NPS-LM-11-184

ACQUISITION RESEARCH
SPONSORED REPORT SERIES

Analysis of U.S. Military Helicopter Operations in Support of Humanitarian Assistance and Disaster Relief

15 December 2011

by

LCDR Thomas Clementson, USN, and

Lt. Charles Fisher, USN

Advisors: Dr. Susan K. Heath, Assistant Professor. and

Brad Naegle, Senior Lecturer

Graduate School of Business & Public Policy

Naval Postgraduate School

Prepared for: Naval Postgraduate School, Monterey, California 93943

The research presented in this report was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

To request Defense Acquisition Research or to become a research sponsor, please contact:

NPS Acquisition Research Program
Attn: James B. Greene, RADM, USN, (Ret.)
Acquisition Chair
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road, Room 332
Monterey, CA 93943-5103
Tel: (831) 656-2092
Fax: (831) 656-2253
E-mail: jbgreene@nps.edu

Copies of the Acquisition Sponsored Research Reports may be printed from our website, www.acquisitionresearch.net

ANALYSIS OF U.S. MILITARY HELICOPTER OPERATIONS IN SUPPORT OF HUMANITARIAN ASSISTANCE AND DISASTER RELIEF

ABSTRACT

The objective of this project was to compare the relationship between Type Model Series platforms' maintenance capability degradation and route selections, using different priorities and timelines. By identifying, the top 10 maintenance failures and communicating these needs through the chain of command and supply chain, it will minimize the mission capability degradation and maximize our aircraft availability. Establishing delivery routes that will maximize the number of sorties each aircraft can fly will help determine what percentage of overall demand we can meet. As the DoD budget continues to decrease, we need to find a more efficient way to maximize resources and reduce costs. The research team analyzed the impact of assigning aircraft by the lowest cost per flight hour in comparison to the other available T/M/S platforms. This analysis also clarifies the cost benefit analysis of the Amphibious Readiness Group versus Carrier Strike Group battle groups. Using the lessons learned from this project will help ensure that each humanitarian assistance disaster relief mission is delivering the right supplies by the right T/M/S platforms for the right price.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

We would like to thank our families and friends for their love, care, and support throughout the MBA program and throughout the long days and nights we spent working on this project. We could not have done this without them.

We also thank the following Naval Postgraduate School (NPS) staff:

Professor Susan Heath and Professor Brad Naegle, we thank you for your guidance, support, and patience throughout this project. Most especially, we thank you for agreeing to work with us on this project and giving up your valuable time to guide us even at short notices.

Professor Eitelberg and Professor Hudgens, thank you for setting the foundation for this work. We could not have started without your guidance.

Thank you all for your contributions and support.

THIS PAGE INTENTIONALLY LEFT BLANK

NPS-LM-11-184

ACQUISITION RESEARCH SPONSORED REPORT SERIES

Analysis of U.S. Military Helicopter Operations in Support of Humanitarian Assistance and Disaster Relief

15 December 2011

by

LCDR Thomas Clementson, USN, and

Lt. Charles Fisher, USN

Advisors: Dr. Susan K. Heath, Assistant Professor. and

Brad Naegle, Senior Lecturer

Graduate School of Business & Public Policy

Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AFAST	Aviation Financial Analysis Tool
AOR	Area of Responsibility
A_o	Operational Availability
ARG	Amphibious Readiness Group
ASUW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
ATO	Air Traffic Officer
AVCAL	Aviation Consolidated Allowance List
BCM	Beyond Capable Maintenance
CPH	Cost per Hour
CSAR	Combat Search and Rescue
CSG	Carrier Strike Group
CVW	Carrier Air Wing
DoD	Department of Defense
DRAT	Disaster Relief Assessment Team
DV	Distinguished Visitor
GSM	Global Systems Mobil
GTMO	Guantanamo Bay, Cuba
HA/DR	Humanitarian Assistance Disaster Relief
HSL	Helicopter Anti-Submarine Squadron Light
IMA	Intermediate Maintenance Activity
JCOA	Joint Center for Operational Analysis
JTF-H	Joint Task Force-Haiti
KIAS	Knots of Indicated Air Speed
LAMPS	Light Airborne Anti Purpose System
LHA	Amphibious Assault Ship
LHD	Amphibious Assault Ship
LPH	Landing Platform Helicopter
LZ	Landing Zone
MEDEVAC	Medical Evacuation
MCW	Max Cargo Weight
MC%	Mission Capability Percentage
MTBF	Meant Time Between Failures
NATOPS	Naval Air Training and Operating Procedures Standardization
NAVAIR	Naval Air Force Command
NGO	Non-Government Organization
NMCS	Non-Mission Capable Supply
NWDC	Navy Warfare Development Center
OFDA	Office of Foreign Disaster Assistance
ORM	Operational Risk Management
OUR	Operation Unified Response
PAX	Passengers

PM	Preventative Maintenance
PUK	Pak up Kit
ROA	Relief Operating Area
SAR	Search and Rescue
SOUTHCOM	Southern Command
TACRON 21	Tactical Air Control Squadron Two One
T/M/S	Type/Model/Series
TYCOM	Type Wing Commander
USAID	Unites States Agency for International Development
U.S.C.	*United States Code*
UTC	Universal Central Time
VERTREP	Vertical Replenishment
VTOL	Vertical Take-Off Landing

I. INTRODUCTION

Helicopters are invaluable, especially helicopters coming in from the sea, where they can be refueled and resupplied out on our carriers, and are not taking up space at airfields or putting a logistics base at airfields.

—Collin Powell, U.S. Secretary of State, January 3, 2005 (as cited in Elleman, 2007)

In recent years, the world has seen numerous natural disasters in which the military has played key roles with humanitarian assistance and disaster relief (HA/DR). A key component of HA/DR is to assure that relief is received is through a timely and efficient logistics network.

Sea basing is a vital aspect of the U.S. military logistics abilities during relief efforts. Sea basing is a naval capability that provides commanders with the ability to conduct selected functions and tasks at sea without reliance on infrastructure ashore ("Sea-basing," 2011). The ability to launch and recover helicopters for humanitarian assistance from the sea, and the capacity to go virtually anywhere on land where aid is needed, is important for the military. Our research team decided to draw on lessons learned from prior disasters to help identify the best combination of helicopters for supporting HA/DR missions, considering disaster requirements, aircraft and air platform availability and features, and critical maintenance considerations.

Since time can be a vital factor in providing the necessary relief, it is imperative that the U.S. military has the most up-to-date and accurate plan available. In order to create an effective plan like this the military needs to know the best combination of aircraft, supplies, and parts necessary to support various levels of HA/DR missions.

A. PROBLEM STATEMENT

Natural disasters often strike without sufficient forewarning. The U.S. military forces are as prepared as possible, but there is the potential of catching them off guard due to the unpredictable timing of natural disasters and the damage they leave behind. Many times these forces are engaged in their normal exercises and the U.S. government calls them away to aid in relief missions when necessary.

When the USS *Abraham Lincoln* (CVN-72) was asked to aid in the relief efforts for the tsunami in Indonesia, Helicopter Antisubmarine Squadron 2 (HS-2) accumulated approximately 1,200 hours of flight time from January 15 to March 29, 2005 (Elleman, 2007). These hours were equivalent to the flight time in the first three months of a normal deployment. These extended hours caused the squadron to incur extra maintenance hours to keep helicopters available.

In such situations, not only does the squadron have to worry about unplanned maintenance that may occur, but planned maintenance also becomes an issue. Before squadrons deploy, their operations departments estimate how many hours the squadrons will fly during the deployment; these estimations are the basis for each squadron's preventative maintenance (PM) cycles.

In recent U.S. military efforts in disaster relief, such as those in Indonesia and Haiti, aircraft carriers and amphibious assault ships were the primary vessels using helicopters. The helicopters used were primarily CH-46, CH-53, and SH-60 helicopters, which all have different assets to offer for disaster relief. During the Haiti relief efforts from January 15 to February 1, 2010, these helicopter types flew over 1,000 hours in support of Haiti relief efforts, delivering approximately 500 tons of supplies into the country and evacuating more than 435 medical patients (LaGrone, 2010).

Unfortunately, using helicopters in disaster relief efforts can lead to excess degradation or increased life cycle cost. Based on the lessons learned in Operations Unified Response (Haiti) and Unified Assistance (Indonesia), we identify in this thesis the optimal combination of helicopters to support a catastrophic HA/DR mission.

B. OBJECTIVES

Our primary objective in this project was to draw on lessons learned from prior disasters to help identify the best combination of helicopters for supporting HA/DR missions. To achieve this objective, we considered disaster requirements, aircraft and air platform availability and features, and critical maintenance considerations. We considered the various sea-based platforms used during U.S. military disaster relief efforts and their assigned aircraft, and then used general statistical comparisons and cost per flight hour efficiency hierarchy to determine the best combination of helicopters to support a HA/DR mission.

Our secondary objective in this research was to identify the top 10 maintenance non-mission capable supply (NMCS) failures and to analyze whether ships should carry excess parts for unexpected HA/DR missions that may occur during a deployment. We examined the U.S. military helicopters normally used in HA/DR missions and analyzed the type and quantity of each part needed by the military to maintain each Type Model Series (T/M/S) platform's mission capability percentage. Planning and coordination by squadrons, air wings, and Type Commanders (TYCOM) is essential for a smooth transition to any missions that may occur.

Our third research objective was to analyze the cost—in both time and money—of various helicopters used during HA/DR efforts. In this analysis, we determined the most efficient helicopter(s) to use for each mission based on priority demand. Cost per hour (CPH) and the time necessary to deliver critical supplies or personnel are key factors in assigning the correct number of T/M/S platforms to each priority. We examined the amount of fuel and the possible number of hours flown with the various helicopters, determining possible cost savings when using the best helicopter for the correct mission.

Although our main objective in this research was not to examine the correct types of ships the Navy should use for disaster relief efforts, we felt a need to address possible Battle Group options in order to help us identify the proper helicopters. The differences between the makeup of squadrons in a Carrier Strike Group (CSG) and the makeup of squadrons in an Amphibious Readiness Group (ARG) assault ship will determine which battle group is the most cost effective.

C. REASERCH QUESTIONS

To determine how the U.S. military can best utilize one of its key logistics components for HA/DR efforts, we had to answer some central questions. The following research questions assisted us in laying the foundation for our research:

1. What combination of type model series (T/M/S) platforms will best contribute to the effectiveness of a sea base in supporting an HA/DR mission?

2. How do maintenance and repair factors affect the available flight hours per aircraft for a catastrophic HA/DR mission?

3. Which battle group type provides the best support of HA/DR missions?

D. SCOPE AND LIMITATIONS

In this research, we focused on two recent disaster relief efforts, the tsunami in Indonesia and the earthquake in Haiti, to analyze lessons learned using U.S. military helicopters in HA/DR efforts. By focusing on the extended flight hours incurred during these missions, we demonstrate the difficulties a squadron experiences in preparing for these missions. The variability and uncertainty of when a disaster will occur are major factors in these difficulties. The Navy has the burden of weighing time, resources, and dollars against expeditiously providing HA/DR support. Is the Navy providing the right level of support for HA/DR missions at the right time and for the right price? What does a squadron need to be aware of that will better prepare it for unexpected disaster relief missions? Will the U.S. military utilize the best possible helicopter resources to maximize its logistics efforts?

The primary limiting factor in this research was the limited information on lessons learned specific to helicopter maintenance. The Navy Warfare Development Center (NWDC) provided the Navy with lessons learned, but most of the data we collected from the NWDC did not give specific data for maintenance costs incurred during both HA/DR missions. The NWDC is still gathering and organizing Haiti relief information in support of Operation Unified Response (OUR). In addition to these limitations, HS-2 has since transitioned to another T/M/S helicopter, making it difficult to gather historical data on maintenance costs they incurred.

E. METHODOLOGY

We began our analysis by reviewing numerous sources of information pertaining to the Indonesia and Haiti disaster relief efforts, as well as by reviewing U.S. Navy helicopter maintenance literature. We consolidated all the data we collected to develop historical relevance and trends specific to HA/DR helicopter operations. We began our analysis by reviewing numerous sources of information pertaining to the Indonesia and

Haiti disaster relief efforts, as well as by reviewing U.S. Navy helicopter maintenance literature. We consolidated all the data we collected to develop historical relevance and trends specific to HA/DR helicopter operations. Once we acquired the data, we built our model using tropical storm Ketsana as our example. We then analyzed each model using a priority system that combined each T/M/S platform's maximum capability and CPH efficiency hierarchy. Each model we used we generated from the last model, and we then analyzed it to see where we needed to improve the model.

THIS PAGE INTENTIONALLY LEFT BLANK

II. BACKGROUND

For this review, we examined literature pertaining to humanitarian logistics. It is important to understand the nature of each disaster and the part that time plays in providing relief support. Understanding this will help with understanding the role of the long-range heavy-lift aircraft in sea basing and America's role in past and current HA/DR missions. We need to ensure we use the right resources to provide aid as quickly as possible as America's role in HA/DR missions continue to grow.

A. MEHTODOLOGY AND LITERATURE REVIEW

In the literature review, we introduce humanitarian logistic concepts, helicopter operations, and military operations. The information provided in this review aids us in our descriptions of helicopter operations and in our comparison of two models of helicopter that supported HA/DR missions in Haiti and Indonesia.

1. Humanitarian Logistics

In Aruna Apte's (2010) monograph, titled "Humanitarian Logistics: A New Field of Research and Action," she discussed critical actions needed to execute effective humanitarian logistics when disasters strike. Her monograph described how potential disaster responses involving the management of logistics are a major factor in preparing for humanitarian responses, and she explained that it is necessary to understand disasters to understand humanitarian logistics (Apte, 2010).

In Wassenhove's (2006) article "Humanitarian Aid Logistics: Supply Chain Management in High Gear" he stated the importance of logistics operations and getting the right goods to the right people at the right place and at the right time. He also claimed that humanitarian organizations are beginning to become aware, as the private sector did over a decade ago, that logistics

- is crucial to the performance (effectiveness and speed) of current and future operations and programs;
- serves as a bridge between disaster preparedness and response, between procurement and distribution, and between headquarters and the field;

- provides a rich source of data because it is this department that handles the tracking of goods (data that could be used to analyze post-event effectiveness); and
- is the most expensive part of any relief operation and the part that can mean the difference between a successful or failed operation.

2. Disaster Classifications

It is important to know how difficult a particular humanitarian relief operation may be in order to classify a disaster based on time and location. The basis of natural disaster classifications are preparation, prepositioning, and ongoing relief operations. Each of these three is normally in one of the four quadrants of Apte's (2010) model by a disaster's specific category, as seen in Figure 1.

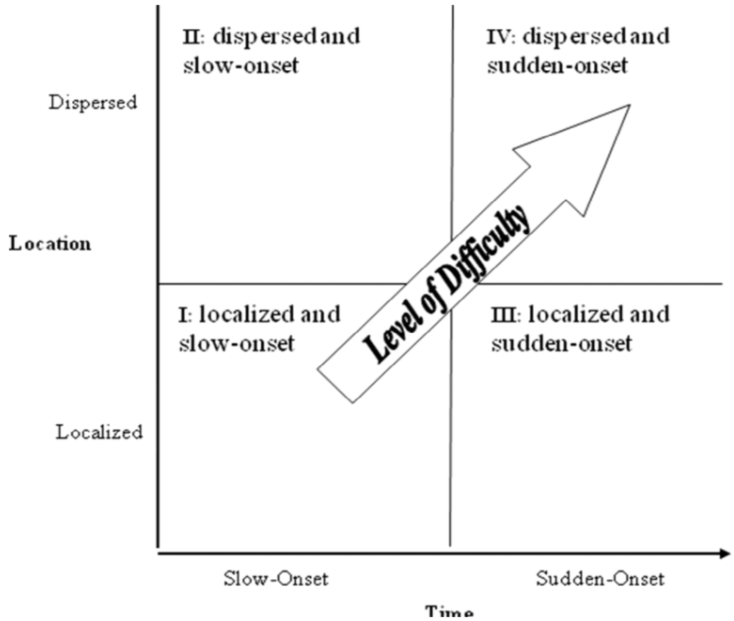

Figure 1. Classification of Disasters
(Apte, 2010, p. 14)

The classification descriptions are as follows:

- Quadrant I: Localized and slow-onset. This gives the preparation team time to catch up and stage the required logistics to help geographically contain the disaster.
- Quadrant II: Dispersed and slow-onset. Preparation for a disaster can help but prepositioning becomes a challenge. It requires a substantial budget and enormous amounts of time to coordinate everyone involved and to ensure

the delivery of the right amount of supplies to the right place at the right time. Disaster response is the key to success for this quadrant.

- Quadrant III: Localized and sudden-onset. This creates problems in all three roles—preparation, prepositioning, and ongoing relief—due to the obvious uncertainties. However, because of the localization of the disaster, the level of operational difficulty, compared to the sudden and dispersed disasters in the fourth quadrant, is somewhat low.
- Quadrant IV: Dispersed and sudden-onset. This quadrant poses the most problems. The sudden impact does not allow time to prepare or preposition, and the dispersed area makes it almost impossible to get the right supplies to the right areas at the right time.

3. Long-Range Heavy-Lift Aircraft to Enable Sea Basing

The objective of sea basing is to have the ability to deliver supplies over long distances by air without the use of truck convoys. This strategy minimizes its footprint on foreign soil while reducing the demand of the already taxed airports and airfields. Ground forces rely heavily on air support for logistical needs (National Research Council [NRC], 2005). During the Indonesia tsunami relief efforts, the U.S. military delivered 2.2 million pounds of relief supplies—consisting of 113,000 pounds of food, 16,000 gallons of water, and 140,500 pounds of other supplies—within a 24-hour period. The use of sea basing was critical in accomplishing this HA/DR mission due to the massive devastation that destroyed roads, bridges, and docks (Elleman, 2007).

4. Logistics Productivity of Aircraft

LTG Phillip Shutler, USMC, (Ret.; 1999), discussed aircraft productivity in sea base logistic support. His research was based on combat situations, but the basic concept of sea-based operations can be linked directly to HA/DR missions. In combat situations, having trucks positioned 225 miles from the ship and having no knowledge of the safety conditions of trucks or roads are conditions common to HA/DR. When conditions are unknown, rotary aircraft often deliver needed supplies and are instrumental in personnel evacuation. The CH-53 is more than capable of carrying heavy loads and of landing where necessary in established landing zones. The distance the aircraft can travel, the load it can carry, and the amount of fuel it needs all play important roles in deciding on the specific aircraft to use.

Fuel conservation in logistics operations is always a major concern. Transporting items, whether supplies or personnel, can be costly due to fuel expenses alone. There is a direct tradeoff between useful load and fuel consumption for helicopters. By reducing the fuel rate to just the amount needed for a particular mission, the helicopter can carry a useful load for very short distances. When referring to no-load distances, the maximum flyable distance with one single passenger (PAX) determines this number. This would be one trip under emergency conditions without refueling.

B. MILITARY SUPPORT OF HA/DR BACKGROUND

1. The Department of Defense's Role in Foreign Assistance

Opportunities to cultivate good relations with foreign populations, militaries, and governments are developing through humanitarian assistance (Serafino, 2008). Because of its manpower and assets, the DoD has always played a role in U.S. efforts to assist foreign governments and militaries. Congress, through legislation, has instituted a variety of authorizations to enable the DoD to carry out these activities. The three purposes, historically, for which the DoD has provided foreign assistance are the following:

1. Responding to humanitarian and basic needs.
2. Building foreign military capacity and capabilities.
3. Strengthening foreign governments' ability to deal with internal and international threats through state-building measures. (Serafino, 2008, p. 1)

When it comes to U.S. government organizations responding to natural or man-made disasters, the DoD is normally the first agency to arrive. Title 10 of the *U.S. Code* (U.S.C.) authorizes the DoD to provide assistance in humanitarian emergencies and recovery efforts. The DoD provides transportation, funding, or both, when necessary, for humanitarian assistance under Title 10.

10 U.S.C. § 2561 (Humanitarian Assistance, 2006) is the primary authority for the DoD to transport humanitarian supplies when a disaster occurs. This code authorizes the DoD to appropriate funds when required for humanitarian assistance, specifically for providing transportation relief, as well as other worldwide humanitarian purposes. The Secretary of State determines if this provision is used to order the DoD to provide specific assistance wherever it may be needed. This assistance can include helicopter

transportation, road and bridge repair, or delivery of temporary water supplies. The submission of an annual report to Congress notifying them of the use of the funds is mandatory.

The Denton Amendment—or 10 U.S.C. § 402 (Transportation of Humanitarian Relief Supplies to Foreign Countries, 2006), which was named after former Senator Jeremiah Denton—authorizes the transport of privately donated humanitarian supplies and disaster assistance on U.S. military ships and aircraft on a space-available basis. If any other U.S. government aid needs transportation, they reserve the right to bump private donations from transport. The United States Agency for International Development (USAID) and the Office of U.S. Foreign Disaster Assistance (OFDA) must certify that private donations are appropriate for the specific HA/DR mission.

The DoD also provides substantial emergency humanitarian relief assistance in a wide variety of other circumstances. Sometimes in cooperation with and under the authorities of other agencies, the DoD provides humanitarian assistance, including food, shelter and supplies, medical evacuation, refugee assistance, logistical and operational support, and rehabilitation services (Serafino, 2008).

2. Current History of Military Humanitarian Assistance

The U.S. military has played a role in disaster relief efforts many times in the past. Immediately following the 1906 earthquake and fire in San Francisco, the U.S. Army provided aid in response to the initial impact of the disaster (Burgess, 1957). In 1991, the U.S. 1st Marine Expeditionary Force was returning home from Desert Storm, but the U.S. Government diverted them to assist in disaster relief efforts (Cossa, 2005) in Bangladesh, which had just lost more than 130,000 people to a typhoon. On January 12, 2005, approximately 15,000 U.S. military personnel were providing HA/DR assistance to tsunami victims in Indonesia (Elleman, 2007). Throughout the past 100 years, the U.S. military has always made an effort to have a presence in both domestic and foreign disaster relief.

3. Current U.S. Military Humanitarian Assistance and Disaster Response

Naval service capabilities have continued to prove their effectiveness in disaster response missions like Operation Tomodachi, which was in response to the devastating earthquake and tsunami in Japan. The normal use of these capabilities is to establish maritime security and project combat power. U.S. forces were involved in 366 humanitarian assistance missions between 1970 and 2000. This number becomes much more significant when compared to the 22 combat missions during the same period (United States Marine Corps [USMC], United States Navy [USN], & United States Coast Guard [USCG], 2010).

Expeditionary naval forces have training in crisis response operations with extreme circumstances and severe risks to the population. Naval service mission readiness is enhanced through reactive HA/DR operations across a number of military operations. The ability to employ expeditionary naval capabilities throughout a broad range of situations clearly demonstrates how the Navy is set up to respond to disasters and provide humanitarian assistance (USMC, USN, & USCG, 2010).

4. Helicopter Use and Procurement

The U.S. military continues to play a vital role in HA/DR worldwide, and helicopters have been important to the success of past missions. Helicopter support for worldwide U.S. military operations has seen an increase and expansion that is significant enough to call for changes in U.S. security and defense (Galdorisi & Truver, 2007). Helicopters once had the reputation of a less significant subset of operational war fighting missions. Because rotary-wing assets are often the only aircraft capable of rescuing stranded survivors or delivering sufficient supplies to provide needed relief in remote areas, HA/DR missions have started to place increased demands on the Navy helicopter community in recent years.

Sea basing and the use of helicopters for logistic support have played a tremendous role in the U.S. military's success. Using a sea base for logistic support during various missions such as HA/DR support has become increasingly important in recent years. The air connectors (i.e., helicopters) that the U.S. military uses to support a sea base must have sufficient space to support the volume of cargo that must be transported in support of any high-tempo operations ashore (Galdorisi & Truver, 2007).

Some of these high-tempo operations, such as HA/DR missions, have caused the DoD to respond with changes in the acquisition process for helicopter procurement. They are working towards adding assets that will give them better efficiency when it comes to fulfilling their assigned missions.

5. Summary

With each disaster classification causing various problems in providing humanitarian logistical support, it becomes evident that prepositioning supplies around the world and sending available resources as quickly as possible will determine how much of which demand we can fill.

The U.S. military has the assets needed to provide HA/DR and is very capable of assisting in HA/DR missions both domestically and in foreign nations. Helicopter procurement needs to take into consideration HA/DR missions when deciding on future acquisitions. Consideration for long-range heavy lift will be essential to the success of future missions.

C. EXAMPLES OF NAVY HELICOPTER HA/DR OPERATIONS

In this section we discuss the Indonesia tsunami as well as the Haiti earthquake and how U.S. military aircraft played a vital role in both relief efforts. The complexity of these operations, which combines multiple branches of the U.S. military located in multiple areas operating together, can be difficult. The following sections will demonstrate the branches' abilities to deliver the necessary supplies under these circumstances.

1. Indonesian Tsunami

At approximately 0600 on December 26, 2004, a 9.3 magnitude earthquake hit off the coast of Sumatra (CSF-536 Joint Force Air Component Commander [JFACC]/Air Force Forces Commander [AFFOR], 2005). The earthquake sent tsunamis tearing through the Indian Ocean, causing the death and disappearances of 295,000 people, while displacing an additional 400,000 people in eight different countries (USAID, 2005). Table 1 gives a snapshot of the death toll for each of the countries affected by the earthquake and tsunami.

Table 1. Death Totals Per Country
(USAID, 2005)

Thailand	5,400
India	8,800
Sri Lanka	30,000
Andaman Islands	1,200
Indonesia	240,000
Malaysia	66
Bangladesh	2
Myanmar	90
Maldives	75

After the initial assessment of the damage, Joint Task Force-536 designated the Utapao, Thailand, airport as the most capable airport to host the joint supply hub. Within 72 hours of the tsunami occurring, the joint supply hub was able to allow the U.S. military to start delivering rescue supplies. Over the 47 days of the mission, 102 aircraft from all four military branches, including 17 different T/M/S platforms, delivered an average of 270 tons of rescue supplies each day (CSF-536 JFACC/AFFOR, 2005, p. 7). Table 2 gives a detailed description of the aircraft type used and the airports where they operated. The average number of airlift relief tons flown per day during Operation Unified Assistance (OUA) exceeded that of any other humanitarian assistance or disaster relief operation since the Berlin Airlift.

Table 2. Land-Based Aircraft

Location	Type	Service	# of Aircraft
Utaphao	C-130	AF	8
	KC-130	Marines	2
	C-21	AF	1
	P-3	Navy	3
Jakarta	C-130	AF	4
Langkawi	MC-130H	AF SOC	5
Paya Lebar	CH-46		4
	C-2		4
Colombo	HC-130	CG	2
	HH-60	AF	6
Diego Garcia	P-3	Navy	2
Kadena	KC-135	AF	2
Futenma	KC-130	Marines	2
Global	C-5	AF	6
	C-17	AF	4
TOTAL			55

The OUA aircraft were operating from nine different land bases (Utapao, Jakarta, Langkawi, Paya Lebar, Colombo, Diego Garcia, Kadena, Futenma, and Global) and five sea bases (USS *Abraham Lincoln*, USS *Bonhomme Richard*, USS *Duluth*, USS *Fort McHenry*, and USS *Niagara Falls*). Table 3 lists the Service branch and the type of sea-based helicopters used. Using the hub-and-spoke delivery method, all incoming rescue supplies flew into the Utapao airport to be unloaded, sorted, and then transported to the various operating bases for distribution to landing zones as needed.

Table 3. Sea-Based Aircraft

Location	Type	Service	# of Aircraft
ALCSG	M/SH-60	Navy	16
BHRSEG	CH-46	Marine	9
	CH-53	Marine	4
	M/SH-60	Marine	6
	UH-1	Marine	3
Duluth	CH-46	Marine	3
Ft McHenry	CH-46	Marine	4
Niagara Falls	MH-60	Navy	2
TOTAL			47

2. Haiti Earthquake

At 21:53 UTC on January 12, 2010, a 7.0-magnitude earthquake struck off the Coast of Haiti, 16 miles west of the Port-au-Prince airport, with the region surrounding the airport receiving the most damage. The severity of this earthquake devastated the country as a whole, causing over 230,000 fatalities and 196,500 injuries, and displacing over 1,200,000 people. The earthquake destroyed a large portion of villages and government infrastructure, including homes, schools, and the Ministry Headquarters (Joint Center for Operational Analysis [JCOA], 2010).

In order to support relief efforts, the U.S. government designated U.S. Southern Command (SOUTHCOM) as the supporting military command and started operating Joint Task Force Haiti (JTF–H). The JTF–H established Guantanamo Bay (GTMO), Cuba, as the designated joint supply hub to run the hub-and-spoke network to distribute disaster supplies to the needed areas of Haiti. Due to the enormous scale of operations for the Haiti mission, the help of 140 countries, 1,000 non-governmental organizations (NGOs), 22,000 U.S. military personnel to include 33 ships and 41 aircraft were used to aid in the HA/DR mission (JCOA, 2010). The aircraft used were operating from one airfield, 40 landing zones, and three sea bases, which included the USS *Carl Vinson*, USS *Nassau*, and USS *Bataan*. Using the hub-and-spoke delivery method, all incoming rescue supplies flew into the GTMO airfield to be unloaded, sorted, and then transported to the various landing zones for distribution as needed. Figure 2 from Commander, Helicopter Sea Combat Wing Atlantic (CHSCWL) provides a description of how many of each T/M/S platforms and ships were used as sea bases.

Unit	Forces	Ashore/Afloat Locations
HM-14	5 x MH-53E	• USS CARL VINSON (CVN 70)
HM-15	3 x MH-53E	• USS BATAAN (LHD 5)
HSC-2	2 x MH-60S	• USS WASP (LHD 1)
HSC-22	3 x MH-60S	• USS NASSAU (LHA 4)
HSC-26	2 x MH-60S	• USNS LEWIS & CLARK (T-AKE 1)
HSC-28	4 x MH-60S	• USNS SACAGAWEA (T-AKE 2)
HSC-9	2 x MH-60S	
HS-11	2 x HH-60H, 2 x SH-60F	• USNS COMFORT (T-AH 20)
HS-15	1 x HH-60H, 4 x SH-60F	• Naval Station Guantanamo Bay, Cuba
9 Squadrons	*30 Helicopters*	• Port au Prince, Haiti

Figure 2. CHSCWL Haiti Force Summary
(Monagle, 2011)

D. U.S. NAVY HELICOPTER RESOURCES FOR HA/DR

The U.S. Navy uses various types of aircraft designed for specific types of missions. They each have size, speed, weight, and space limitations that come into play when deciding which type we should use for HA/DR missions. Each one brings something different to the mission that we will further explore in this section.

1. H-60 Helicopter Background

H-60 helicopter utilization has been a part of naval aviation since 1983 when the SH-60B was introduced (Federation of American Scientists [FAS], 2010b). There are several H-60 variations used for different mission purposes, including anti-submarine warfare (ASW), anti-surface warfare (ASUW), search and rescue (SAR), and cargo lift. The SH-60B's configuration is primarily for Light Airborne Multipurpose System (LAMPS) missions for the Navy. These helicopters are normally onboard cruisers, frigates, and destroyers.

The HH-60H and the SH-60F are utilized onboard the aircraft carriers. There is normally one squadron comprised of six to eight of these aircraft. The primary missions of the HH-60H are combat search and rescue (CSAR) and naval special warfare support. The primary mission of the SH-60F is to detect, classify, and destroy hostile submarines by using ASW. CSAR and naval special warfare support are the secondary missions of the SH-60F. Both helicopter types can also perform other missions such as logistics support (LOG), vertical replenishment (VERTREP), medical evacuation (MEDEVAC), SAR, and ASUW. The helicopters have a maximum gross weight of 21,885 pounds.

The Navy is now in the process of implementing the MH-60R and the MH-60S into its inventory. The MH-60R's design combines the capabilities of the HH-60H and SH-60F, while the MH-60S has replaced the SH-60B. Having the Carrier Air Wing restructured will now allow for two H-60 squadrons with 19 helicopters. There will now be a mix of nine MH-60S/R helicopters onboard the carrier with the other 11 disbursed throughout the rest of the Carrier Strike Group (CSG). The helicopter has a maximum gross weight of 22,500 pounds.

2. H-53 Helicopter Background

The CH-53E operates off amphibious assault ships designed to transport personnel, supplies, and equipment in support of amphibious assault operations. It is normally carried onboard LHA-, LHD-, and Landing Platform, Helicopter (LPH)-type ships. Designed to operate day and night, even in adverse weather conditions, the helicopter has the capability to transport items either internally or externally. The Marine Corps fleet of CH-53E is presently being considering as a medium lift helicopter (FAS, 2010a).

The CH-53E normally seats 37 passengers, but with centerline seats installed, it has the ability to seat 55 passengers. The helicopter has a maximum gross weight of 73,500 pounds but has a maximum weight on wheels of 69,750 pounds.

3. H-46 Helicopter Background

The CH-46E *Sea Knight* is a medium-lift helicopter that operates on amphibious assault ships alongside the CH-53E transporting troops, supplies, and equipment in support of amphibious operations. Other mission tasks this helicopter can provide are over-water search and rescue augmentation, as well as MEDEVAC of casualties to suitable medical facilities. The *Sea Knight* is currently in the process of a phase-out, with the MV-22 *Osprey* as its replacement.

The *Sea Knight* has a maximum gross weight of 24,300 pounds either internally or externally. Passenger capacity is 25, and for MEDEVAC purposes is 15 litters with two attendants. Range for the *Sea Knight* is 132 nautical miles with a speed of 145 knots. The helicopter has a maximum interval of continuous mission operations that is not to exceed eight hours, meaning that the helicopter continues hot refueling without stopping the rotors during the mission. This can be a possible issue when determining the distance needed to travel and the load/unload timeframe needed for certain missions.

4. MV-22 Helicopter Background

The MV-22 *Osprey* is a medium-lift tilt-rotor aircraft, giving it the combined capabilities of a Vertical Take-Off and Landing (VTOL) and the speed range, range, and service ceiling of a turboprop airplane. Some of the mission tasks of the *Osprey* include emergency evacuation and MEDEVAC of casualties to suitable medical facilities. It also provides fleet logistics support, which includes long-range and shore support. The size and abilities make the aircraft a valuable asset to HA/DR missions Marines may support.

Maximum VTOL gross weight for the *Osprey* is 52,600 pounds, while Short Take-Off (STO), has a gross weight of 57,000 pounds. The aircraft's passenger capacity rates at 24, with the ability to carry 12 litter patients with four medical attendants.

5. Summary

This chapter discussed the capabilities of the four aircraft commonly used by the U.S. Navy in HA/DR missions. Each platform specializes in certain missions but have the same basic capabilities for HA/DR. The H-60 is smaller and carries about a third of what the CH-53 can carry, but its smaller size gives it the capability to get in to smaller areas. The CH-46 and the MV-22 have the same passenger capabilities, but the MV-22 has a higher gross weight.

III. CHALLENGES AND LESSONS LEARNED FROM PAST DISASTERS

Previous HA/DR missions provide lessons learned to help correct any issues and find better ways to accomplish a mission. We retrieved lessons learned from the NWDC, and we performed a cross-case analysis to determine if the Navy repeats some of the same issues detailed in the lessons learned. In our analysis we discovered very few of the same issues, which could suggest issues occurred because of national security reasons, because of procurement problems, or because the problem was only relevant to the specific disaster area.

One common theme that continuously came up in the lessons learned was communication. Everything done in the military is planned and briefed to ensure that all of those involved know their responsibilities. However, how and when the military briefs differs between the Navy and the DoD. Communication between the Carrier Air Wing (CVW) staff, aircraft carrier operations department, beach detachment personnel, landing zones (LZs), supply depots, and NGOs is a very complicated process, and it is difficult to ensure everyone is on the same communication network. Having a reliable communications network can play a vital role in helicopter operations during HA/DR missions. The ability to have helicopters in the correct place, with the correct supplies, and at the correct time can make a huge difference in the success of the entire mission.

A. INDONESIA

The Department of the Navy was able to collect valuable lessons learned data from the Indonesia tsunami that will be able to assist them in HA/DR missions. It will be evident later in the chapter when we discuss Haiti that they repeat very few of the same mistakes but still have the same underlying issues such as communication and training.

1. Communication Lessons From Indonesia

Communicating the proper location on which to focus relief efforts required a combination of working with government officials, watching news coverage, and listening to the recommendations from the survey teams. During the Indonesian tsunami relief, some villages set up their own communication network by hanging up colored flags to indicate what type of supplies the villagers needed (Joint Lessons Learned Information System [JLLIS], 2008d).

Aircrew debriefs on safe and acceptable landing zones were critical to the tsunami relief success. Intelligence officers on board the aircraft carrier updated charts and kneeboards with latitude and longitude information to ensure aircrew flew directly to safe LZs to drop off supplies. Quickly setting up a communication network with NGOs for safely flying in and out of the area of operation (AOR) helps ensure the NGOs safely arrive at their destination while keeping them from interfering and slowing down helicopter support operations (JLLIS 2008d).

2. Production Lessons From Indonesia

Personnel transport is as much of a priority in HA/DR missions as the movement of supplies. The SH-60 helicopter's design is for ASW, SAR, anti-ship warfare, cargo lift, and special operations. In response to the ever increasing numbers of HA/DR missions, the SH-60 has added another mission aspect to its list of uses for naval air support. During Operation Unified Assistance (OUA), a lesson learned was that the configuration for air wing carrier-based helicopters was not for PAX transfer, but after reconfiguration, was more suitable for this purpose.

Three versions of the SH-60, as well as the MH-60, participated in OUA and all configurations were different, giving each one different maximum PAX capacities. A description of the aircraft T/M/S, normal gear used or internal equipment, and PAX capacity are in Table 4 (JLLIS, 2008c).

Table 4. **Maximum Passenger Capacity**

Aircraft T/M/S	Normal Gear Used/ Internal Equipment	Number of Air Crewmen	Passenger Capacity
SH-60B	Sonabouy Launchers and Magnetic Anomaly	3	4 - 5
SH-60F	Dipping Sonar and Reeling Machine	4	4 - 6
SH-60H	Configured for SAR Missions	4	6 - 13
MH-60	Configured for Vertical Replenishment	4	21

Removing extra equipment from the helicopters would double the maximum PAX capacity these aircraft could carry (JLLIS, 2008c). Reconfiguration of these aircraft took minimal time and the adaptations had very little impact on the aircraft's operational capabilities. Even though these aircraft were easy to reconfigure in a minimal time period, having aircraft already configured would save even more time in relief efforts.

The use of rotary-wing aircraft allowed Expeditionary Strike Group Five (ESG-5) to effectively and efficiently deliver bulk HA/DR supplies along the northwest coast of Indonesia directly to those in need. During a 15-day period, ESG-5 was able to deliver approximately 1.5 million pounds of supplies to the tsunami-battered Indonesian people. Because members of ESG-5 were able to leapfrog bottlenecks and inefficiencies ashore, they maximized delivery of HA/DR supplies (JLLIS, 2008e).

The Navy designated Singapore as the main logistics hub for the purpose of sea basing during the relief efforts in Indonesia. CLF ships loaded with HA/DR supplies would travel the Straits of Malacca from Singapore to the relief operating area (ROA) assigned. Rotary-wing aircraft played a vital role in relief efforts by permitting naval commanders to exploit their advantages. The aircraft delivered supplies directly to the areas affected. Isolated pockets of survivors were able to receive relief assistance from the rotary-wing aircraft, which could reach the survivors along the coast and the river valley leading inland. Logistics efforts operated best through the sea, minimizing touch points and therefore maximizing the amount of timely relief provided to survivors (JLLIS, 2008f).

The sole use of helicopters from the USS *Abraham Lincoln* was to aid relief missions when they first arrived in theater. As the operation progressed and more ships arrived in theater, the helicopters began doing more PAX and mail movement, taking them away from relief missions. Supporting some of the distinguished visitor (DV) and media flights eventually affected resource allocation because some of these flights required standby helicopters to be turning and ready to go. Generation of flight schedules occurred late in the evening for the next day's flight operations. Many times, after the flight schedules were generated there were deviations, causing issues with helicopter asset management. The carrier's operations department needs to be able to factor in the DVs and media to ensure that the HA/DR mission is not affected (JLLIS, 2006a).

3. Evacuation Lessons From Indonesia

The tsunami in Indonesia destroyed much of the road infrastructure in the ROA, as well as the Indonesian medical infrastructure. Helicopters played a vital role in transporting displaced personnel requiring medical attention. Time is a major factor in the saving of a life, but because the USS *Mercy* was not equipped with its own helicopters to air lift patients, it had to rely on U.S. helicopters to make these transports, preventing the use of these helicopters for other missions. If the *Mercy* had its own helicopters, it could have directly supported the mission of supplying medical assistance at a quick and constant pace (JLLIS, 2008a).

4. Training and Environmental Lessons From Indonesia

Helicopter Anti-submarine Squadron Light (HSL) aircrew lacked the required training to perform confined-area landings. Putting aircrew in this situation placed them at a higher risk in an already high-risk situation. In order to overcome this situation, senior aircrew conducted the training onsite. Training aircrew to perform confined-area landings before a deployment can allow pilots to be ready for these types of situations and prevents the waste of valuable time that could be focused on the HA/DR mission (JLLIS, 2006b).

The safety of the helicopter aircrew is always a concern for relief commanders during relief efforts. It is important that the aircrew's briefings are proper prior to a mission on the AOR to try to minimize any disrespect or apparent insensitivity to the local residents. During the Indonesian tsunami relief, there was some concern about the religious connotations of using the Red Cross symbol rather than a red crescent, due to the large Muslim population in the area (JLLIS, 2008b).

The United Nations (UN) relied on other organizations such as the U.S. to deliver supplies early in the response effort. The United Nations stated that it would have 12 to 15 helicopters to help support helicopter operations, but they were only able to supply seven in theater throughout the mission (JLLIS, 2008f).

B. HAITI

We can see in the lessons learned from the Haiti earthquake that the Navy has learned some lessons from previous disasters but continues to have the same underlying issues in communication and training. This could attest to the fact that each HA/DR mission is different and has certain aspects that must be handled differently.

1. Communication Lessons From Haiti

E-mail, local cell phones, and other communication devices are most likely down after a disaster strikes—as demonstrated in the recent Haiti earthquake disaster. When the use of OCONUS and BlackBerry cell phones is necessary, it takes approximately a month to acquire the proper overseas data package for the cell phone to work. Because HA/DR missions are so hard to predict, it is very hard to acquire this capability in such a short period. The recommendation is that each sea-based command has its own unlocked global systems for mobile (GSM) phones. It has become common for the military to use BlackBerry phones with GSM to send text messages and e-mails for communication. In addition, the Navy uses these phones as modems that multiple computers can link to and send e-mails from. However, the BlackBerry has had problems with communicating sensitive information sometimes considered classified information (JLLIS, 2010c).

During the Haiti relief efforts, it was realized that the air plan from the aircraft carrier and the surface plan from the amphibious ships needed to be published in a timely manner to facilitate the ships' planning for the next day's missions. Amphibious ship and helicopter movements needed to be staggered in order to avoid any conflict between the two. When amphibious ships and helicopters do not communicate properly, it can lead to missed delivery of supplies or transport of personnel needed to complete the HA/DR missions. This is why it is important to avoid assuming that the surface and air plans have been de-conflicted to account for cargo and PAX movement (JLLIS, 2010d).

When relief personnel were distributing supplies to local churches, organizations, and groups, many of those needing relief attempted to obtain more than allotted to their group. As a result, it became crucial to track the recipients of the HA/DR supplies that were delivered. Obtaining addresses and other forms of information made it much easier to track who got which supplies and when (JLLIS, 2010i).

Having a separate transmission frequency devoted to aircraft mission communications could possibly reduce the transmission traffic and allow for a better flow of communication and setting of priorities for aircrew. During OUR, aircrews often had the task of transporting personnel or supplies, and they sometimes discovered, after arriving at the LZ, that another helicopter had just taken the personnel or supplies away. This miscommunication wasted precious time and resources that could have been better used supporting the mission (JLLIS, 2010h).

2. Production Lessons From Haiti

During the Haiti relief efforts, the best mix of medium lift (e.g., MH-60S) and heavy lift (e.g., CH-53E) helicopters depended on the specific landing zone area. The ability to get into densely populated areas with the MH-60 proved to be valuable in Haiti. Limited use of the CH-53 in these areas was mainly due to the rotor backwash. After the first few days, relief personnel were able to move more of the relief supplies by ground and to start using the aircraft more for personnel and patient transport.

The space and heavy lift capability of the CH-53 make it valuable when communication ground lines are not available and when there is a need for amphibious lift to move supplies. The MH-60 serves better in concentrated disaster areas where logistics depend on intact lines of communications. It is important for the area commander of a disaster relief mission to assess the needs of a particular disaster for better assignment of aircraft to HA/DR task forces.

The SH-60 provides airlift support and supplies over short distances, confined spaces, or sloping landing areas. Its small cargo and PAX area limit its operational capacity. The CH-53 specializes in transporting large amounts of supplies and personnel. However, due to its need for a large landing area, the CH-53 will normally only fly to and from the ships and airfields for their assigned missions (JLLIS, 2010a). This limits its ability to reach confined areas in need of relief.

Air Transit Office (ATO) requirements significantly increase during HA/DR missions. During the first two weeks of the Haiti HA/DR mission, the ATO facilitated the movement of over 8,100 personnel and 2.9 million pounds of cargo (JLLIS, 2010l). This is not a part of the normal operations of a CVN during a deployment. The process of effectively operating the ship as a sea base is considerably different from cyclic operations the ship normally conducts underway. Communication between air operations and the ATO are critical to efficient operations, and this communication is difficult when the ATO is supporting more personnel and cargo than normal. The ATO should be augmented by both junior and senior personnel to effectively operate in the HA/DR environment.

Relief supplies were arriving to Guantanamo (GTMO) base supply faster than the Joint Logistics Hub (JLH) could process them. This increased the need for operators for material handling equipment such as K-loaders and 10K and 6K forklifts. This shortage could have caused excessive delays in handling, processing, and shipping materials to specific disaster areas. The cooperation between the USS *Carl Vinson* (CVN-70) and the JLH minimized the impact by transferring personnel from the ship to work at the JLH. In the future, all JLHs will need augmentation with the proper qualified personnel to handle the additional workload (JNLLIS, 2010b).

Having the right amount of support equipment and qualified personnel to operate is essential. During OUR there was only one aircraft power cart and liquid oxygen cart available to support 13 aircraft forward deployed to GTMO, impacting the squadron's ability to perform maintenance until more support equipment arrived. There is a need for the proper accounting of additional personnel and support equipment, especially those pertaining to maintenance, when standing up forward deployed HA/DR bases (JLLIS, 2010n).

The way items from the various organizations were packaged made it difficult at times to move and deliver the relief items. One example was the donated water bottles, which came in a variety of packaging. Water bottles taped together became very hard to palletize and stack compared to bottles received in boxes. These taped water bottles eventually fell off the pallets and broke open on the decks during transport up and down the ramps (JLLIS, 2010e). Shrink-wrapped cargo received from commercial vendors and pallets stacked higher than recommended safe levels caused pallets to fall during vertical replenishment, creating a safety issue for personnel and the aircraft (JLLIS, 2010f).

During the initial rush to push large amounts of relief supplies to Haiti, the Navy accepted responsibility for transporting cargo that required very specific delivery requirements for NGOs. These special delivery requirements resulted in command-level planners managing public relations with the consigners back in the U.S. and the media attached to the cargo. These parties could not readily understand the delay in the transportation of this cargo ashore. As spare helicopter sorties became available, the Navy moved the cargo to the designated position. Planners who accept cargo with very specific destinations on behalf of NGOs, such as an address or latitude and longitude, need to take into account the logistical impact of delivering this cargo. Accepting this type of cargo may actually slow the flow of time-critical HA/DR supplies. It may be beneficial to condition the acceptance of such cargo on the ability to transport it to a location decided upon by the commander of the task group (JLLIS, 2010j).

Although the advertised water production capacity of the aircraft carrier is 400,000 gallons per day, the realistic capacity for producing, packaging, transporting, and distributing the water is significantly less. Initially, when the aircraft carrier arrived, there was no capability to distribute water produced because there were no containers in which to ship it. Subsequently, shipments of five-gallon containers and collapsible water flasks allowed distribution of larger quantities of water, but the shipments were then limited by the lift capability of aircraft conducting sorties from the ship. Even in the best case, the capacity to deliver water remained significantly below the 400,000 gallon-per-day capability of the ship (JLLIS, 2010m).

3. Evacuation Lessons From Haiti

The USS *Carl Vinson* advertised its ability to accommodate up to 50 medical beds, but available doctors and equipment limits its real capability to handle injuries from severe disasters. With limited surgical capacity, the real throughput of the ship is significantly less than advertised. MEDEVAC patients use a significant number of the helicopters available for use when supporting HA/DR missions. The Navy could supplement the aircraft carrier and other medical facilities with additional doctors and equipment for a more efficient mission. During OUR, even when a sufficient number of doctors and supply of equipment supplies arrived on the USNS *Comfort*, which had an advertised capacity of 1,000 beds, it was learned that 400 of those beds were bunk style and not suitable for non-ambulatory patients (JLLIS, 2010m).

In extreme circumstances, the flight deck can operate for longer durations at the cost of increased risk of mishaps due to deck crew fatigue. High demand for air assets routinely requires more than the 10-hour limit. In the early phases of OUR, the operational tempo drove flight operations routinely beyond the 10-hour Amphibious Assault Ship (LHA/LHD) Naval Air Training and Operating Procedures Standardization (NATOPS) limit for continuous flight operations. Additionally, the ships needed to fly numerous single-spot MEDEVAC responses in the middle of the night. This required activation of the deck crew during what would normally be their down time. Augmentation of the air department onboard the ship is a necessity prior to deploying for HA/DR contingency operations. This mitigates the risk of unpredictable flight operations. Increasing the number of flight deck personnel from the waterfront ships by 20 would greatly enhance deck-operating capability and reduce the risk of injury or mishap (JLLIS, 2010k).

During the opening days of OUR, the mass causality situation resulting from the earthquake quickly overwhelmed the medical capability on the scene. Request for MEDEVAC flights far exceeded the available air assets. USNS *Comfort* became the central point for all evacuation requests. USNS *Comfort* requested air assets through

Tactical Air Control Squadron Two One (TACRON 21), which in turn assigned missions without any prioritization or precedence. The on-scene medical assessment lacked the details necessary to prioritize effectively. Many times, the U.S. Navy sent several assets to the same request because no tracking system was in place. MEDEVAC requests were incomplete, missing important information, including pick-up location, destination, number of patients, and the time the patient would be ready for transport. Aircraft tasking was haphazard and aircrews were pushing the limits of safety and operational risk management (ORM). Without prioritization, the treatment of each MEDEVAC case was as if it were urgent, when in fact many patients could have waited. In multiple cases, aircraft rushed to LZs only to find that patients were not there yet, or that the LZ information was incorrect. This wasted valuable resources that could been better used expediting supplies or MEDEVACS in need of immediate attention (JLLIS, 2010g).

A temporary helicopter shelter was installed onboard the USNS *Comfort*, which kept the flight deck from being used to its full potential. The shelter housed and provided maintenance for an air detachment of two MH-60s that were onboard for medical airlift. When the flight decks of the *Carl Vinson* and the USS *Bataan* were not available, having the helicopters on the *Comfort* allowed for some operational flexibility.

4. Training and Environmental Lessons From Haiti

Military forces working from a sea base deliver effective support at the onset of the crisis and leave a minimal footprint ashore. During the Haiti mission, Marines supported by the Amphibious Readiness Group (ARG) helicopters could return to their ships at night, thereby reducing negative perceptions of American imperialism or a military takeover of the humanitarian mission (JLLIS, 2010o).

C. CHAPTER SUMMARY

In this chapter, we presented challenges and lessons learned from the relief efforts in Indonesia and Haiti pertaining to the U.S. military airlift response. Indonesia was the first of the two events to occur, but some of the same issues persisted five years later in Haiti. Both efforts shared a few of the same basic problems with communication, operations, and training that caused scheduling complications with helicopter operations or the over-demand of helicopter use during helicopter operations and slowed down relief efforts. It is important that the DoD take these lessons and challenges into consideration when it plans and trains for future HA/DR missions. Improving efficiency and preventing the relief workers from making the same mistakes is important when evaluating the lessons learned from past disasters.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. MODELING IN SUPPORT OF RESEARCH QUESTION

Every natural disaster has the possibility to present a unique and dynamic logistical problem. The strength, speed, and devastation of a natural disaster are a few of the things that will determine how many rescue supplies, as well as the number of victim transports, are needed to support a disaster relief mission. It is important to make a timely decision to identify the needed resources in order to send them to the disaster area as quickly as possible. This timely decision will help to determine how quickly the delivery process will happen. By analyzing the similarities and differences of the CSG and the ARG, we prepared a cross-case analysis (Mathison, 2005) to evaluate the effectiveness of helicopter operations in disaster relief missions. Before we could analyze each T/M/S platform in our model, we needed to establish what kind of disaster we were dealing with and how much time the DoD had to put together a response.

A. MODEL DISASTER SCENARIO

In our model we used a Quadrant III, localized and sudden onset disaster, as discussed in Chapter 2. The disaster scenario we modeled begins with a satellite picking up a tropical storm in the Pacific Ocean. Weather experts are confident that this tropical storm will hit a specific island. The Navy reviews its available resources and sends a CSG from the Seventh Fleet and an ARG from the Fifth Fleet for possible assistance. Because of the advanced warning of this potential disaster, it allows the CSG to arrive on scene two days after the storm hits (D+2) and the ARG to arrive on Day 7 (D+7). Upon arrival, the Disaster Relief Assessment Team (DRAT) informs the rescue team that there is a local population of 3,000,000, with 420,000 displaced personnel and over 3,700 people who need to be MEDEVAC to safety. The DRAT informs the U.S. military that all of the main roads leading to the affected areas are flooded and the only way to get aid to the area is by helicopter. There is a supply hub set up on a nearby island that has a runway where aircraft are bringing in supplies. This runway can also serve as a landing zone for helicopters to transport personnel and supplies in and out. After receiving all of the necessary information, the CSG begins flight operations as it waits for other support platforms to arrive on scene.

B. OVERVIEW OF MODEL

The purpose of this model is to answer one question: How can we be more efficient in meeting the overall demands of the HA/DR mission? To get at this question, we constructed the model to help identify key areas in which we could improve the efficiency of the Navy and Marine Corps delivery process. This overview explains how we obtained, used, and analyzed the research information we included in the model.

1. Helicopter Raw Data

Using information gathered from program managers and data analysts from Naval Air Systems Command (NAVAIR), as well as the official NAVAIR website (www.navair.navy.mil), the setup of the model took into consideration the following information for the SH-60, H-46, H-53 and MV-22 performing operations during a HA/DR mission. The max cargo weight and max passenger capacity information is from the specific T/M/S platforms' NATOPS manuals. Table 5 describes each type of raw data we used for the aircraft.

Table 5. Helicopter Input Data Types

Aircraft Mission Capable Percentage	Due to planned and unplanned maintenance, it is very rare to have 100% of the aircraft on scene mission capable.
A_o (Operational Availability)	The number of aircraft available multiplied by the mission capable percentage of that day. This number will decide the percentage of aircraft that will fly each route. A_o will change when specific T/M/S platforms experience MC degradation (Office of the Chief of Naval Operations, 2003).
Max Cargo Weight (MCW)	The amount (in pounds) of supplies each T/M/S can carry and safely deliver in that environment. This number will change depending on the temperature, humidity, and winds.
Max Passenger Capability	This is the number of passengers that each T/M/S can safely carry.
Aircraft Available on Scene	Where each ship was when given the order to respond to the HA/DR mission will determine when, what type of, and how many aircraft show up.

2. Timeline

The use of a timeline helped determine when response resources, such as the CSG and ARG with the various T/M/S platforms, arrive and depart on the scene. Day 0 (D+0) was the day of the disaster. Day 14 (D+14) was the last day of flight operations in support of the mission that we modeled. Because of the fact that the various T/M/S aircraft are coming from different geographical locations, it was important to be able to assess the impact of different arrival timeframes.

3. Demand

Demand was broken down into six separate categories. Displaced personnel, overall water, critical survival water, food, MEDEVACs, and medical supplies were the items needing attention in the model. Knowing the demand was necessary to determine efficient responses.

a. Displaced Personnel

Before understanding how we calculated the other demands, we needed to calculate the number of displaced people who need water, food, medical supplies, MEDEVAC, and transportation to a safe area from the total population. We did not use information from Indonesia or Haiti because their disasters derived from earthquakes and our model uses a tropical storm. By using data from fact sheets on Tropical Storm Ketsana, we were able to develop percentages of displaced personnel (USAID, 2009).

Multiplying the total affected population of 3,000,000 by the 14% calculated from the fact sheets, we arrived at the number of 420,000 displaced people that need water, food, medical supplies, and transportation. It is important to remember that the number of displaced drives the overall daily demand in the model. The displaced daily demand dropped by 1.5% of the total affected population each day, which ultimately dropped the daily water and food demands by the same percentage (USAID, 2009).

b. Overall Water

The USAID field guide recommends 8.5 gallons of water a person per day, which converts to 70 pounds of water per displaced person a day. This total includes the total amount of water needed to stay hydrated, cook, and bathe. By multiplying the number of displaced personnel by the 70 pounds needed per day, we calculated 29,400,000 pounds of water demanded for the first day (USAID, 2005). This percentage drops as the displacement percentage drops every day.

c. Critical Survival Water

The USAID field guide recommends that each person needs one fifth of their total water needs for hydration purposes. This model focuses on how quickly we can meet the critical survival water demand. In order to calculate this demand we divide the total water demand by five. Therefore, a total water demand for the day at 29,400,000 pounds of water resulted in 5,880,000 pounds of critical survival water needed on the first day of flight operations. This percentage drops as the displacement percentage drops every day.

d. Food

The food demand calculations derive from the USAID field guide manual, which sets a requirement of 540 grams per person per day (USAID, 2005), or 1.2 pounds of food per person per day. By multiplying 420,000 by 1.2 you get a demand of 504,000 pounds of food on the first day of operations. This percentage drops as the displacement percentage drops every day.

e. MEDEVAC

We calculated MEDEVAC demand at 0.0009% of the total displaced population by using MEDEVAC data from fact sheets on Tropical Storm Ketsana (USAID, 2009). By multiplying 420,000 displaced by 0.0009%, we found that 378 people would need immediate medical attention and transportation to the supply hub. The MEDEVAC demand does not drop by the same percentage as the displaced percentage drops. MEDEVAC demand that is not met rolls into the next day's MEDEVAC demand. This continues until all MEDEVACs to the hub are complete.

f. Medical Supplies

By using data from fact sheets on Tropical Storm Ketsana, we were able to develop percentages of MEDEVAC personnel (USAID, 2009). Because of the lack of information, we assumed that one out of every ten people who need medical attention would need MEDEVAC. Therefore, if 378 people need MEDEVAC, we multiplied that number by 10 and came up with 3,780 people who needed standard medical attention. We then multiplied the 3,780 people by 1.22 pounds a day per person, giving a product of 4,612 pounds of medical supplies needed on the first day of operations (Department of the Army Headquarters, 1990). Due to previous medicine delivered and people receiving treatment, we assumed that this demand would drop twice as fast as the displacement percentage.

4. Mission Capability Percentage

We requested mission capability percentage (MC%) information from the Warfighter Response Center located on the NAVAIR website at www.navair.navy.mil for each T/M/S platform. Each T/M/S platform was not able to provide the same number of years' worth of data. We took the average MC% of all years available for the SH-60, H-46, H-53, and MV-22, which were 68%, 75%, 76%, and 67%, respectively. The MC% ultimately drives how many aircraft are available for use. If each T/M/S platform had the same number of aircraft, the T/M/S platform with the higher MC% would have more aircraft available for use than a T/M/S platform with a lower MC%.

As flight hours increase during the missions, there is a potential for an increase in maintenance failures on the aircrafts. The local supply systems on the ships do not have the inventory to support a drastic increase in failed aircraft items. This increase would be due to increased HA/DR flight missions, in which the aircraft experience almost three times as many flight hours as normal. This increase in failed items depletes the local supply system, which lowers the MC%. To approximate the effects of increased maintenance failures, we modeled an MC% degradation of 10% every five days of flying.

5. Routes and Route Capacity

In our scenario, flight operations run between three main areas: the supply hub, the ship, and an LZ within the disaster area. The three areas are located approximately 10 nautical miles (11.5 miles) from each other. In the disaster scenario, the LZ has been severely flooded and needs food, water, and medical supplies transported in and injured and displaced people transported out. Because of the damage to the infrastructure, helicopters were determined to be the best means of transportation for the relief mission. The supply hub serves as the primary distribution point for food and medical supplies, as well as a drop-off point for MEDEVAC and displaced people. The ship supplies all water demand. The model uses four possible routes to handle the transportation demands of the disaster. These routes are described in Table 6.

Table 6. Route Descriptions

Route	Route Type	Route Description
1	Ship to LZ to Ship	On this route, they load water on the ship, unload at the LZ, and return empty to ship.
2	Ship to LZ to Hub to Ship	On this route the designated helicopter loads water on the ship, unloads water at the LZ and loads up MEDEVAC and/or displacements, unloads them at the supply hub, and then returns to the ship.
3	Ship to Hub to LZ to Ship	On the route, there is no loading of water on the ship. They fly empty to the hub, load food and medical supplies at the hub, unload food/medical supplies at LZ, and then return to the ship.
4	Ship to Hub to LZ to Hub to Ship	On this route, there is no loading on the ship. They fly empty to the hub, load food and medical supplies at the hub, unload at LZ and load MEDEVAC and displacements, unload at supply hub, and return to the Ship.

The sorties, or one completed flight mission per route per day for Routes 2 and 3, are the same, with three sorties for each one. Routes 1 and 4, with six and two sorties, respectively, differ because of the number of stops the helicopters need to make in order to finish their route. In order to figure out how many sorties were available for each route, we made a few assumptions. We assumed it took 30 minutes to load and refuel the helicopter, 30 minutes to unload it, and 30 minutes to fly from any of the three locations to the other.

Through previous lessons learned, all helicopter flight operations performed were during the daylight. We therefore assumed that there were only 720 minutes, or 12 hours, of flight time available each day. We then divided the total sortie time into the flight time available to get the number of sorties the helicopters on each route can perform per day. We assumed that an aircraft could perform its mission as long as it did not exceed 180 minutes of flying time. Table 7 describes the route types and the times for each one.

Table 7. Route Type and Flight Time

		Load	Flight	Unload & Load	Flight	Unload & Load	Flight	Unload & Load	Flight	Total Flight Time	Total Route Time	Total Sorties/ Route	Flight Time Available
Route#1	Ship-LZ-Ship	30	30	30	30	0	0	0	0	60	120	6	720
Route#2	Ship-LZ-Hub-Ship	30	30	60	30	30	30	0	0	90	210	3	
Route#3	Ship-Hub-LZ-Ship	30	30	30	30	60	30	0	0	90	210	3	
Route#4	Ship-Hub-LZ-Hub-Ship	30	30	30	30	60	30	30	30	120	270	2	

Each route capacity is driven by the number of aircraft available multiplied by MCW or PAX, multiplied by sorties available per route for each T/M/S platform on that route. For example, if there were two SH-60s and two MH-53Es assigned to Route 1 on Day 2, the max capacity for that route would be (2 * 21,885 lbs. * 6) + (2 * 69,750 lbs. * 6) for a total route capacity of 1,099,620 pounds of water for D+2. It is important to remember that the route capacity changes as the aircraft assigned to the route changes due to the changing demands and priorities of the mission.

6. Priority

Since there is no clear-cut set of rules for establishing priority between food, critical survival water, overall water, medical supplies, MEDEVACs, and displacements, the information we used to set the priorities for the model needed a baseline. In order to accomplish this, we multiplied mission capable aircraft by the percentage of aircraft devoted to a specific route. All four routes in the model received 25% of each T/M/S available.

The model transports food and medical supplies along the same route segment. Therefore, we needed to establish a priority of food relative to medical supplies. The priority for food demand calculation derives from using a percentage of the total volume of all demand. Since we had a food demand of 504,000 pounds of food and a medical supply demand of 4,611 pounds, we added them and divided it by the food demand and discovered that the food demand was 99% of the combined total, while the medical percentage was calculated as 100 - 99% = 1%.

It is important to remember that this demand changes on a daily basis. In most cases, the percentage split gets smaller for medical supplies because the demand drops twice as fast as the food demand.

MEDEVACs and displaced people also share a route segment. In this case, it is important to remember that delivering MEDEVACs takes full priority over delivering displaced personnel.

7. Efficiency

In this model we analyzed the percentage of demand met across all six categories over the 14-day mission. Simply stating that the model delivered 50,000,000 pounds of supplies may sound impressive; however, this number does not tell us if the model met total demand. These models examine different ways to increase the total demand percentage, as well as the tradeoffs needed to accomplish this.

C. RESPONSE A VERSUS RESPONSE B

Every Carrier Air Wing (CVW) and Marine Expeditionary Unit (MEU) carries a slightly different number of T/M/S platforms on deployment. Based on the research of previous HA/DR missions, we chose to model the most conservative combination of aircraft attached to a CSG and ARG. We initially chose to model two possible responses. The first model, considered the traditional model, consists of the old CSG and ARG aircraft makeup that has one H-60 squadron in the CVW and a CH-46 assigned to the MEU. The second model, considered the new version, is slightly different, with the CVW having two H-60 squadrons and the MV-22 replacing the CH-46 in the MEU. The two responses titled Model 1 Response A, considered the traditional model, and Model 2 Response B, considered the new model, were used to demonstrate two different CSG and ARG designs.

In Response A, the CSG had 15 SH-60 helicopters attached, seven attached to the aircraft carrier and eight more embarked on the destroyer squadron and supply ships in the strike group (U.S. Navy, 2011). The ARG traditionally has nine CH-46s and four CH-53s attached to the LHD, as well as six SH/MH60 helicopters embarked on the Dock Landing Ship LSD and LPD ships. In addition, in Response A of the model, there were six SH-60 helicopters embarked on two destroyers and a cruiser ordered onto the scene. In this response, the total aircraft on scene by Day 14 was 27 H-60s, eight MH-53s, four CH-53s and nine CH-46 helicopters. The H-60 arrival was 13 on Day 2, two on Day 3, seven on Day 7, and two each on Days 9 and 10. The MH-53s arrived on Day 2 while the CH-53s and CH-46s did not arrive until Day 7.

Response B was set up with the new composition of aircraft that the U.S. Navy and Marine Corps are working towards using. The CSG now has 19 SH-60 helicopters attached to the CAG, which is an increase of four SH-60 helicopters in the CSG. The helicopters are now a part of the CAG and, depending on the composition of the destroyer squadron, a detachment of helicopters may embark on their ships. This ensures that the CAG has a direct say as to a mission’s priority and the best use of the carrier air group’s resources. The ARG now has 10 MV-22 aircraft attached to the ARG instead of the CH-46. There are still four CH-53s and six MH/SH-60 helicopters embarked on the LSD and LPD. The total aircraft on scene by Day 8 in this response was 31 H-60s, eight MH-53s, four CH53s, and 10 MV-22 aircraft. The H-60 arrival was 17 on Day 2, two on Day 3, and two each on Days 7, 8, 9 and 10. The MH-53s arrived on Day 2 while the CH-53s and MV-22s did not arrive until Day 7.

THIS PAGE INTENTIONALLY LEFT BLANK

V. MODEL 1: ANALYSIS RESPONSE A VERSUS RESPONSE B

In this chapter, we examine Model 1 results between Response A and Response B. We decided to use the total percentage, total pounds, and total passengers delivered in order to give the best description of the model's results. The total percentage of demand delivered for each of the six categories shows the demands that the model did and did not meet. This chapter explains why the model did not meet those demands and some possible changes we could make to the model in order to reduce the overall unmet demand. The total pounds and passengers delivered describe exactly how much demand each model delivered when comparing Response A and Response B models to each other. When the volume of water demand is high, delivering 1% more or less over the mission may not explain the difference as well as showing that the model delivered one million more or less pounds of water over that same mission.

A. RESPONSE A

1. Results

The Response A model did not meet the critical survival water needs on any day over the 14-day mission. The total critical survival water shortage gradually declined from 4,858,320 pounds on Day 2 to 3,149,610 by Day 14. Therefore, in this case, the model met only 28% of the critical survival water demand over the 14-day mission. The model never met overall water demand (which includes critical survival water demand) and the unmet demand gradually decreased from 28,378,000 pounds on Day 2 to 22,435,000 pounds by Day 14. The model did, however, meet 100% of the food demand by the end of Day 2.

The model met all medical supply demand by the end of Day 2. In this response, we had three people remaining from Day 2, so in reference to MEDEVAC, the model delivered everyone who needed immediate medical attention by the end of the first flight on Day 3. There was a total transfer of 7,168 displaced people to safety over the 14-day mission.

Table 8 gives a breakdown of the total percentage of demand met for the six categories, as well as a breakdown of the total passengers and pounds delivered over the 14-day mission period. This model delivered a total of 25,526,493 pounds of food, water, and medical supplies, as well as 8,743 passengers to safety.

Table 8. Response A Timeframe Breakdown

	Day 1-6 Total Delivered	Day 1-6 Demand	Day 1-6 Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Day 7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	5,502,330	28,518,000	0.19	14,032,260	41,042,400	0.34	19,534,590	69,560,400	0.28
Water	5,502,330	142,590,000	0.04	14,032,260	205,210,000	0.07	19,534,590	347,802,000	0.06
Food	2,444,400	2,444,400	1.00	3,517,920	3,517,920	1.00	5,962,320	5,962,320	1.00
Medical Supplies	13,489	13,489	1.00	16,094	16,094	1.00	29,583	29,583	1.00
MEDEVAC	378	378	1.00	0	0	0.00	378	378	1.00
Displacements	1,197	420,000	0.00	7,168	420,000	0.02	7,168	420,000	0.02
						Total Pounds	25,526,493		
						Total PAX	7,546		

2. Analysis

Aircraft utilization for the model is 100% for delivering water, MEDEVAC, and displacements. With the 25% distribution of aircraft, the model meets food demand every day with capacity to spare. Days 2 through 14 had excess aircraft utilization that gradually grew from 12% on Day 2 to 59% spare capacity by Day 14. Under the 10% mission degradation, all T/M/S felt the effects of the degradation. Table 9 explains how each T/M/S was affected and when the affect occurred. We cover the effects of the degradation on lost capacity in Table 10.

Table 9. Mission Affectability on Aircraft

Effects of 10% Degradation													
T/M/S	Day 2 MC%	Aircraft on Scene	Ao	Day 7 MC%	On Scene	Ao	Day 2 Difference in MC%	Aircraft Decrease	Day 12 MC%	On Scene	Ao	Day 2 Difference in MC%	Aircraft Decrease
SH-60	0.68	13	8	0.61	22	13	15	2	0.55	27	14	18	4
MH-53E	0.50	8	4	0.45	8	4	4	0	0.41	8	3	4	1
CH-46	0.00	0	0	0.75	9	6	0	0	0.67	9	6	7	1
CH-53E	0.00	0	0	0.75	4	3	0	0	0.68	4	2	3	1

Response A is a simple baseline model that shows poor aircraft utilization and maintenance capability percentages. By not using the available aircraft 100% of the time and not accounting for specific maintenance associated with the increased flight hours, this model lost opportunities to meet the critical survival water, overall water, and displacement demands.

The lost operational aircraft data in Table 10 shows how many aircraft were lost over the 14-day mission for each T/M/S platform due to the 10% mission capability degradation. By multiplying those lost aircraft by the number of sorties they fly per day and by their MCW, the total lost capacity due to maintenance failures is 3,628,980 pounds.

Table 10. Response A Lost Capacity

T/M/S	Timeframe	Lost Aircraft	Lost Capacity
SH-60	D7 - D11	1	656,550
	D12 - D14	4	393,930
			1,050,480
MH-53	D7 - D11	0	0
	D12 - D14	1	1,255,500
			1,255,500
CH-46	D12 - D14	0	0
CH-53	D12 - D14	1	1,323,000
		Total	**3,628,980**

The overall percentage of demand met over this mission shows that this model only meets 28% of its critical water, 6% of its overall water, and 1.7% of the displacement demand. By not establishing a priority system that maximizes the mission's operational available aircraft and taking steps to maintain MC%, this model would require other responding organizations to pick up the remaining 72% of the critical water survival, 94% overall water, and 98.3% displacement demands.

B. RESPONSE B

1. Results

The Response B model did not meet critical survival water on any day over the 14-day mission. The total critical survival water demand gradually declined from

4,700,000 pounds on Day 2 to 2,600,000 pounds by Day 14. This meant that model was able to meet 35% of the critical survival water demand over the 14-day mission. The model was also not able to meet the overall water demand during the 14-day mission. It gradually decreased the unmet demand from 28,200,000 pounds on Day 2 to 21,900,000 pounds by Day 14. In the case of overall water demand, the model met 7% of the demand over the mission. There was 100% delivery of food for every day of the mission.

The delivery of medical supplies for every day of the mission was 100%. The model was able to deliver all 378 MEDEVAC personnel who needed immediate medical attention on the first day of flight operations. The response was able to transport 8,793 displaced personnel.

Table 11 gives a breakdown of the total percentage of demand met for the six categories. The table also breaks down the total passengers and pounds delivered over the 14-day period mission. The model was able to deliver a total of 38,821,204 pounds to the landing zone and 9,171 passengers to safety.

Table 11. Response B Timeframe Breakdown

	Day 1-6 Total Delivered	Day 1-6 Demand	Day 1-6 Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Day 7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	6,043,984	28,518,000	0.21	18,283,444	41,042,400	0.45	24,327,428	69,560,400	0.35
Water	6,043,984	142,590,000	0.04	24,327,428	347,802,000	0.07	24,327,428	347,802,000	0.07
Food	2,444,400	2,444,400	1.00	5,962,320	5,962,320	1.00	5,962,320	5,962,320	1.00
Medical Supplies	13,489	13,489	1.00	29,583	29,583	1.00	29,583	29,583	1.00
MEDEVAC	378	378	1.00	0	0	0.00	378	378	1.00
Displacements	1,310	420,000	0.00	7,483	420,000	0.02	8,793	420,000	0.02
						Total Pounds	30,319,331		
						Total PAX	9,171		

2. Analysis

Aircraft utilization was 100% for delivering water, MEDEVAC and displacements. The 25% distribution of aircraft allowed the model to meet food demand every day with capacity to spare. Day 2 through 14 had excess aircraft capacity on Route 3 that ranged from 23% on Day 2 to 67% by Day 14 of spare capacity. Table 12 describes the effects all of the T/M/S felt under the 10% mission degradation over five fly days.

Table 12. Mission Affectability on Aircraft

T/M/S	Day 2 MC%	Aircraft on Scene	Ao	Day 7 MC%	On Scene	Ao	Day 2 Difference in MC%	Aircraft Decrease	Day 12 MC%	On Scene	Ao	Day 2 Difference in MC%	Aircraft Decrease
SH-60	0.68	17	11	0.61	25	15	17	2	0.55	31	17	21	4
MV-22	0.00	0	0	0.67	10	6	0	0	6.00	10	6	7	1
MH-53E	0.50	8	4	0.45	8	3	4	1	0.41	8	3	4	1
CH-53E	0.00	0	0	0.76	4	3	0	0	0.68	4	2	3	1

Response B is a simple baseline model with six additional SH-60 aircraft. These additional aircraft increased the overall percentage of demand met; however, this model still shows poor aircraft utilization percentages and maintenance capabilities. By not using the available aircraft 100% of the time and not accounting for specific maintenance associated with the increased flight hours, this model lost opportunities to meet the critical water survival, overall water, and displacement demands. The amount of lost operational aircraft available from Table 13 shows how many aircraft from each T/M/S platform the 10% mission capability degradation affected. When you multiply those lost aircraft by the number of sorties they fly per day and by their MCW, the total lost capacity is 4,618,980 pounds. (We derive the numbers of aircraft affected in Table 14 from Table 12.)

Table 13. Response B Lost Capacity

T/M/S	Timeframe	Lost Aircraft	Lost Capacity
SH-60	D7 - D11	1	656,550
	D12 - D14	4	393,930
			1,050,480
MH-53	D7 - D11	0	0
	D12 - D14	1	1,255,500
			1,255,500
CH-46	D12 - D14	1	990,000
CH-53	D12 - D14	1	1,323,000
		Total	**4,618,980**

The overall percentage of demand met over this mission shows that this model only met 35% of its critical survival water, 7% of its overall water, and 2% of its displacement demand. By not establishing a priority system to maximize the aircraft available and not taking steps to maintain or increase MC%, this model would require some other organization to pick up the remaining 30% of the critical water survival, 86% overall water, and 98% displacement demands.

C. COMPARING RESPONSE A TO RESPONSE B

When comparing the six categories from both responses, both Response A and Response B deliver 100% of demand each day for MEDEVAC, food, and medical supplies. The difference between the two responses became evident when analyzing the amount of critical survival water and overall water demand delivered in Response B. During Response B, the model was able to meet 35% of the critical water survival demand, compared to only 28% from Response A. The difference between the two models is 4,792,838 pounds, or 7% more critical water delivered by Response B. However, the overall water delivered only went up from 6% in Response A to 7% in Response B. With the overall high volume of water demand, the 4,792,838 pounds increase in critical survival water delivered only resulted in a 1% increase in the overall water demand met.

1. Lost Capacity

Although there were additional aircraft on scene in Response B, the 10% mission capability degradation still negatively affected aircraft availability. This degradation decreased the total amount of operational aircraft available and increased the total lost capacity from Response A to Response B by 1,110,000 pounds. This meant that it was possible to deliver an additional 1,110,000 pounds of critical survival water if we could maintain the same mission capability percentages that we had when the T/M/S platforms arrived.

2. Aircraft Utilization

Adding aircraft to Response B increased the aircrafts' spare capacity assigned to Routes 3 and 4 (the food and medical supply routes). Although an increase in the capacity is a good thing, when the spare capacity increases by 11% in a HA/DR mission and there is still unmet demand somewhere else, it means that more aircraft sit on the flight deck instead of helping to meet the required demands. This additional spare capacity would get more use on Routes 1 and 2, where critical survival water, overall water, and displacement demands have not already been met.

D. CONCLUSION

In this baseline model, it is clear that Response B, with the additional aircraft, is the better model. Response B's percentage of demand met was higher in all six categories and ended up delivering 4,792,838 pounds more of rescue supplies to the landing zone and 1,625 more passengers to safety.

Nevertheless, the same problems underlie both responses. Having too much spare capacity on some routes and not enough capacity on others leads to wasted opportunities. These wasted opportunities translate into real people suffering every day until we meet that demand.

In an effort to increase our capacity to deliver supplies and passengers, we analyzed the value of each route, considering how much each route delivered and comparing them to each other. We did this by assigning two SH-60s to each route and multiplying the MCW by the number of sorties each route could complete. To account for the transportation of passengers, we assumed that 10 MEDEVAC or displaced people equaled 21,885 pounds. From our model, it was clear that Route 4 delivered the least value because it did not add any value on two of its legs (ship–hub and LZ–ship) and flight time constraints allowed only two sorties a day per aircraft. Therefore, we decided to investigate the question, "What would the results be if we eliminated Route 4 and established different models based on a priority system that maximized the operational aircraft and minimize the spare aircraft capacity per route?" We addressed this question through additional models described in the next chapter. Table 14 describes the best route value.

Table 14. Value Per Route

	Route 1 (Water)		Route 2 (Water/Medical/PAX)		Route 3 (Food/Supplies)		Route 4 (Food/Supply/PAX)	
Sorties		6		3		3		2
Route Description	Ship-Lz(Water)	21,885	Ship-LZ(Water)	21,885	Ship-Hub(nothing)	0	Ship-Hub(Nothing)	0
	Lz-Ship(Nothing)	0	LZ-hub(pax)	21,885	Hub-LZ(Food/supply)	21,885	Hub-LZ(food/supply)	21,885
			Hub-ship(nothing)	0	LZ-Ship(nothing)	0	LZ-Hub(Pax)	21,885
							Hub-Ship	0
Total (2 AC each route)		131,310		131,310		65,655		87,540
Assume 8 AC Total 10 PAX = 21885 Cargo Pounds								

VI. ALLOCATION OF HELICOPTERS TO ROUTES

After analyzing Model 1's Response A and Response B, we identified two areas that were constraining the model's potential: a poor aircraft utilization rate on Route 3, and only providing two sorties a day on Route 4. Both constrained the model and affected its ability to meet demand. In this chapter, we focus on these issues by eliminating Route 4 and setting aircraft priorities to maximize each available aircraft's utilization rate.

A. MODEL 2: HEURISTIC APPROACH

The emphasis of this model was equal distribution of whole aircraft across all three routes to assess the effect of eliminating Route 4. For example, if there were seven SH-60s available, two aircraft would first go to Route 1, the next two aircraft would go to Route 2, and finally, two aircraft would go to Route 3. With one aircraft left over and the priority given to Route 1, the last aircraft's assignment is to Route 1.

This model operates on the assumption that there is no given set of priorities on the six categories of demand or which T/M/S platform to use as a delivery method. Based on Model 1's Response A versus Response B analysis, we wanted to identify if the total pounds and passengers delivered would increase if Route 4 was eliminated and those aircraft moved to Routes 1, 2, and 3.

The results show the importance of identifying the capacity of each route. Those routes with the most capacity should be used to deliver as much of the required demand as possible, and those routes that do a little of everything less efficiently should be eliminated. These eliminated routes may provide a specialty that could be more beneficial later in the mission. However, in the first 14 days of a mission on the routes that deliver the most rescue supplies, it is critical to maximize all available aircraft to ensure the meeting of MEDEVAC demand as quickly as possible.

1. Category Results

The model never met critical survival water demand and only delivered 72% of the critical survival water demand over the 14 days. The unmet critical survival water demand gradually dropped from 4,000,000 pounds on Day 2 to 1,600,000 pounds on Day 14. The model also never met the overall water demand. The overall capacity increased with the arrival of the ARG on Day 7, which allowed it to meet 10% of the overall demand. It was also able to meet 12% of the demand on Days 7 through 14 when the CSG and ARG were working together delivering water. The overall unmet water demand gradually decreased from 27,600,000 pounds on the first day of operations to 21,000,000 pounds on the last day.

Daily food demand was not met until Day 6. The CSG alone did not have enough aircraft available to meet this demand. On Day 7, the model meets food demand very quickly with the arrival of the ARG and the falling daily demand. This led to excess capacity on Route 3 for the next eight days of the mission.

With an overall demand of 378 people who needed a MEDEVAC, the model was able to deliver 285 people on the first day of operations (Day 2). Delivery of the remaining people occurred on Day 3. This model shows a capacity to meet demand with the initial CSG response. Daily medical supply demand was not met until Day 6. The CSG alone did not have enough aircraft available to meet this demand. On Day 7 the model was able to meet food demand with the arrival of the ARG. This led to excess capacity on Route 3 for the next eight days of the mission. The model never met displaced demand, although it did gradually decrease from 420,000 people to 413,781 people.

2. Model Analysis

There was 100% aircraft utilization on Routes 1 and 2, but Route 3 still had excess capacity. The excess capacity started on Day 6 (1%) and gradually increased until Day 14 (56%). This wasted capacity would get better utilization on other routes that still have unmet demand.

The heuristic model delivers 10,274,492 more pounds of supplies and 2,859 fewer passengers than the baseline 25% Response B model. This model showed that focusing on the routes that deliver the most demand by cutting out the routes that were less efficient increased the overall percentage of demand met for five of the six categories. The tradeoff in this model was a lower number of displacements transported with an increase in the total pounds delivered and meeting the MEDEVAC demand one day sooner. This model fully utilized its aircraft until Day 6, whereas the baseline model had excess capacity starting at Day 2. Table 15 gives a breakdown of the heuristic model results.

Table 15. Heuristic Distribution

Huerestic Distribution	Day 1-6 Total Delivered	Day 1-6 Demand	Day 1-6 Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Day 7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	9,379,800	28,518,000	0.33	25,336,320	41,042,400	1.00	34,716,120	69,560,400	0.72
Water	9,379,800	142,590,000	0.07	25,336,320	205,212,000	0.12	34,716,120	347,802,000	0.10
Food	2,330,199	2,444,400	0.95	3,517,920	3,517,920	1.00	5,848,119	5,962,320	0.98
Medical Supplies	13,489	11,321	1.19	16,094	29,583	0.54	29,583	29,583	1.00
MEDEVAC	378	378	1.00	0	0	0.00	378	378	1.00
Displacements	762	420,000	0.00	5,172	420,000	0.01	5,934	420,000	0.01
						Total Pounds	40,593,823		
						Total PAX	6,312		

B. MODEL 3 PRIORITY

In this model, we prioritized demand categories and based the assignment of aircraft on these priorities in an attempt to better utilize capacity. The design of the model was to meet the demand for current priority before fulfilling the demand of the next lower priority. This model also gave priority to the aircraft with the highest MCW/PAX capability to fulfill the given priority. Route 1 was used over Route 2 for the delivery of critical survival water because of the higher number of sorties it had available to meet the critical survival water demand. Aircraft assignment was based on the aircraft that were available that have the highest MCW or PAX capability, depending on which demand was being fulfilled. The following list shows the categories, their assigned route, and its measurement:

- Critical survival water—Routes 1 & 2 (lbs.) – 6 sorties/day
- MEDEVAC— Route 2 (PAX) – 3 sorties/day
- Food/medical supplies— Route 3 (lbs.) – 3 sorties/day
- Overall water— Routes 1 & 2 (lbs.) – 6 sorties/day
- Displaced—Route 2 (PAX) – 3 sorties/day

For example, since priority one is critical survival water (Route 1 [lbs.]), the model would use the MH-53E because it has a higher MCW than the SH-60. The model used the minimal amount of each T/M/S platform needed to meet demand. The remaining aircraft assignments were to the next priority (MEDEVAC) until fulfilling all demand.

This model and all subsequent models use Response B as their baseline. Setting different priorities changed the overall demand met, so we set meeting priority demands in the following order, from highest to lowest: critical survival water, MEDEVAC, overall water, food, medical, and displaced people. What we learned was that by setting certain demands as higher priorities directly affected the percentage of demand met in other categories. An example would be making it a priority to deliver critical survival water before meeting any other demand, which may affect how quickly meeting the MEDEVAC demand occurs. With limited resources, the models in this chapter show how to increase the total pounds of rescue supplies delivered and ensure the transfer of all MEDEVAC and displaced personnel as soon as possible.

1. Aircraft Assignment

Unlike the prior models, this model has changing aircraft-to-route assignments over the response days as needed to meet demand in the order of priority. When the CSG arrived on Day 2 it had the MH-53E and SH-60 to choose from. We assigned all available aircraft to Route 1 to fulfill the critical survival water demand. Since the available aircraft could not meet this demand, the assignment of aircraft did not change until Day 7 when the ARG arrived. On Day 7, we reassessed the aircraft assignments to account for the additional aircraft and their capabilities to fulfill the required demand.

With these additional aircraft on scene and the 10% mission capability degradation starting to affect the model, we assigned all available MH-53Es, CH-53Es, and MV-22s to Route 1. With only the SH-60s left to assign, we assigned the available 6.75 SH-60s to Route 1 to fill the rest of the critical survival water demand. We then assigned the remaining 8.25 SH-60s to Route 2 to fulfill the MEDEVAC demand. By the end of Day 7, the model met all daily critical survival water, but there was still a need for the transport of 131 MEDEVACs. On Day 8, because of the displacement percentage drop, we reallocated 0.50 of a SH-60 from Route 1 and 3.75 SH-60s from Route 2 to start fulfilling the food and medical supply demand on Route 3. By the end of Day 8 the model fulfilled the critical survival water and MEDEVAC demand and SH-60s had begun delivering food and medical supplies to Route 3. From Day 9 through 14, we reassigned the SH-60s from Route 3 to Route 1 in order to help fulfill the overall water demand. We were able to do this because the displacement percentage drop decreased the daily demand for food enough to redistribute aircraft as needed.

Since this model was never able to fulfill the overall water demand, it was never able to dedicate any resources to transporting the displaced. This model shows how using priorities and best available capabilities can significantly increase the total pounds delivered while meeting the critical survival water by Day 7 and the MEDEVAC demand by Day 8. The downside to this model is that the delivery of any food or medical supplies was delayed until Day 8 and daily demand was not met until Day 9. This model accomplished our goal of increasing the total pounds delivered and fulfilling the daily demands faster than the heuristic approach in Model 2.

2. Category Results

This model uses 99.4% of the aircraft that were available. With these available aircraft, the model was able to deliver 89% of the critical survival water demand. MEDEVAC was the second priority and the response filled 100% of the demand by Day 7. The response did not fill food and medical supplies, which were the third and fourth daily priorities, until Day 9, after the ARG arrived on scene and provided additional capacity to meet demand. Overall water was the fifth priority and the model never met demand during this mission. The response did, however, deliver 22% between Days 7 and 14 when the entire HA/DR team was on scene and 18% of the overall water demand during the 14-day mission. The model only delivered four displaced personnel because the overall water demand was so high and transporting the displaced was our last priority in this model.

3. Model Analysis

This model demonstrated that by assigning priorities and using the T/M/S platform available with the highest MCW or PAX capability, it could deliver 23,000,000 more pounds of rescue supplies than the heuristic model. When comparing the total pounds delivered by category, the data indicated a 10% advantage in aircraft utilization, 15% more critical survival water, and 14% more overall water demand satisfied than the heuristic model. This model fulfilled 100% of the MEDEVAC and medical supply demand.

In order to fulfill MEDEVACs and critical survival water demands first, this model fulfilled 49% less of the food demand. This model showed that having priorities and rules to distribute the available T/M/S platforms increased the aircraft utilization and overall percentage of rescue supplies delivered, but sacrificed the timely delivery of food, medical supplies and MEDEVACs. Table 16 gives the results of the priority model.

Table 16. Priority Distribution

Priorities	Day 1-6 Total Delivered	Day 1-6 Demand	Day 1-6 Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Day 7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	16,117,290	28,518,000	0.57	45,994,489	41,042,400	1.12	62,111,779	69,560,400	0.89
Water	16,117,290	142,590,000	0.11	45,994,489	205,212,000	0.22	62,111,779	347,802,000	0.18
Food	0	2,444,400	0.00	3,517,920	3,517,920	1.00	2,936,199	5,962,320	0.49
Medical Supplies	0	13,489	0.00	27,565	27,565	1.00	45,734	41,054	1.11
MEDEVAC	0	378	0.00	0	0	0.00	378	378	1.00
Displacements	0	420,000	0.00	0	420,000	0.00	4	420,000	0.00
						Total Pounds	65,093,712		
						Total PAX	383		

C. MODEL 4 COST PER HOUR (CPH)

With the CPH model, we addressed the cost benefit analysis of assigning aircraft to the routes that best matched those platforms' strengths and assessed whether that fulfilled a higher percentage of demand across our six categories. We took the individual cost per flight hour for each T/M/S platform and divided it by the MCW and PAX capabilities. This gave us the cost of moving one pound of weight per flight hour and the cost of transporting one passenger on each T/M/S platform. Based on these costs, the aircraft assignments were to those routes that provided the best value until they met the daily demand. Once we fulfilled that demand, that specific platform assignment was to the next task it does best.

By looking at Table 17, it is easy to tell that the MV-22 and MH-53E are more cost effective in every area when compared to the SH-60 and CH-53E. The confusion comes when asking how much better or worse a specific platform is at delivering one demand over the other. We used the MV-22 as the baseline for the most efficient delivery method. The team then divided the MV-22 cost per pounds and PAX by each individual T/M/S platform cost per pounds and PAX to give an efficiency comparison among the four T/M/S platforms. From these calculations, we determined that one platform is clearly more cost effective at delivering certain categories.

Table 17. Efficiency Hierarchy for lbs./PAX

TMS	CPH	MCW	PAX	Cents Per Pound	Pound Efficiency	Dollars Per PAX	PAX Efficiency	Route 2 Tiebreaker	
MV-22	$6,600	55,000	24	$0.12	1	$275.00	1	2.00	1st
MH-53E	$11,275	73,500	37	$0.15	0.78	$304.73	0.90	1.68	2nd
SH-60	$3,995	21,885	10	$0.18	0.66	$399.50	0.69	1.35	3rd
CH-53E	$12,100	42,000	38	$0.29	0.42	$318.42	0.86	1.28	4th

1. Assigning Aircraft

We still decided to use the same priority system only when deciding if it should allocate resources between Routes 1, 2, and 3. For example, if an aircraft had a higher efficiency in delivering pounds rather than PAX, the aircraft assignment was to the route that fulfilled the highest priority. If we did not meet the critical water demand, then the aircraft went to Route 1, but if we fulfilled the critical survival water, the aircraft assignment went to fulfilling the food and medical supply demand, the overall water demand, and finally the displacement demand.

When deciding the assignment of aircraft to Route 2, we added both efficiency categories (since Route 2 delivers both poundage [water] and PAX [MEDEVAC and displaced]) and assigned the T/M/S platform with the highest combined percentage. After fulfilling the MEDEVAC demand, the T/M/S platform assigned to Route 2 continued to deliver the displaced personnel until another platform arrived on scene with higher cost efficiency.

On Day 2, the only two T/M/S platforms to choose from were the MH-53E and SH-60. The MH-53E PAX efficiency is higher than its pound efficiency, so it was assigned to Route 2. The SH-60s have higher pound efficiency, so their assignment went to Route 1. Since the model never meets critical survival water demand and no other aircraft arrived on scene, this distribution of aircraft remained the same until D+7 when the ARG arrived with additional aircraft.

With the arrival of the ARG on Day 7, we needed to reallocate resources to best use the available T/M/S aircrafts. The arrival of the MV-22 changed which aircraft had the highest efficiency in delivering the critical survival water. However, since the MV-22 also had the highest PAX efficiency, we had to ask how much better the MV-22 is than the next highest platform. The MV-22 was 22% more efficient than the MH-53E in delivering poundage and 10% more efficient in delivering PAX. Based on this information, we assigned the MV-22 to Route 1 in order to fulfill the critical survival water demand. Since the MH-53E is the next best platform in both categories, we needed to determine how much better it was. Since the MH-53Es had a higher PAX efficiency rating, their assignment was to Route 2.

When comparing the SH-60 to the CH-53E, the data showed that the CH-53E is 17% more efficient than the SH-60 at delivering poundage. With this information we assigned three CH-53Es to Route 1 to fulfill the critical survival water demand. With only the SH-60 available, we assigned 11.5 SH-60s to fulfill the critical survival water demand. We then assigned the remaining 3.5 SH-60s to Route 3 to fulfill food and medical supply demand.

On Days 8 through 11, the displaced percentage gradually drops, which decreases the demand for critical survival water, food, medical supplies, and overall water demand.

As the demand drops for critical survival water, it allows us to redistribute the SH-60s to Route 3 to fulfill the food/medical supply demand. Once we meet the food and medical supply demand, we redistributed that extra aircraft capacity back to Route 1 to help fulfill the overall water demand.

On Days 12 through 14, the mission capability degradation decreased the overall CH-53Es and SH-60s available by one aircraft each. This led us to assigning 11.5 SH-60s to Route 1 to fulfill the critical survival water demand and 5.5 to food and medical supply demand (Route 3) and zero to meet the overall water demand (Route 1).

2. Category Results

The model used 99% of its available aircraft. Realizing the effects of the degradation did not occur until Days 7 and 12, in which the impacts reduced the overall aircraft available. The model was still able to deliver 73% of the overall critical survival water demand, but this was not until Day 7. Filling the second priority was on the first day of flight operations with the delivery (on Day 2) of all 378 MEDEVACs. This model transported 6,882 displaced personnel, which was 2% of the overall demand. The model never met overall water demand during this mission. However, it did deliver 20% between Day 7 through 14 when the entire HA/DR team was on scene and 15% of the overall water demand during the 14-day mission. Meeting 100% of food and medical supply demand only happened on Days 10, 11, and 14. Mission degradation caused the model to miss meeting the demand on Days 12 and 13. This model did, however, deliver 51% of the overall food demand and 43% of the medical supply demand.

3. Model Analysis

This model's choice to allow the MH-53E to keep delivering the displaced instead of redistributing the aircraft to fulfill other demands showed the potential of how many displaced can be transported by dedicating a platform to what it does best. The ability to assign aircraft by the highest efficiency gave this model the ability to provide the most cost-effective solution. This model delivered 8,850,000 pounds less than the priority-driven Model 3, while taking five days longer to meet critical water demand. However, it did deliver 6,878 more displaced personnel, had a 1% aircraft utilization advantage, and was five days faster delivering the MEDEVAC personnel. The effects of mission degradation disrupted the models ability to fulfill the food/medical supply demand. Table 18 describes this information.

Table 18. CPH Description

CPH	Day 1-6 Total Delivered	Day 1-6 Demand	Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	11,932,290	28,518,000	0.42	41,612,625	41,042,400	1.01	53,150,985	34,780,200	1.52
Water	11,932,290	142,590,000	0.08	41,612,625	204,212,000	0.20	53,150,985	346,802,000	0.15
Food	0	2,444,400	0.00	3,041,033	3,517,920	0.86	3,041,033	5,962,320	0.51
Medical Supplies	0	13,489	0.00	44,631	90,055	0.50	44,631	103,544	0.43
MEDEVAC	378	378	1.00	0	0	0.00	378	378	1.00
Displacements	2,922	420,000	0.01	5,824	420,000	0.01	6,882	420,000	0.02
						Total Pounds	56,236,649		
						Total PAX	7,260		

This model's true advantage would come into play when demands are small enough to perform with fewer aircraft. When this happens, it would be necessary to make a decision as to which T/M/S platforms would continue the mission and which ones would leave. Based on the current demands and priorities, leadership could make a qualified decision that best supported the mission, while minimizing the overall costs.

D. MODEL 5 CPH (2)

Based on Model 4 (CPH), we wanted to model what would happen if we used the same priority system that we used in Model 3. This change in priority allowed us to redistribute the aircraft on Route 2, once MEDEVAC demand was met, to the next highest demand that needed fulfilling. This allowed a CPH-based model that was more comparable to the priorities model (Model 3).

1. Assigning Aircraft

On Day 2, the model only required 2.5 MH-53Es to fulfill the MEDEVAC demand on Route 2. The remaining 1.5 MH-53E and all SH-60 assignments went to Route 1 to fulfill the critical survival water demand.

On Day 3, we met MEDEVAC demand and redistributed the MH-53Es to Route 1 along with the SH-60s to help fulfill the critical survival water demand. Since the model never met critical survival water demand, the assignment of aircraft remained the same until Day 7. During Days 8 through 11, the displaced percentage dropped the overall food and medical supply demand enough to redistribute the SH-60s from Route 3 to Route 1 in order to fulfill the overall water demand.

With the arrival of the ARG on Day 7, we redistributed the resources based on the new efficiency hierarchy. The arrival of the MV-22 changed which aircraft had the highest efficiency in delivering the critical survival water, so we assigned all MV-22s to Route 1. Since there was no MEDEVAC demand, we assigned all four MH-53Es and three CH-53Es to Route 1 to fulfill the critical survival water demand. We then assigned 6.75 SH-60s to complete the critical survival water demand and distributed 7.5 SH-60s to fulfill the food and medical supply demand. We then assigned the remaining 0.75 of the SH-60s' capacity back to Route 1 to help fulfill the overall water demand. This was also the first day that the 10% mission capability degradation affected the T/M/S platforms on scene and reduced the total number of aircraft available.

During Days 12 through 14, the model suffered another 10% MC drop that reduced the total number of CH-53Es and SH-60s available on scene by one each. This reduction in aircraft forced us to use more SH-60s to fill the critical survival water demand instead of using those resources to fill the next priority.

2. Category Results

Mission degradation did not affect the model until Days 7 and 12, but the model still was able to use 99.4% of its aircraft available. The model delivered 88% of the overall critical survival water demand on Day 3. The model never met the overall water demand during this mission. However, the model did deliver 22% between Days 7 and 14 when the entire HA/DR team was on scene and 18% of the overall water demand during the 14-day mission. The delivery of all 378 MEDEVACs occurred on the first day of flight operations but only delivered 34 of the displaced personnel. The model did not fill food and medical supply demand until Day 7. When the ARG arrived on scene, the extra capacity allowed the model to fill 59% of the food demand and 69% of the medical demand.

3. Model Analysis

This model delivered 70,000 fewer pounds of supplies and 30 more displaced personnel, held a 1.4% aircraft utilization advantage, delivered MEDEVACs six days faster, and filled food and medical supply demand two days faster. This equals 10% more food and 19% more medical supplies delivered when compared to the priorities model. This model also met the critical survival water demand on the same day as the priority model (Day 7). However, it delivered 1% less critical survival water and the same 18% of the overall water demand over the 14-day mission. Overall, this model delivers 1% less critical survival water, but gains advantages in four other categories. If the leadership is willing to sacrifice that 1% of the critical survival water, they meet a greater percentage in overall demand of the other five categories. The ability to choose platforms that provide the best cost effectiveness ultimately ensures that each aircraft is delivering what it should. Table 19 gives a breakdown of the CPH (2) model results.

Table 19. CPH (2) Description

CPH(2)	Day 1-6 Total Delivered	Day 1-6 Demand	Day 1-6 Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Day 7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	15,594,165	28,518,000	0.55	45,485,663	41,042,400	1	61,079,828	34,780,200	0.00
Water	15,594,165	142,590,000	0.11	45,485,663	205,212,000	0.22	61,079,828	347,802,000	0.18
Food	800,611	2,444,400	0.33	3,515,553	3,517,920	1.00	3,515,553	5,962,320	0.59
Medical Supplies	3,663	13,489	0.27	29,583	29,594	1.00	29,583	43,083	0.69
MEDEVAC	378	378	1.00	0	0	0.00	378	378	1.00
Displacements	34	420,000	0.00	0	420,000	0.00	34	420,000	0.00
						Total Pounds	64,624,964		
						Total PAX	413		

E. MODEL 6 TIMELINE COMPARISON (ARG VS. CSG)

There is a debate in the Navy over which support platform is more beneficial. Is the CSG more useful in a HA/DR mission over the ARG? We modeled the overall percentage of demand fulfilled in the six categories. This model used the same rules and assumptions as Model 5 (CPH2). To set up the model, we changed the number of aircraft available by having the ARG arriving first on Day 2 and the CSG arriving on Day 7.

1. Assigning Aircraft

On Day 2, the model had three platforms to choose from: the MV-22, SH-60, and CH-53-E. The MV-22 has the highest efficiency under both passenger and poundage categories. When comparing the MV-22 to the SH-60 and CH-53E, we discovered that the MV-22 was 14% better than the CH-53E at delivering PAX and 34% better than the SH-60 with poundage delivery. With this information, we assigned the MV-22 to Route 1 to fulfill the critical survival water demand. The CH-53E’s highest efficiency is in delivering passengers, which is why we assigned 2.5 CH-53Es to fulfill the MEDEVAC demand and those remaining we assigned to Route 1 to help fill the critical survival water demand. We assigned all available SH-60s to Route 1 to help fulfill the critical survival water demand.

The model filled the Day 3 MEDEVAC demand on Day 2, which allowed redistribution of the CH-53E to Route 1. When comparing poundage efficiency, the data shows that the CH-53E is 3% more efficient. Therefore, we assigned the three available CH-53Es and four available SH-60s to Route 1. Since this model never met critical survival water demand, the distribution of aircraft remained the same until the CSG arrives on Day 7.

The arrival of the CSG on Day 7 gave us additional aircraft and capabilities. The MV-22 was still the most cost efficient and we assigned it to Route 1. The MH-53E was second in efficiency and we assigned it to Route 1. The SH-60 was third most efficient in delivering pounds, so we assigned 13.75 SH-60s to Route 1 to fulfill the critical survival water demand. We assigned the remaining SH-60s to Route 3 to help fulfill the food and medical supply demand. We then assigned 1.25 CH-53Es to fulfill the food and medical supply demand and allocated the remaining 0.75 CH-53E capacity to Route 1 to help fulfill the overall water demand.

During Days 8 through 11, as the displacement percentage dropped, we could redistribute the CH-53Es from Route 3 to Route 1 and the SH-60s from Route 1 to Route 3. On Day 12, the mission capability degradation reduced the number of MV-22s, MH-53Es, and SH-60s available by one each. This forced us to distribute an additional 4.75 SH-60s to Route 1 to fulfill the critical survival water demand. This reduced the SH-60s on Route 3, which increased the required CH-53Es needed to fulfill the food and medical supply demand on Route 3 and decreased the aircraft dedicated to fulfilling the overall water demand.

2. Category Results

Mission degradation did not affect the model until Days 7 and 12, but the model still was able to use 97% of its aircraft available. The model did not meet the critical survival water demand until Day 7. The model never met the overall water demand during this mission. The model filled 13% of the overall water demand by Day 6 and 18% of the overall water demand by Day 14. The delivery of all 378 MEDEVACs occurred on the first day of flight operations but only delivered 34 of the displaced personnel. The model delivered 59% of the food and medical supply demand by Day 14.

3. Model Analysis

This model describes how over the first six days of the mission, the ARG out performs the CSG with the delivery of 4% more critical survival water. This model delivers the same percentage of food and medical supplies and overall water as Model 4 (CPH2). Overall, this model shows how important the ARG resources are in fulfilling the demand as soon as possible. Over the 14 days of this mission, this model delivered 2,500,000 more pounds of rescue supplies than when the CSG arrived first. Table 20 displays this information.

Table 20. ARG vs. CSG Description

ARG vs CSG	Day 1-6 Total Delivered	Day 1-6 Demand	Day 1-6 Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Day 7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	19,141,200	28,518,000	0.67	45,285,919	41,042,400	1.10	64,427,119	69,560,400	1.00
Water	19,141,200	142,590,000	0.13	45,285,919	205,212,000	0.22	64,427,119	347,802,000	0.19
Food	0	2,444,400	0.00	3,051,720	3,517,920	0.87	3,051,720	5,962,320	0.51
Medical	0	13,489	0.00	29,583	45,205	0.65	29,583	58,694	0.50
MEDEVAC	0	378	0.00	378	378	0.00	378	378	1.00
Displacements	0	420,000	0.00	4	420,000	0.00	4	420,000	0.00
						Total Pounds	67,508,422		
						Total PAX	382		

F. MODEL 6 PERFECT UNION MODEL

We analyzed the effects of getting the required resources on scene more quickly in this model. This particular model only differed in that we used the assumption that the CSG and ARG could both arrive on scene at Day 2 and immediately begin flight operations. The model achieves the best fulfillment percentage of demand in each of the six categories over the 14-day mission. This model used the same priorities and rules to assign aircraft as Model 5 (CPH2).

1. Assigning Aircraft

On Day 2, there were four T/M/S platforms to choose from with 45 aircraft to distribute. From the efficiency breakdown, we assigned the MV-22 to Route 1. The MH-53E ranks second in both poundage and PAX efficiency but has the higher efficiency in delivering PAX between the two aircraft. Therefore, its assignment was to Route 2 in order to fulfill the MEDEVAC demand, with the remaining aircraft assigned to Route 1 to fulfill the critical survival water demand. The SH-60s have the next highest poundage efficiency and we assigned them to Route 3. The assignment of the remaining SH-60s was to Route 1 in order to fulfill the overall water demand. The CH-53Es were last on the poundage efficiency and assigned to Route 1 in order to fulfill the overall water demand. The model used these same steps for Days 3 through 14.

2. Model Results

Mission degradation did not affect the model until Days 7 and 12, but the model was still able to use 98% of its aircraft available. The model delivered 100% of the overall critical survival water and MEDEVAC demand on the first day of flights. The model never met overall water demand during this mission, but was able to fill 24% of the overall water demand. It was able to meet the food and medical supply demand on Day 2 and filled 93% and 100% of the demand respectively.

3. Model Analysis

This model demonstrates, based on our priorities and rules for assigning aircraft, that the most this response can deliver is 82,478,000 pounds of rescue supplies and 413

PAX as described in Table 21. The model did not meet overall water demand and none of the displacement demand, which meant outside organizations would have to fulfill them.

Table 21. Perfect Union Description

Perfect Union	D+1-6 Total Delivered	D+1-6 Demand	D+1-6 Percent Demand Met	D+7-14 Total Delivered	D+7-14 Demand	D+7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	33,682,770	28,518,000	1.18	43,242,660	41,042,400	1.05	76,925,430	69,560,400	1.11
Water	33,682,770	142,590,000	0.24	43,242,660	205,212,000	0.21	76,925,430	347,802,000	0.22
Food	2,005,460	2,444,400	0.82	3,517,920	3,517,920	1.00	5,523,380	5,962,320	0.93
Medical Supplies	13,489	13,489	1.00	16,094	16,094	1.00	29,583	29,583	1.00
MEDEVAC	378	378	1.00	0	0	1.00	378	378	1.00
Displacements	12	420,000	0.00	0	420,000	0.00	12	420,000	0.00
						Total Pounds	82,478,393		
						Total PAX	390		

When comparing the total percentage of demand fulfilled between the first five days and the last seven days, we noticed that the last seven days had a smaller percentage of demand fulfilled. After further analysis, we attributed this loss in efficiency to the 10% MC degradation. With all aircraft on scene at Day 2, it ultimately caused each T/M/S platform to suffer two mission capability degradations. Previous models only showed the SH-60 and MH-53E suffering two separate MC% degradations, with the other T/M/S platforms only suffering one degradation. These degradations across all the T/M/S resulted in 11,945,000 pounds of rescue supplies that went undelivered.

VII. THE EFFECTS OF MAINTENANCE ON A HA/DR MISSION

From previous lessons learned, we now know that during a catastrophic HA/DR mission the average aircraft flies three times more flight hours than it normally would. For example, a CH-53E on deployment normally flies around 30 hours during a 30-day timeframe. If an HA/DR mission lasts 30 days, this would mean that the CH-53 would have to fly 90 hours in that 30-day timeframe. The sudden increase in flight hours on the aircraft participating in the mission would place a strain on the local supply system of items not stocked. In addition, the sudden increase in flight hours decreases the A_o of all platforms involved.

Using the NAVAIR anchor desk customer support program via the NAVAIR website (www.navair.navy.mil), we identified the top 10 NMCS parts that could most likely cause the MC% to fall for U.S. Navy helicopters involved in these missions. We believe that by identifying these top 10 items and using the Mean Time Between Failures (MTBF) for all items listed, we predicted how many of the parts will be needed to satisfy the first 14 days of an HA/DR mission.

During the research process, we were unable to obtain all of the proper information from the Aviation Financial Analysis Tool (AFAST) to identify on average what exactly went wrong with each item of the top 10 list and the average cost to fix the items. Since the only consistent cost information we were able to acquire for all platforms was the BCM cost, we decided to give a worst-case analysis on all platforms except the SH-60. We were unable to obtain the MTBF for the top 10 maintenance failures for the SH-60. Without the MTBFs, we were unable to predict how many failures would occur with the increased flight hours for this platform.

A. MAINTENANCE FAILURES AND BCM COSTS

The CH-53E can expect to need 27 additional parts spread over the top 10 for a BCM cost of $5,360,000. This leads the pack with the least amount of maintenance failures and the lowest overall BCM costs. The MV-22 comes in second with 146 expected maintenance failures and a BCM cost of $22,750,000. The MH-53E comes in last with 178 top 10 maintenance failures with a BCM cost of $30,780,000. (See the appendix for BCM break-down and expected failures for each T/M/S platform.)

The BCM costs show a worst-case total maintenance costs to fix the top 10 NMCS maintenance issues. The expected failures is a very realistic possibility that the carrier air group maintenance officer (CAGMO), ship supply officer (SUPPO), and respective wing readiness officer (WRO) need to account for and identify how and when these assets will be delivered to the disaster area. The longer it takes to identify the required spare parts to maintain each T/M/S platforms mission capability percentage, the worse the MC% degradation will be. Table 12 shows the effects of MC% degradation.

B. MODEL RESPONSE SCENARIOS

We assumed that a 95% customer service level to protect us against variability in demand was already in use and that the ship was already carrying an inventory based on each aircraft flying 30 hours a month. The delta between what the ship's supply already had in inventory, based on these assumptions, and how many more the ship needed to support the additional flight hours in an HA/DR mission determined how many parts needed to be identified and transported to the response area for each T/M/S to maximize each platform's MC%.

Recognizing that having these additional parts available would not eliminate the mission degradation, we modeled only a 50% reduction in overall mission degradation, resulting in only a 5% reduction in mission capability every five days. Reducing the mission degradation to 5% every five days increased our overall aircraft availability, therefore increasing the total pounds of supplies and passengers delivered.

1. Results

In this model, it only took until Day 7 to meet critical survival water demand. The model never met overall water demand and delivered only 18% during the 14-day mission. The overall unmet water demand gradually decreased from 26,800,000 pounds on Day 2 to 18,500,000 pounds on Day 14. Although the model was only able to deliver 59% of the overall food demand, during Days 7 through 14 the model delivered 100% of all food. The model was able to deliver all 378 people on the first day of operations, but meeting the displaced personnel demand did not happen. The model only delivered 34 displaced personnel.

2. Model Analysis

This model demonstrated how increasing the MC% for the aircraft during a mission yielded greater overall results. We were able to deliver 1,468,000 more pounds of critical survival water. Reducing the mission capability degradation increased the available aircraft and allowed us to fulfill a greater percentage of demand. Getting ahead of the degradation curve allowed continuous distribution of more aircraft as the mission went on. Table 22 gives the MC% degradation results.

Table 22. 5% MC Degradation

Priorities	Day 1-6 Total Delivered	Day 1-6 Demand	Day 1-6 Percent Demand Met	Day 7-14 Total Delivered	Day 7-14 Demand	Day 7-14 Percent Demand Met	Total Delivered	Total Demand	Total Percent Met
Critical Survival Water	15,594,165	28,518,000	0.55	46,375,133	42,041,400	1.10	61,969,298	69,560,400	0.83
Water	15,594,165	142,590,000	0.11	46,375,133	205,212,000	0.23	61,969,298	347,802,000	0.18
Food	0	2,444,400	0.00	3,517,920	3,517,920	1.00	3,517,920	5,962,320	0.59
Medical Supplies	0	13,489	0.00	29,583	29,583	1.00	29,583	43,072	0.69
MEDEVAC	378	378	1.00	0	0	0.00	378	378	1.00
Displacements	34	420,000	0.00	0	420,000	0.00	34	420,000	0.00
						Total Pounds	65,516,801		
						Total Pax	413		

THIS PAGE INTENTIONALLY LEFT BLANK

VIII. CONCLUSIONS

It is evident that the U.S. military will continue its involvement in HA/DR missions worldwide; therefore, it is increasingly important to be able to support these missions in the best way possible. Government policies provide guidance and support to the DoD for HA/DR missions. Military strategic plans emphasize how important supporting disaster relief missions are to the national strategy of the United States. The ability to support HA/DR missions as efficiently as possible can help disaster areas receive the required aid in the shortest possible time and in the most cost-effective way.

Looking at the involvement of the U.S. military in previous disasters, it is clear that helicopters play a vital role in HA/DR missions. Their ability to get in and out of a variety of areas with destroyed roads and infrastructures is a major reason for their importance to relief efforts. Their range, capabilities, and ability to adapt to most terrains make them the most obvious transportation resources to use in HA/DR missions.

A. RESEARCH LESSONS LEARNED

The CSG’s transition from the traditional design of the T/M/S platform combination into a new T/M/S platform combination with two helicopter squadrons attached to the CVN will increase the delivery capacity of the CSG. The replacement of the CH-46E with the MV-22 on the ARG also enables the readiness group the ability to deliver a greater percentage of overall demand. We showed that this new combination of helicopters can significantly increase the total percentage of demand filled. The additional SH-60s increased the CSG’s capabilities by 541,650 pounds, which equates to 7,737 more people receiving their overall water demand. The increased capabilities of the MV-22 ultimately delivered 2,113,500 more pounds of rescue supplies than what the ARG could deliver with the CH-46. This equated to 30,192 more people receiving their overall water demand. This increase in capabilities delivered critical rescue supplies at a faster rate.

Because each HA/DR mission is unique, it is important to quickly analyze what resources will be needed to send the best mix to support the mission. The most beneficial resources are those that can arrive on scene the quickest and start delivering critical rescue supplies. As additional ships with various aircraft arrive on scene, the mission leaders can redistribute the aircraft based on a priority list and based on the T/M/S platform that they believe will best fill each required demand.

Based on the priority list we developed, we have identified a recommended hierarchy of aircraft to use when fulfilling passenger and poundage demands. Assuming all future responses will have a combination of T/M/S platforms comparable to Response B, leadership should assign the CH-53E, MH-53E, MV-22, and SH-60 when delivering rescue supplies and passengers based on the platform that has the greatest capacity for that particular priority.

Using our cost-efficiency hierarchy, the assignment of aircraft goes first to the category of demand they are most efficient at based on their cost per flight hour. Our research shows that when delivering water, food, and medical supplies, leadership should assign them in this order: MV-22, MH-53E, SH-60, and then the CH-53E. When delivering MEDEVAC and displaced personnel, leadership should assign them in this order: MV-22, MH-53E, CH-53E, and SH-60.

Since both models use 99% of the aircraft capacity, it is hard to show a cost dollar savings with this model. The true value of the CPH model is demonstrated when leadership must choose which T/M/S platforms to leave behind and which platforms and ships to move on to the next emergency. In comparison to the MV-22, not all the other aircraft meet the mission requirements as efficiently. While the SH-60 offers more aircraft, it costs 0.06 cents more per pound and $125 more per passenger than the MV-22 to operate. The MH-53E costs 0.03 cents more per pound and $29 more per passenger. The CH-53E costs 0.17 cents more per pound and $48 more per passenger. Because the MV-22 is the most cost-efficient helicopter platform in the mission, it allows the ARG to overcome the CH-53E low cost efficiency.

B. RECOMMENDATIONS

From our CSG versus ARG model, the final percentage of demand fulfilled between the two models shows that the ARG delivers a greater percentage of overall demand at a cheaper price. Based on this information, we can now assume that the ARG is more cost effective and operationally effective than the CSG for HA/DR missions similar to the one we modeled. While the CSG provides a quicker response, assuming they both start from the same distance, it is clear that the capabilities that the ARG provides fulfill a greater percentage of overall demand once it arrives on scene.

Understanding that each mission is unique and carefully analyzing the operational environment of the disaster area are essential to the success of the mission. After making the decision that the MV-22 can land and take off safely in the area, the DoD should use as many of the MV-22 aircraft as they can spare to deploy to the disaster area. For example, removing the CH-53E from the sea-basing ARG could allow enough space to embark four additional MV-22 aircraft. A second option to consider is sending a second ARG to the HA/DR mission and removing the CSG from the disaster area as soon as possible. The main reason for having the CSG in an area is the political importance and medical capabilities of the aircraft carrier. Keeping the CSG on scene can prove to cost more and waste the capabilities the other non-utilized T/M/S platforms attached to the CAG. A second ARG would supply enough medical capacity to supply the medical teams in the LZs at a faster rate for a cheaper price until the medical ships show up. A third option is to send more MH-53Es to take the place of the CH-53Es on the ARG. (Since the MH-53E provides the second greatest value, it is a better option than both the CH-53E and SH-60s.)

As the American population continues to grow into a more fiscally conservative nation, the DoD is forced to find cheaper and more efficient ways to conduct its missions. Our model shows that assigning aircraft according to their cost efficiency, and then following the given priority system, allows each platform to maximize its capabilities and deliver a greater percentage of overall demand. Cost savings is the second advantage because when the total number of needed aircraft drops, it allows those in charge to use the most cost-effective platforms first to carry out the mission.

C. FURTHER RESEARCH

Due to time and information limitations, we were not able to investigate all aspects of interest we initially identified. Other possible models or points of consideration would be to compare the values of this model under a different disaster scenario in which the landing zone clearance plays a role. Incorporating landing limitations should increase the value of the SH-60 when compared to other T/M/S platforms.

There is also need for further analysis on the cost of maintenance in support of these missions. Including unit cost and figuring out the BCM percentage of those expected failures will give a clearer total dollar for each squadron in support of the mission. Our theory is that by identifying which items fail the most and using the BCM percentage, we could figure the BCM cost for each of the top 10 items. For those fixable items at the Intermediate Maintenance Activity (IMA), there is usually a trend as to what needs repair. Using AFAST data to find the cost to fix the non-BCM items and multiplying it by the predicted number of failures would provide the DoD with better maintenance cost information for supporting a HA/DR mission.

The table for the expected HA/DR missions failures for each T/M/S platform is located in the appendix. This table is incomplete and requires additional SH-60 information. From our research, the CH-53E ranks in the lower tier of our cost efficiency hierarchy; however, it ranks first in the lowest amount of expected maintenance failures. The MTBF for this platform's top ten maintenance failures is significantly lower than the other T/M/S platforms. This leads to fewer maintenance failures and overall lower maintenance costs during the mission.

We also recommend using possible modeling programs such as linear programming and Crystal Ball. Using linear programming could provide an optimal solution to meet the given priorities for the number of aircraft to assign to each route to meet the daily demands. Using Crystal Ball to measure the variability in the delivery system will give a more realistic percentage of overall demand fulfilled over each day of the response. Setting the variability parameters on mission capable percentages and overall efficiency in loading and unloading each T/M/S platform will yield a better assessment of the ability to meet the overall demand in each category under uncertainty.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX

Table 23. H-60 Top 10 Maintenance Failures

TEC	Nomenclature	BCM Price
AHZN	DAMPENER,VIB	$19,856.00
YPAA	RADIO SET	$9,076.00
AHZN	COMPUTER,DIG	$500,475.00
AHZN	STARTER,ENGI	$12,843.00
AHZN	RECEIVER,TRA	$49,926.00
AHZN	PUMP,HYDRAULIC	$23,790.00
AHZN	CONTAINER,FI	$3,525.00
AHZN	ACCUMULATOR,	$10,416.00
YPAA	RADIO SET	$11,597.00
AHZN	PROCESSOR,RA	$272,882.00

Table 24. CH-46 Top 10 Maintenance Failures

TEC	Nomenclature	Unit Price	BCM Price	MTBF	Monthly Expected Failures	14-Day Expected Failures	Current AVCAL	Increase Needed	Difference	Unit Cost	BCM Cost
AHRH	AIMS,ACQUISITION UN	$3,694	$60,862	0.00233	5.66	7.93	10	13	3	$11,082.00	$482,629.23
AHRH	TRANSMISSION,MECHAN	$235,604	$1,146,690	0.00131	3.18	4.45	6	8	2	$471,208.00	$5,097,336.81
AHRH	BLADE ASSY,COMPOSIT	$13,470	$251,539	0.00471	11.45	16.03	17	23	6	$80,820.00	$4,031,996.93
AHRH	BLADE ASSY,COMPOSIT	$16,375	$304,656	0.00472	11.46	16.05	17	23	6	$98,250.00	$4,889,164.32
AHRH	HEAD,ROTARY WING	$326,315	$382,476	0.00232	5.64	7.89	10	13	3	$978,945.00	$3,018,585.73
AHRH	FLIGHT CONTROL GROU	$6,428	$90,923	0.00282	6.86	9.61	11	15	4	$25,712.00	$873,432.27
AHRH	CYLINDER ASSEMBLY,A	$8,709	$10,747	0.00316	7.67	10.74	12	16	4	$34,836.00	$115,384.48
AHRH	HEAD,ROTARY WING	$314,900	$371,665	0.00179	4.36	6.10	8	10	2	$629,800.00	$2,268,203.30
AHRH	CYLINDER ASSEMBLY,A	$5,364	$10,236	0.00423	10.28	14.39	16	21	5	$26,820.00	$147,302.10
AHRH	ENGINE CONTROL ASSY	$6,940	$46,401	0.00107	2.60	3.64	5	7	2	$13,880.00	$168,682.47
									Total	$2,371,353.00	$21,092,717.65

Table 25. CH-53 Top 10 Maintenance Failures

TEC	Nomenclature	Unit Price	BCM Price	MTBF	Monthly Expected Failures	14-Day Expected Failures	Current AVCAL	Increase Needed	Difference	Unit Cost	BCM Cost
AHXC	MAIN ROTOR DAMPER	$20,899.00	$15,794.00	0.01292	6.20	8.68	11	14	3	$47,382.00	$181,495.58
AHXC	TAIL ROTOR PITCH SHAFT SUPPORT	$15,868.00	$12,694.00	0.00135	0.65	0.91	2	3	1	$14,379.58	$14,379.58
AHXC	TAIL ROTOR GEARBOX	$102,416.00	$73,302.00	0.00112	0.54	0.76	2	2	0	$77,341.13	$77,341.13
AHXC	TAIL ROTOR BLADE	$344,324.00	$28,839.00	0.00551	2.64	3.70	6	7	1	$1,274,107.53	$1,274,107.53
AHXC	MAIN ROTOR SWASHPLATE	$264,770.00	$105,244.00	0.00202	0.97	1.36	3	3	0	$359,901.77	$359,901.77
AHXC	MAIN GEAR BOX	$1,168,954.00	$997,311.00	0.00067	0.32	0.45	1	2	1	$529,652.93	$529,652.93
AHXC	PRIMARY SERVO	$109,544.00	$40,408.00	0.00461	2.21	3.10	5	6	1	$339,168.23	$339,168.23
AHXC	TAIL ROTOR SERVO	$23,861.00	$19,089.00	0.00135	0.65	0.91	2	3	1	$21,622.83	$21,622.83
AHXC	BLADE, ROTARY WING	$176,606.00	$117,604.00	0.00966	4.64	6.49	8	11	3	$1,146,955.62	$1,146,955.62
AHXC	MAIN ROTOR HEAD	$2,341,486.00	$1,691,191.00	0.00090	0.43	0.60	2	2	0	$1,414,569.40	$1,414,569.40
									Totals	$5,225,081.02	$5,359,194.60

Table 26. MH-53 Top 10 Maintenance Failures

TEC	Nomenclature	Unit Price	BCM Price	MTBF	Monthly Expected Failures	14-Day Expected Failures	Current AVCAL	Increase Needed	Difference	Unit Cost	BCM Cost
AHXJ	MAIN GEARBOX	$3,512,229	$1,198,876	0.00040	0.77	2.32	2	3	1	$1,198,876.00	$8,148,016.69
AHXJ	ENGINE AIR PARTICLE SEP (EAPS)	$82,056	$70,008	0.00430	8.25	24.75	13	17	4	$280,032.00	$2,030,524.11
AHXJ	PENDANT ASSY AFT CABIN AMCM WINCH	$10,178	$10,178	0.00282	5.41	16.24	9	12	3	$30,532.77	$165,276.87
AHXJ	MAIN FUEL CONTROL (-419)	$127,890	$24,356	0.00295	5.67	17.01	10	12	2	$48,712.00	$2,175,740.52
AHXJ	MAIN ROTOR TANDEM SERVO	$169,468	$33,342	0.00148	2.84	8.51	6	7	1	$33,342.00	$1,441,545.05
AHXJ	APP GAS TURBINE POWER PLANT	$106,414	$58,660	0.00094	1.80	5.41	4	5	1	$58,660.00	$576,029.39
AHXJ	MAIN ROTOR BLADE (composite)	$307,759	$93,768	0.00564	10.83	32.48	16	22	6	$562,608.00	$9,995,577.33
AHXJ	ALL NACELL			0.00537	10.31	30.93	16	21	5	$0.00	$0.00
AHXJ	AFCS COMPUTER	$207,203	$9,073	0.00456	8.76	26.29	14	18	4	$36,292.00	$5,447,820.46
AHXJ	AMCM HYDRAULIC PUMP	$54,444	$12,482	0.00255	4.90	14.69	9	11	2	$24,964.00	$799,929.03
									Total	$2,274,018.77	$30,780,459.44

Table 27. MV-22 Top 10 Maintenance Failures

Nomenclature	BCM Price	MTBF	Monthly Expected Failures	14-Day Expected Failures	Current AVCAL	Increase Needed	Difference	BCM Cost
LH/RH SWASH PLATE ACTUATOR	$93,322	0.00272	6.92	9.69	11	15	4	$904,231.69
RH ENGINE ASSY	$311,303	0.00704	17.89	25.04	25	34	9	$7,795,728.65
NO 3&4 VARIABLE FREQ GENERATOR	$35,351	0.00893	22.68	31.75	31	41	10	$1,122,394.25
LH PROP ROTOR BLADE ASSY	$77,679	0.00251	6.37	8.91	11	14	3	$692,297.05
LH/RH CENTRAL DEICE DISTRIB	$17,101	0.00395	10.04	14.06	15	20	5	$240,360.30
1&2 CONSTANT FREQ GENERATOR	$59,348	0.00532	13.51	18.91	20	26	6	$1,122,561.11
RH PROP ROTOR BLADE ASSY	$79,208	0.00215	5.45	7.63	9	12	3	$604,428.43
LH/RH SWASH PLATE DRIVE TUBE	$20,330	0.00196	4.98	6.97	9	11	2	$141,751.92
LH PROPROTOR GEARBOX ASSY	$649,418	0.00415	10.54	14.76	16	21	5	$9,582,283.85
NACELLE PANEL	$63,161	0.00244	6.20	8.67	11	14	3	$547,806.14
							Total	$22,753,843.39

LIST OF REFERENCES

Apte, A. (2010). Humanitarian logistics: A new field of research and action. *Foundations and Trends in Technology, Information and Operations Management, 3*(1), 1–100.

Burgess, C. (1957). The armed forces in disaster relief. *The ANNALS of the American Academy of Political and Social Science, 309*(1), 71–79.

Cossa, R. (2005). *South Asian tsunami: U.S. military provides "logistics backbone" for relief operation*. Retrieved from http://www.reliefweb.int/rw/rwb.nsf/db900sid/EGUA-6A6R98?OpenDocument

CSF-536 Joint Force Air Component Commander (JFACC)/Air Force Forces Commander (AFFOR). (2005, May 17). *Operation Unified Assistance: Lessons learned and observations.*

Department of the Army Headquarters. (1990). *Staff officers' field manual: Organizational, technical, and logistical data planning factors (Vol. 2).* Retrieved from http://www.globalsecurity.org/military/library/policy/army/fm/101-10-1_2/FM101-10-1-2.PDF

Elleman, B. A. (2007). *Waves of hope: The U.S. Navy's response to the tsunami in northern Indonesia*. Retrieved from the Naval War College website: http://handle.dtic.mil/100.2/ADA463367

Federation of American Scientists (FAS). (2010a). CH-53E Sea Stallion, CH-53D Super Stallion, MH-53E Sea Dragon, MH-53J Pave Low III. Retrieved from http://www.fas.org/programs/ssp/man/uswpns/air/rotary/h53.html

Federation of American Scientists (FAS). (2010b). SH-60 LAMPS MK III Seahawk. Retrieved from http://www.fas.org/programs/ssp/man/uswpns/air/rotary/sh60seahawk.html

Galdorisi, G. V., & Truver, S. C. (2007). Helicopter procurement: Playing with fire. *Proceedings, 133*(9), 64–68.

Humanitarian Assistance, 10 U.S.C. § 2561 (2006).

Joint Center for Operational Analysis (JCOA). (2010). *Operation Unified Response Haiti earthquake response.* Retrieved from https://community.apan.org/.../Operation-United-Respose-JOCA-Rep

Joint Lessons Learned Information System (JLLIS). (2006a, October 26). *Helo OPS: C2 and apportionment of HELO missions.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=1443

Joint Lessons Learned Information System (JLLIS). (2006b, October 26). *HSL unprepared landing training.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=1510

Joint Lessons Learned Information System (JLLIS). (2008a, July 31). *Embarkation of USN helicopters on USNS Mercy.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=438

Joint Lessons Learned Information System (JLLIS). (2008b, July 31). *Helicopter safety handbills*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=1479

Joint Lessons Learned Information System (JLLIS). (2008c, July 31). *Helo OPS: Aircraft configurations for HA/DR OPS–PAX capacities.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=1440

Joint Lessons Learned Information System (JLLIS). (2008d, July 31). *Helo OPS: Remote landing zones, LZ identification.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=1464

Joint Lessons Learned Information System (JLLIS). (2008e, July 31). *Reluctance of UN to assume control*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=461

Joint Lessons Learned Information System (JLLIS). (2008f, July 31). *Sea-basing and the Expeditionary Strike Group.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=461

Joint Lessons Learned Information System (JLLIS). (2010a, April 16). *Balance of medium lift and heavy lift helicopters*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=4704

Joint Lessons Learned Information System (JLLIS). (2010b, April 16). *GTMO air cargo movement.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=4663

Joint Lessons Learned Information System (JLLIS). (2010c, April 16). *NMCI Blackberry OCONUS data activation delay*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=4584

Joint Lessons Learned Information System (JLLIS). (2010d, April 16). *Surface and air plan deconfliction.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=4873

Joint Lessons Learned Information System (JLLIS). (2010e, April 16). *Water containers and delivery*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=4876

Joint Lessons Learned Information System (JLLIS). (2010f, April 23). *Packaging/palletizing of cargo was not conducive to transferring*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5014

Joint Lessons Learned Information System (JLLIS). (2010g, April 28). *Air MEDEVACS.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5062

Joint Lessons Learned Information System (JLLIS). (2010h, April 28). *Create a separate aircraft frequency to coordinate changing mission requirements.* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5074

Joint Lessons Learned Information System (JLLIS). (2010i, April 29). *Distributing supplies to local organizations*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5120

Joint Lessons Learned Information System (JLLIS). (2010j, April 29). *Non-government organizations cargo consignment to specified consignees*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5128

Joint Lessons Learned Information System (JLLIS). (2010k, April 29). *Sea based air hub operating sustainability*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5124

Joint Lessons Learned Information System (JLLIS). (2010l, May 6). *Carrier Air Transfer Office requirements*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5236

Joint Lessons Learned Information System (JLLIS). (2010m, May 6). *Truth in advertising*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5255

Joint Lessons Learned Information System (JLLIS). (2010n, May 14). *Aircraft support equipment*. Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=5287

Joint Lessons Learned Information System (JLLIS). (2010o, December 08). *Operation Unified Response - Haiti: Sea base (U).* Retrieved from https://www.jllis.mil/NAVY/index.cfm?disp=lms.cfm&doit=view&lmsid=4811

LaGrone, S. (2010, February 22). Natural disaster, manmade response: US assets dominate Haiti relief effort. *Jane's Navy International*, 3.

Mathison, S. (2005). *Encyclopedia of evaluation*. Thousand Oaks, CA: Sage.

Monagle. (2011). Navy helicopters in the humanitarian assistance/disaster relief (HA/DR) mission. PowerPoint Presentation at the 2001 Aviation Maintenance Symposium, Virginia Beach, VA.

National Research Council (NRC). (2005). *Sea basing: Ensuring joint force access from the sea* [ebrary version]. Retrieved from http://www.ebrary.com/corp/

Office of the Chief of Naval Operations. (2003). *Operational availability of equipments and weapons systems* (OPNAVINST 3000.12A). Retrieved from http://doni.daps.dla.mil/Directives/03000%20Naval%20Operations%20and%20Readiness/03-00%20General%20Operations%20and%20Readiness%20Support/3000.12A.pdf

Sea-basing. (2011). In *Dictionary.com*. Retrieved from http://dictionary.reference.com/browse/sea-basing

Serafino, N. M. (2008, December 9). *The Department of Defense role in foreign assistance: Background, major issues, options for Congress* (CRS Report No. RL34639). Retrieved from the Congressional Research Service website: http://www.crs.gov

Shutler, P. (1999). *Naval expeditionary logistics: Enabling operational maneuver from the sea* [ebrary version]. Retrieved from http://www.ebrary.com/corp/

Transportation of Humanitarian Relief Supplies to Foreign Countries, 10 U.S.C. § 402 (2006).

United States Agency for International Development (USAID). (2005, September). *Field operations guide: For disaster assessment and response.* Retrieved from http://www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/resources/pdf/fog_v4.pdf

United States Agency for International Development (USAID). (2009, December 15). Philippines—Tropical storms [Fact sheet]. Retrieved from http://www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/countries/philippines/template/fs_sr/fy2010/philippines_ts_fs11-12-15-2009.pdf

United States Marine Corps (USMC), United States Navy (USN), & United States Coast Guard (USCG). (2010). *Naval operations concept (NOC) 2010: Implementing the maritime strategy*. Retrieved from the U.S. Navy website: http://www.navy.mil/maritime/noc/NOC2010.pdf

U.S. Navy. (2011). Our ships. Retrieved from http://www.navy.mil

Wassenhove, L. (2006). Humanitarian aid logistics: Supply chain management in high gear [dagger]. Palgrave Macmillan. doi:10.1057/palgrave.jors.2602125

THIS PAGE INTENTIONALLY LEFT BLANK

2003 - 2011 SPONSORED RESEARCH TOPICS

Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness
- Naval Aviation Maintenance and Process Improvement (2)

- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

A complete listing and electronic copies of published research are available on our website: www.acquisitionresearch.net

THIS PAGE INTENTIONALLY LEFT BLANK

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CALIFORNIA 93943

www.acquisitionresearch.net