
5	1.65	1.00	4,824	5.41	204.8	51,925	10.50	204.8	51,925	51,925	51,925
6 (L)	1.65	0.40	4,903	5.41	81.9	52,775	-	Liftable deck			
7	2.35	2.00	4,739	7.71	409.7	51,010	15.09	409.7	51,010	51,010	51,010
8 (L)	1.65	0.18	3,393	5.41	36.9	36,522	-	Liftable deck			
9	2.30	1.00	3,184	7.55	204.8	34,272	12.63	204.8	34,272	34,272	34,272
10 (L)	1.65	0.18	2,898	5.41	36.9	31,194	-	Liftable deck			
11	1.65	1.00	1,741	5.41	204.8	18,740	10.50	204.8	18,740	18,740	
12	1.65	0.18	1,718	5.41	36.9	18,492	5.41	36.9	18,492		
Total			48,687			524,062			345,618	155,947	252,123

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APPENDIX K: EXCERPT OF EXCEL OUTPUT FILE

		Gioia data		schedule = ship per month									
		mil					mil				route capacity		
Replication	cont schedule	% cont	# cont	Time	total cont	RO-RO-schedule	% RO-RO	# RO-RO	Time RO-RO	total RO-RO	cont	RO-RO	lash
1	4.28	0.00	0.00	29.33	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
2	4.28	0.00	0.00	28.86	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
3	4.28	0.00	0.00	29.15	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
4	4.28	0.00	0.00	28.80	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
5	4.28	0.00	0.00	29.08	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
6	4.28	0.00	0.00	29.05	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
7	4.28	0.00	0.00	29.34	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
8	4.28	0.00	0.00	29.22	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
9	4.28	0.00	0.00	28.98	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
10	4.28	0.00	0.00	29.04	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
11	4.28	0.00	0.00	29.02	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
12	4.28	0.00	0.00	29.25	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
13	4.28	0.00	0.00	29.27	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
14	4.28	0.00	0.00	29.49	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
15	4.28	0.00	0.00	29.10	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
16	4.28	0.00	0.00	29.22	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
17	4.28	0.00	0.00	29.37	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
18	4.28	0.00	0.00	28.83	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
19	4.28	0.00	0.00	29.20	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
20	4.28	0.00	0.00	28.87	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
21	5.28	0.00	0.00	26.85	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
22	5.28	0.00	0.00	26.65	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
23	5.28	0.00	0.00	26.57	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
24	5.28	0.00	0.00	26.38	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00
25	5.28	0.00	0.00	26.43	1038.0	0.00	0.00	0.00	0.00	0.00	346.00	0.00	30.00

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APPENDIX L: EXCERPT OF PORT DETAIL OUTPUT

	Gioia			if no mil mat "cont %" will display delivered material							
Replication #	time	cont % total mat	ship capacity	Rep #	time	RO-RO	ship capacity	Rep #	time	lash	ship capacity
1.00	15	346.00	346.0	1.00	15	4500.00	4500.0	1.00	17	30.00	30.0
1.00	22	692.00	346.0	2.00	15	4500.00	4500.0	2.00	16	30.00	30.0
1.00	29	1038.00	346.0	3.00	15	4500.00	4500.0	3.00	16	30.00	30.0
2.00	15	346.00	346.0	4.00	16	4500.00	4500.0	4.00	16	30.00	30.0
2.00	22	692.00	346.0	5.00	15	4500.00	4500.0	5.00	16	30.00	30.0
2.00	29	1038.00	346.0	6.00	15	4500.00	4500.0	6.00	16	30.00	30.0
3.00	15	346.00	346.0	7.00	16	4500.00	4500.0	7.00	16	30.00	30.0
3.00	22	692.00	346.0	8.00	15	4500.00	4500.0	8.00	16	30.00	30.0
3.00	29	1038.00	346.0	9.00	15	4500.00	4500.0	9.00	16	30.00	30.0
4.00	15	346.00	346.0	10.00	15	4500.00	4500.0	10.00	16	30.00	30.0
4.00	22	692.00	346.0	11.00	15	4500.00	4500.0	11.00	16	30.00	30.0
4.00	29	1038.00	346.0	12.00	15	4500.00	4500.0	12.00	16	30.00	30.0
5.00	15	346.00	346.0	13.00	15	4500.00	4500.0	13.00	16	30.00	30.0
5.00	22	692.00	346.0	14.00	15	4500.00	4500.0	14.00	16	30.00	30.0
5.00	29	1038.00	346.0	15.00	15	4500.00	4500.0	15.00	16	30.00	30.0
6.00	15	346.00	346.0	16.00	15	4500.00	4500.0	16.00	16	30.00	30.0
6.00	22	692.00	346.0	17.00	16	4500.00	4500.0	17.00	16	30.00	30.0
6.00	29	1038.00	346.0	18.00	15	4500.00	4500.0	18.00	16	30.00	30.0
7.00	15	346.00	346.0	19.00	15	4500.00	4500.0	19.00	16	30.00	30.0
7.00	22	692.00	346.0	20.00	15	4500.00	4500.0	20.00	16	30.00	30.0
7.00	29	1038.00	346.0	21.00	16	4500.00	4500.0	21.00	17	30.00	30.0
8.00	15	346.00	346.0	21.00	25	9000.00	4500.0	21.00	26	60.00	30.0
8.00	22	692.00	346.0	22.00	15	4500.00	4500.0	22.00	16	30.00	30.0

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APPENDIX M: EXCERPT FROM OUTPUT DATA FILE - ATLANTIC

Atlantic global view								
repl	cont	time	repl	roro	time	repl	lash	time
60.00	498.00	13.09	63.00	23495.00	17.50	229.00	27.00	21.37
60.00	844.00	14.98	63.00	43528.00	19.07	229.00	51.00	32.96
60.00	1342.00	22.48	63.00	64485.00	24.62	229.00	73.00	38.43
60.00	1688.00	24.33	63.00	84136.00	25.89	230.00	26.00	20.23
60.00	2186.00	31.79	63.00	107535.00	31.27	230.00	54.00	32.34
60.00	2532.00	33.39	63.00	128964.00	34.46	230.00	80.00	38.59
61.00	320.00	18.94	63.00	146544.00	38.86	231.00	24.00	23.36
61.00	754.00	20.14	64.00	19072.00	18.47	231.00	50.00	31.32
61.00	1069.00	24.13	64.00	42242.00	20.68	232.00	20.00	21.24
61.00	1492.00	26.35	64.00	61103.00	26.07	232.00	49.00	32.29
61.00	1977.00	29.35	64.00	79171.00	27.56	233.00	24.00	21.09
61.00	2276.00	33.80	64.00	99208.00	33.58	233.00	47.00	27.82
61.00	2656.00	37.81	64.00	116480.00	34.11	234.00	22.00	21.72
62.00	380.00	19.36	64.00	136992.00	38.71	234.00	42.00	31.64
62.00	645.00	20.60	65.00	16684.00	16.44	235.00	25.00	25.08

repl = replication number

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APPENDIX N: STRATEGIC SEALIFT INVENTORY

Strategic Sealift Inventory
(As of 1 November 2004)

The following list of militarily useful ships is compiled from information furnished by the MSC Program Managers, the Maritime Administration (MARAD) and other authoritative sources. The figures are updated monthly

Category	Dry	Tanker	PAX	Total
MSC Force	**64**	**8**	**0**	**72**
Fast Sealift Ships (FSS)	8			
Large Medium-Speed RO/RO (LMSR)[1]	19			
Maritime Prepositioning Ships (MPS)	16			
PREPO (U.S. Charters)	6			
PREPO (RRF Tendered to MSC)	1	2		
RRF (Operational)	10			
Other U.S. Charters	4	2		
USNS Tankers		4		
Ready Reserve Force	**41**	**5**	**0**	**46**
Auxiliary Crane Ship (T-ACS)	10			
Breakbulk (BB)	2			
Lighter Aboard Ship (LASH)	3			
Sea Barge (SEABEE)	2			
Roll On/Roll Off (RO/RO)	22			
Combo	0			
Aviation Support (T-AVB)	2			
U. S. Commercial	**102**	**55**	**1**	**158**
Readiness Agreements [2]	94	20	0	114
Breakbulk	5			
Container	69			
Container RO/RO	8			
RO/RO	5			
Car Carrier	7			
Other U.S. Commercial	8	35	1	44

Category	Dry	Tanker	PAX	Total
Effective U. S. Control[3]	**40**	**17**	**2**	**59**
VTA Tankers		6		
Non-VTA Tankers		11		
Other Allies[4]	**48**	**11**	**0**	**59**
Overall Total	**295**	**96**	**3**	**394**

Notes:

1. All nineteen LMSRs have joined the MSC Force. Three are Preposition, nine Surge, and seven are operational.
2. Includes the following:
   - Maritime Security Program (MSP) and Voluntary Intermodal Sealift Agreement (VISA) for dry cargo ships.
   - Voluntary Tanker Agreement (VTA) for tankers.
   - Sealift Readiness Program (SRP) for both.
3. EUSC ships are normally available only after requisitioning is authorized, except for those tankers enrolled in the Voluntary Tanker Agreement (VTA).
4. These ships are dedicated to USCINCPAC and identified by name through a bilateral shipping agreement.

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