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THESIS

**OPTIMIZATION CASE STUDY: ISR ALLOCATION IN THE
GLOBAL FORCE MANAGEMENT PROCESS**

by

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September 2016

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**OPTIMIZATION CASE STUDY: ISR ALLOCATION IN THE GLOBAL FORCE
MANAGEMENT PROCESS**

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ABSTRACT

Global Force Management (GFM) is a force-allocation process-driven system that distributes military forces across the globe to meet Combatant Commander objectives. The goal is to match military capabilities provided by the military services to Geographic Combatant Commander requirements. This thesis is a proof of concept for an optimization model that maximizes the distribution of a finite number of full motion video intelligence, surveillance, and reconnaissance (ISR) assets to a prioritized list of requirements to meet national security objectives.

This thesis examines the ISR GFM process. With the insight gained to the process, the model applies a mixed integer linear programming formulation to provide an optimized force allocation recommendation. The model's objective function managed the trade-off between FADM priority and platform consideration, which optimized the allocation 902 hours per day of full motion video to meet 1902 hours per day of 20 CCDR requirements.

The research, methodology, and analyses presented in this thesis is a successful proof of concept proving that this optimization model will objectively inform senior decision makers in the Department of Defense for intelligence surveillance reconnaissance Global Force Management allocation.

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LIST OF ACRONYMS AND ABBREVIATIONS

AOR	area of responsibility
CCDR	Combatant Commander
CONOPS	concept of operations
DEPOD	deployment order
DOD	Department of Defense
EMARSS	Enhanced Medium Altitude Reconnaissance and Surveillance System
FADM	force allocation decision matrix
FMV	full motion video
FP	force provider
GEF	Global Employment of the Force
GFM	global force management
GFMAP	Global Force Management Allocation Plan
GFMIG	Global Force Management Implementation Guidance
ISR	intelligence surveillance reconnaissance
JFC	Joint Force Coordinator
JFP	Joint Force Provider
LRE	launch and recovery element
NATO	North Atlantic Treaty Organization
NSC	National Security Council
OPLAN	operation plan
POTUS	President of the United States
SDOB	Secretary of Defense Orders Book
SECDEF	Secretary of Defense
SIGINT	signals intelligence
SOF	special operations forces
SVTC	secure video teleconference
USAFRICOM	United States Africa Command
USCENTCOM	United States Central Command
USEUCOM	United States European Command

USNORTHCOM	United States Northern Command
USPACOM	United States Pacific Command
USSOUTHCOM	United States Southern Command
USSTRATCOM	United States Strategic Command

EXECUTIVE SUMMARY

Global Force Management (GFM) is a force-allocation process-driven system that distributes military forces across the globe to meet Combatant Commander objectives. The goal of GFM is to match military capabilities provided by the Services to Geographic Combatant Commander requirements. This thesis is a proof of concept for an optimization model that maximizes the distribution of finite number of assets to a prioritized list of requirements.

The Secretary of Defense (SECDEF) directs the Global Force Management (GFM) allocation process in the Dissemination and Guidance for the Employment of the Force. The National Strategic Strategy, the National Defense Strategy, and the National Military Strategy direct, guide, and inform the GFM process. The National Strategic Strategy establishes national priorities; the National Defense Strategy guides the Department of Defense (DOD), which along with the National Military Strategy, provides strategic direction.

The GFM process organizes and distributes military forces to meet Geographic Combatant Commanders (CCDRs) requirements. The allocation process looks across the entire DOD to identify and recommend the most appropriate and responsive force that can meet CCDR requirements. Each force request culminates in a Secretary of Defense (SECDEF) decision and subsequent deployment order to allocate a force. The forces come from several sources, including: a Service Secretary such as the Army, Navy, Marine Corps, or Air Force; a CCDR's assigned forces; or forces from other DOD Agencies. The SECDEF allocates the forces to the requesting CCDR based on informed recommendations from the Joint Staff. The design of the entire global force management process allows the SECDEF to make prioritized decisions for the employment of the force. The product of the GFM process is deployed military forces to the Geographic Combatant Commanders (CCDR).

1. Secretary of Defense. 2015. (U) *Dissemination of the Guidance for the Employment of the Force*. Washington, DC: Department of Defense. This document is classified SECRET.

This thesis focuses on the intelligence, surveillance, and reconnaissance capabilities within the GFM process. Typically, ISR capabilities such as full motion video (FMV) are in high demand by CCDRs. However, the availability of ISR platforms is severely limited. ISR capability is described as high demand and low density. Because of the ability of ISR platforms potentially to provide capability to multiple CCDRs from a common operating location and competing demands for mission critical requirements, the allocation of ISR forces includes close coordination between the Joint Staff, CCDRs, force providers, and the Joint Functional Component Command for Intelligence, Surveillance, and Reconnaissance (JFCC ISR).

The challenge with the current ISR allocation process is objectively quantifying the reason behind a recommended sourcing solution for ISR global allocation. Current military operations across the globe experience more demand from the Geographic Combatant Commanders (GCC) than the Force Providers have assets available to meet the GCC requirements. The Joint Staff, in concert with USSTRATCOM, use many factors to prioritize allocation of assets to include determining which GCC gets the assets and for how long. The decision influencers recommend a resource allocation solution based on experience, force capacity, GCC demand, and the strategic environment provided by guidance from the National Security Council (NSC).

The ISR allocation optimization model applies to any of the ISR requirement capabilities, including but not limited to Full Motion Video (FMV), Signals Intelligence (SIGINT), Communications Intelligence (COMINT), and other intelligence collection capabilities. The complexity of FMV force allocation makes FMV the ideal capability to use for a proof of concept.

Hypothetical data is used to keep this thesis unclassified. The platform capabilities come from a small sampling of ISR FMV platforms that have sufficient open-source information to make the model relevant. The hypothetical CCDR requirements are derived from and loosely based on historical data from GFMAP force allocations. Actual CCDR requirements, force capacities, and FADM priorities are classified. The model uses a methodical approach using known data and informed assumptions to develop reasonable scenarios to implement in the model.

This optimization model and its methodology uses full motion video capability and notional requirements to model the applicability of optimization in the Global Force Management allocation process. The model uses an objective function that to maximize the hours of FMV allocated to each CCDR to meet the prioritized mission requirements. The objective function manages the trade-off between ISR platform constraints and CCDR requirements constraints.

Results from the base model, which only considered FADM for allocation prioritization, shows that with only 902 hours per day of FMV capacity to meet 1902 hours per day of requirements, the optimized solution provided 100 percent of the requirement capability to 12 of the 20 CCDR requirements and a partial allocation of 39 hours per day or nine percent of the requirement to the single next lowest FADM priority requirement. These results are useful to inform senior decision makers within the DOD of which requirements will not receive a capability allocation. The results can be compared against the actual Global Force Management Allocation Plans to highlight which lower FADM priorities are actually receiving a force allocation. The reasons for the differences can inform decision makers that the strategic priorities do not align to how the allocation is being allocated. For force providers and DOD budget personnel, the gaps highlight areas where additional resources can be committed to meet strategic objectives.

Combining and balancing FADM and platform consideration into the optimization model allows decision makers a model that more closely resembles current allocation methods. The results of the combined model change if we modify the $value_{ij}$ parameter for a particular platform. This change may represent where the platform consideration is modified based on new information or just to examine model sensitivity. This is the expected result because the model is using the product of platform consideration times the FADM priority to define $value_{ij}$ in the objective function. The objective function manages the trade-off between FADM priority and platform consideration. The combined model more closely simulates how the force allocations recommendations are made because it takes into account regional geographic realities while managing global strategic priorities.

The current GFM process method cannot quantify and objectively compare the specifics of platform considerations and strategic priority. This model highlights the areas where there may be trade-space for additional allocation opportunities. For example, if the only means to provide capability to a specific ISR requirement is allocating manned aircraft, the model will show what requirements will be affected to meet that limitation. Additionally, by interpreting the results, the CDR can assess where their requirement priorities are evaluated globally across all of the CDR's requirements. The Joint Staff can evaluate the data to verify that the results support the military objectives of the National Military Strategy. If the results do not support the strategic objectives then the CDR priorities and the force provider capacity must be scrutinized to mitigate the capability and requirement gaps. The impact implications are important to the Combatant Commanders for mitigation options and important to the SECDEF for accepting the risk associated with the recommendation.

Combining the optimization model described throughout this thesis with a risk informed model that can be implemented for the force allocation of all ISR capabilities is a logical evolution that optimizes the force allocation decision process that informs the SECDEF for force decisions and responsibility. This thesis critically examines the GFM ISR allocation process and the factors that influence it. With the insight gained about the process, the proof of concept applied a methodical optimization formulation to a complex ISR force allocation problem that is complicated further by significantly less capacity than demand. The research, methodology, and analyses presented successfully prove that this optimization model will objectively inform senior decision makers in the Department of Defense for intelligence surveillance reconnaissance Global Force Management allocation.

I. INTRODUCTION

A. BACKGROUND

Global Force Management (GFM) is a force-allocation process-driven system that distributes military forces across the globe to meet Combatant Commander objectives. The goal is to match military capabilities provided by the Services to Geographic Combatant Commander requirements. This thesis is a proof of concept for an optimization model that maximizes the distribution of finite number of assets to a prioritized list of requirements.

Chapter I begins with a broad description of GFM and the documents that direct and guide the process. It introduces how GFM addresses and balances risk to both the Services and the Combatant Commanders. This chapter asks the question, “What can be added to the GFM process to objectively inform senior decision makers in the Department of Defense for intelligence surveillance reconnaissance (ISR) Global Force Management allocation?” Although GFM addresses the allocation of all military capabilities, this thesis focuses on intelligence, reconnaissance, and surveillance capabilities; specifically full motion video. The requirements demand for ISR and full motion video significantly exceeds global capacity of assets available. This makes ISR full motion video capability an ideal candidate for optimization.

The methodology outlined in Chapter II breaks down the GFM process into decisional process steps. It identifies who the decision makers and influencers are in each step. The purpose of Chapter II is to develop an understanding of the GFM process as it exists today and to get a sense its complexity. With this foundational understanding, the paper describes the specifics of the ISR allocation process. ISR allocation recommendations are based on a combination of objective and heuristic data and variables.

Chapter III introduces the objective function which maximizes the number of hours of ISR capability provided to the Geographic Combatant Commanders in to meet

prioritized mission objectives. It introduces the indices, parameters, and constraints that shape the implementation of the model.

Chapter IV describes in detail, the indices, parameters, and constraints introduced in Chapter III using notional data. It describes the assumptions made in the model development. The model applies a methodical approach using known data and informed assumptions to develop reasonable notional scenarios for implementation in the model. This chapter describes the analyses of the results.

Chapter V summarizes the success of the optimization model and recommends continued development of the model to include all ISR capabilities. It also recommends a model that takes into account risk informed factors. Building on both models, we can apply the next iteration to the emergent allocation process.

1. Global Force Management System Process

The Secretary of Defense (SECDEF) directs the Global Force Management (GFM) allocation process in the Dissemination and Guidance for the Employment of the Force.¹ The GFM process organizes and distributes military forces to meet Geographic Combatant Commanders (CCDRs) requirements.

The National Strategic Strategy, the National Defense Strategy, and the National Military Strategy direct, guide, and inform the GFM process. The National Strategic Strategy establishes national priorities; the National Defense Strategy guides the Department of Defense, and the National Military Strategy provides strategic direction. The following strategic planning documents guide GFM:

- Unified Command Plan signed by the President of the United States (POTUS)
Unified Command Plan (UCP) establishes the combatant commands, identifies geographic areas of responsibility, assigns primary tasks, defines authority of the commanders, establishes command relationships, and

¹ Secretary of Defense. 2015. (U) “*Dissemination of the Guidance for the Employment of the Force.*” Washington, DC: Department of Defense. This document is classified SECRET.

gives guidance on the exercise of combatant command. The President of the United States approves the UCP. The CJCS publishes the UCP for the commanders of combatant commands.

- Joint Strategic Capabilities Plan

The Joint Strategic Capabilities Plan (JSCP) carries out the Chairman of the Joint Chiefs of Staff National Military Strategy and provides guidance to combatant commander and the JCS to accomplish tasks and missions based on current military capabilities.

- Global Force Management Implementation Guidance

The Global Force Management Implementation Guidance (GFMIG) establishes procedures for assignment, allocation, and apportionment of U.S. military forces. The GFMIG includes a military risk matrix.

The Secretary of Defense (SECDEF) approves the GFMIG.

- Guidance for Employment of the Force

The Guidance for Employment of the Force (GEF) provides both the president's guidance for contingency planning and conveys the SECDEF's guidance to focus on the use of existing Department of Defense forces to accomplish near-term objectives.

The GEF establishes the defense posture for a 2–15-year timeframe

The GEF inherently accepts risk and informs decision makers across the DOD to make risk-informed decisions. The GEF prioritizes greatest national security risks and highest consequence issues.

The allocation process looks across the entire DOD to identify and recommend the most appropriate and responsive force that can meet CCDR requirements. Each force request culminates in a Secretary of Defense (SECDEF) decision and subsequent deployment order to allocate a force. The forces come from several sources, including: a Service Secretary such as the Army, Navy, Marine Corps, or Air Force; a CCDR's assigned forces; or forces from other DOD agencies. The SECDEF allocates the forces to the requesting CCDR based on informed recommendations from the Joint Staff.

The allocation process illustrated in Figure 1 is the OV-1 diagram from the Joint Staff Global Force Management Enterprise Integration Architecture document (Joint Staff 2014). The Global Force Management process provides feasible sourcing options to the SECDEF with the decision support process to assess quickly and accurately current and future impact and risks associated with proposed force changes. Each allocation

recommendation balances force provider risk to force with CCDR risk to mission. Assessing force allocation risk is complex. A CCDR must assess risk to current operations while at the same time predicting risk to strategic operational plans.

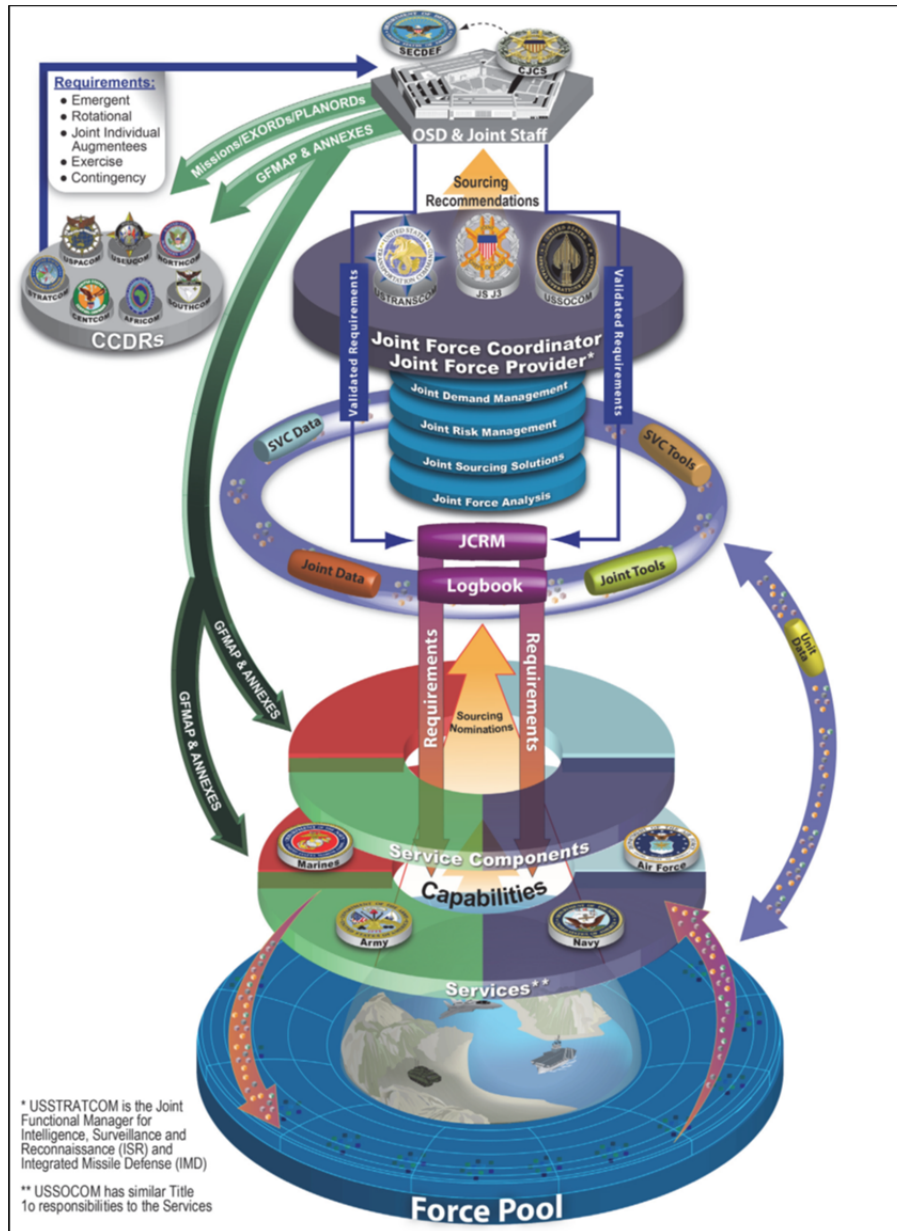


Figure 1. OV-1 Allocation Operational Concept Graphic.
Source: Joint Staff (2014).

This chapter will step through the GFM allocation process and develop an understanding of the GFM process depicted in Figure 1. The allocation process begins when the SECDEF assigns missions and operations to CCDRs. To meet the mission and operations objectives, CCDRs request forces with the capabilities required to achieve mission objectives. For example if a CCDR is required to conduct a strike into a particular area, the CCDR needs to know what and where the targets are. To do that, the CCDR may require an ISR capability such as full motion video to build situational awareness of the battle space. The CCDR will request full motion video as the force requirement.

The GFM process supports both rotational requirements and emergent requirements. Rotational requirements are those operations and missions that CCDRs and Force Providers are able to plan for from fiscal year to fiscal year. For example, to conduct Operation IRAQI FREEDOM (OIF), Commander United States Central Command's (USCENTCOM) strategy requires forces to continue from one fiscal year into the next. USCENTCOM will continue to require ISR capabilities to monitor the situation in Iraq. This plan informs the demand for USCENTCOM's rotational requirements. Emergent requirements are force capabilities needed in addition to the rotational requirements. Emergent requirements happen during the current fiscal year. For example, during the Ebola Crisis in the Commander United States Africa Command (USAFRICOM) Area of Responsibility (AOR), USAFRICOM requested additional medical support capabilities to augment the forces allocated in fiscal year 2014. Emergent requirements typically address the "what's changed?" in a CCDR's AOR within the fiscal year.

The Joint Staff will validate each CCDR's force requirement. Validation includes verifying requirements, assigning a priority, and ensuring the CCDR has the proper authorities to conduct the operation with the requested capability. The Joint Staff as the Joint Force Coordinator (JFC) will assign the Joint Force Provider (JFP) for conventional forces, Special Operations Forces (SOF), or mobility. The JFC and JFP will coordinate with the Air Force, Army, Marines, and Navy, who are the Force Providers (FP) to determine sourcing options to meet the CCDR's requirements. Force providers look

across the complete spectrum of their Service capabilities and balance the need to meet the requirement with the risk to the impact to Service force readiness. With the high demand for combat forces across the globe continuing since 2011, the risk to Service and Force readiness is the most significant factor in force allocation recommendations to the SECDEF. In many force capabilities, there is no additional capacity to meet all of the CCDR's rotational requirements and emergent requirements without a reallocation of forces. This is the case with intelligence, surveillance, and reconnaissance (ISR) capabilities.

The JFC and JFPs critically review the FP nominations including analyzing risk to develop a recommended joint sourcing solution. The Joint Staff will socialize the recommended sourcing solution to the CCDRs and FPs to accurately address both risk to mission and risk to force impacts in order to inform the SECDEF for force allocation decision. When the FP and/or the CCDR do not agree with a recommendation, the issue becomes contentious. The contentious issue will go through a resolution process consisting of action officer and General Officer/Flag Officer (GOFO) level forums. A requirement becomes contentious for several reasons:

1. The FP does not have the capacity to meet a CCDR's requirement to a satisfactory level.
2. The proposed solution meets the requirement, but it is missing the specific unit type wanted by the CCDR.
3. The CCDR has a valid requirement yet there is no capacity to meet the requirement without reallocation from another CCDR.
4. The recommended solution reallocates existing forces in one CCDR's AOR to a different CCDR.

Situation (4) causes many contentious issues for ISR requirements. ISR capability demand far exceeds ISR capacity. When the force providers have all available forces allocated and there is no additional capacity for emergent requirements, it may be necessary to reallocate forces from one CCDR to another. The Joint Staff makes the recommendation to reallocate the assets, and the SECDEF is the approval authority to reallocate assets from one CCDR.

The Joint Staff will staff all resource allocation recommendations. Once staffed, the recommendations become part of the draft Global Force Management Allocation Plan (GFMAP). The Joint Staff will staff the GFMAP to the FPs and CCDRs prior to submitting the sourcing recommendations to the SECDEF. The Joint Staff briefs the draft order through the Joint Staff Directorates and the Office of the Secretary of Defense (OSD) to the Chairman of the Joint Chiefs of Staff (CJCS), OSD leadership. When the SECDEF approves the GFMAP, the Joint Staff publishes the GFMAP. The GFMAP is the SECDEF Deployment Order (DEPOD) for all allocated forces.

2. Risk Assessment

The GFM process takes into account military risk and strategic risk. Strategic risk evaluates and judges both the probability and consequence of threats to the nation. The GFMIG defines military risk as risk to mission and risk to force; it uses the terms to express the overall risk associated with fiscal year requirements. Title 10, U.S.C., section 153 requires CJCS annually to “assess the nature and magnitude of the strategic and military risks with executing” National Military Strategy missions.

Risk to mission is the CCDR’s ability to execute assigned missions at acceptable human, material, financial and strategic costs. Risk to mission should include the CCDR’s assessment of what aspects of the mission will assume risk and for how long. Effective risk to mission assessments includes risk mitigation measures and the impact of those mitigation measures to the mission. In other words, what requirements will not be met and how will that affect meeting mission objectives? This thesis will identify what requirements will not be met.

B. PRIMARY RESEARCH THESIS QUESTION

How do we quantify the tradeoff necessary to reduce contentious decision-making in the Global Force Management allocation process?

This thesis is a proof of concept of an optimization model for ISR allocation within the Global Force Management process. The challenge with the current ISR allocation process is objectively quantifying the reason behind a recommended sourcing solution for ISR global allocation. Current military operations across the globe

experience more demand from the Geographic Combatant Commanders (GCC) than the Force Providers have assets available to meet the GCC requirements. The Joint Staff, in concert with USSTRATCOM, use many factors to prioritize allocation of assets to include determining which GCC gets the assets and for how long. The decision influencers recommend a resource allocation solution based on experience, force capacity, GCC demand, and the strategic environment provided by guidance from the National Security Council (NSC).

C. BENEFIT OF STUDY

This ISR capability optimization proof of concept will take an ISR capability that the GCCs require such as full-motion video (FMV), and show how the allocation can be optimized to meet requirements across the GCCs. To do understand the complexities of the ISR force allocation, the next chapter will describe the allocation process.

II. METHODOLOGY

This chapter describes how a Combatant Commander's capability requirement receives a force allocation. The Global Force Management process is explained step-by-step starting with the CCCR's requirement identified. It ends with a force deployed to meet that requirement and it identifies critical decision points. This chapter also describes the additional steps of the ISR allocation process.

A. GFM PROCESS DESCRIPTION

The design of the entire global force management process allows the SECDEF to make risk informed and prioritized decisions for the employment of the force. The product of the GFM process is deployed military forces to the Geographic Combatant Commanders (CCDR). The GFM process in Figure 2 describes how the CCCRs request forces through a request for forces (RFF) through the validation process, and receives force allocation as ordered by the SECDEF. For the purpose of this report, the scope and specifics of the process is unclassified. For ISR requirements, it is common for the issue to become contentious during the resource allocation process. There are not enough ISR assets to meet CCCR requirements (Secretary of Defense 2016). The entire process is to allow the SECDEF to make risk informed decisions for the employment of the force.

1. The GFM process begins with a RFF from the Geographic Combatant Commander. The request is for a capability needed in that GCC's area of operations that does not already exist.² An example of a capability request is for ISR full motion video from USEUCOM to monitor the refugee crisis of people leaving Syria across the Mediterranean Sea. The Joint Staff receives the RFF via an electronic message.
2. The Joint Staff verifies that the GCC has the authority for the capability of the RFF requested and the force meets the guidance of provided in Chapter I. When the RFF meets validation requirements, it moves to

² Secretary of Defense. 2015. (U) "*Dissemination of the Guidance for the Employment of the Force.*" Washington, DC: Department of Defense. This document is classified SECRET.

validation. If the RFF does not meet the validation requirements, it returns to the CCDR with requests for more information in order to meet the validation requirements.

3. Decision Point. In validation, the J31 Deputy Director approves or denies the validation of the RFF. Validated RFFs proceed to the resource allocation process. Not validated RFFs return to the CCDR. Some of the reasons for not validating an RFF include but not limited to the following:
 - a. The RFF is asking for a validated requirement that already exists.
 - b. The RFF is asking for a requirement that does not meet the SECDEF's strategic direction.
 - c. The RFF is requesting a relook at sourcing without a significant change in the CCDR strategic situation.

Validation simply determines if the CCDR has valid SECDEF approved mission with fiscal authority, legal, and that there is not an existing requirement for the same capability (Joint Staff, 2014). Validation does not consider whether the Force Providers have the capacity to source the request. Validated RFFs may or may not have forces allocated. The SECDEF assumes all of the risk to the CCDR for not providing resources to meet the demand when a validated capability lacks resources. This happens when there are not enough forces to meet all of the requests from all of the COCOMs without breaking the force providers' ability to reconstitute forces from year to year and surge capacity to meet emergent requirements. Many ISR RFFs are validated yet do not receive the required resources.

4. The validated RFF is assigned a GEF priority and a request is sent to the Force Providers for force allocation feasibility. With some requirements, multiple services can source the requested capability. For example, the Navy and the Air Force can source ISR—Signals Intelligence (SIGINT) capabilities with the EP-3 Aries and the RC-135 V/W Rivet Joint. A single Service can only source other capabilities. For example, the Navy is obviously the only Service that can provide a maritime presence with a Carrier Strike Group. The Joint Staff as the Joint Force Coordinator, will use the Force Allocation Decision Model (FADM) to prioritize fulfillment

of requirements.³ The FADM is guidance that provides a flexibility for making force allocation recommendations among competing requests (Joint Staff, 2014). The details of the FADM are classified. However, the intent of the FADM is to align GFM allocation recommendations with Department of Defense priorities. It is a tiered framework where the higher the FADM priority, the more critical the requirement is to strategic end-states and top priority planning efforts (Joint Staff 2014).

5. Decision Point. The Joint Staff sends the RFF to the appropriate service or services for force allocation recommendations. If the service can meet the request, the service accepts the responsibility to provide resources to the RFF. If the service cannot meet the requirement, the service must provide the reason including the risk assessment as to why it cannot meet the request. In some cases, the services will agree to provide resources with the capability with some exceptions or comments, which may outline a different unit to meet the same capability.
 - a. For ISR requirements, there is an additional step in the process. JFCC-ISR will review the ISR RFF and provide force allocation recommendations to the force providers and the CCDRs through the Joint Staff. JFCC-ISR recommendations use trend analysis of requirements from year to year, service capacity to process the collection, and operational constraints such as basing options, over flight permissions, and command and control architecture limitations (Joint Staff 2014).
6. If the Force Provider has the capacity to meet the requirement, the FP sends the resource allocation recommendation to the Joint Staff. If the force provider cannot meet the requirement, the request returns to the Joint Staff for additional staffing, and the recommended solution is contentious between the Force Provider, the CCDR, and the Joint Staff.
7. The Joint Staff will work with both the force provider and the CCDRs to agree on an acceptable resource allocation solution. During the resolution process, force providers provide force availability data and answer questions to give decision makers a better understanding of why the

³ Secretary of Defense. 2015. (U) “Dissemination of the Guidance for the Employment of the Force.” Washington, DC: Department of Defense. This document is classified SECRET.

request is not feasible. Additionally, for many RFFs, the questions go back to the CCDRs for amplifying information. The purpose of this step is to resolve the issues with an acceptable solution from the CCDR and the Force Providers at the lowest decision maker level.⁴

7a. Decision Point. The first step in the adjudication process of a contentious issue is at the Action Officer level via a Secure Video Teleconference (SVTC). The required participants include the action officers from the Joint Staff, the GCCs, and the Services. The SVTC is an opportunity for each stakeholder to make the case why the RFF does not have the resource allocation as required by the CCDR. The Joint Staff is the broker of this step in the process. In some cases, the issue is resolved at this level with a negotiated resource allocation for or a formal withdrawal of the RFF from the CCDRs, removing the RFF. If the issue is not resolved and remains a contentious, it is elevated to the One-Star General Officer Flag Officer (GOFO) level.

7b. Decision Point. If unresolved after the action-officer level process, the contentious issue proceeds to a one-star GOFO level SVTC. The required participants include the one-star GOFO from the Joint Staff, each CCDR, and each Service force provider. This SVTC is an opportunity for each stakeholder to make the case why the recommendation does not meet the CCDR requirement. The Joint Staff is the broker of this step in the process. In some cases, the issue is resolved at this level with a negotiated resource allocation recommendation or a formal withdrawal of the RFF from the GCCs, removing the RFF. If the issue is not resolved and remains a contentious, the issue is elevated to the Three-Star GOFO Operations Deputies (OPSDEP) tank.

7c. Decision Point. If there is no resolution by this stage in the process, the contentious issue proceeds to a three-star GOFO Operations Deputies (OPSDEP) tank for resolution. The required participants include the three-star Operations Deputy GOFO from the Joint Staff, each GCC, and each Service force provider. This meeting is an opportunity for each stakeholder to make the case why the recommendation does not meet the

⁴ Secretary of Defense. 2015. (U) *Dissemination of the Guidance for the Employment of the Force*. Department of Defense, Washington, DC. This document is classified SECRET.

CCDR requirement The Joint Staff is the broker of this step in the process. In some cases, the issue is resolved at this level with a negotiated resource allocation recommendation or a formal withdrawal of the RFF from the GCCs, removing the RFF.

7d. The unresolved issue remains contentious and is elevated to the Four-Star JCS tank. The JCS Tank adjudicates very few RFFs. For example, in fiscal year 2015, one ISR contentious issue went to the JCS for resolution. The specifics of the issue are classified; however, the context of the issue affected the overall force health of the Air Force remote piloted aircraft capability and required the attention and strategic prioritization of the Joint Chiefs of Staff. With a resource allocation decision made for the RFF, a risk to force assessment by the Service and a risk to mission assessment by the CCDR is included in the sourcing recommendation.

8. The Joint Staff compiles the RFFs and the sourcing solutions for SECDEF approval to deploy forces via the Global Force Management Allocation Plan (GFMAP) (Secretary of Defense 2016). The GFMAP authorizes the transfer of and attachment of forces from supporting CCDRs and Secretaries of the Military Departments and attachment to a supported CCDR. If a force allocated to one CCDR is shifted as a force sourcing solution to another CCDR, the CCDR from whom the force is reallocated is not a Force Provider, but must be consulted prior to reallocation.⁵ Emergent ISR sourcing solutions often require reallocation across CCDRs due to the lack of overall ISR capacity. Prioritization on which CCDR will lose capability at the expense of another CCDR is an experienced-based subjective decision that would benefit by the implementation of an objective optimization tool set.
9. Decision Point. The Joint Staff briefs the details and the reason for the recommendation to the SECDEF on contentious issues for decision in GFMAP. The brief includes risk to mission and risk to force impacts. The SECDEF will make a risk informed decision to approve or deny each

⁵ Secretary of Defense. 2016. (U) “*Global Force Management Implementation Guidance FY2016-2017*.” Department of Defense, Washington, DC. This document is classified SECRET.

force recommendation in the GFMAP. The SECDEF assumes the risk to the CCDR mission when the allocation solution does not meet the CCDR requirements. The SECDEF assumes the risk to the force when the force allocation is at the expense of the force provider's force readiness.

10. The SECDEF approves the GFMAP and orders the force via the Global Force Management Allocation Plan (GFMAP) (Secretary of Defense 2016).
11. The process ends when the forces sourced deploy to the CCDR's AOR.

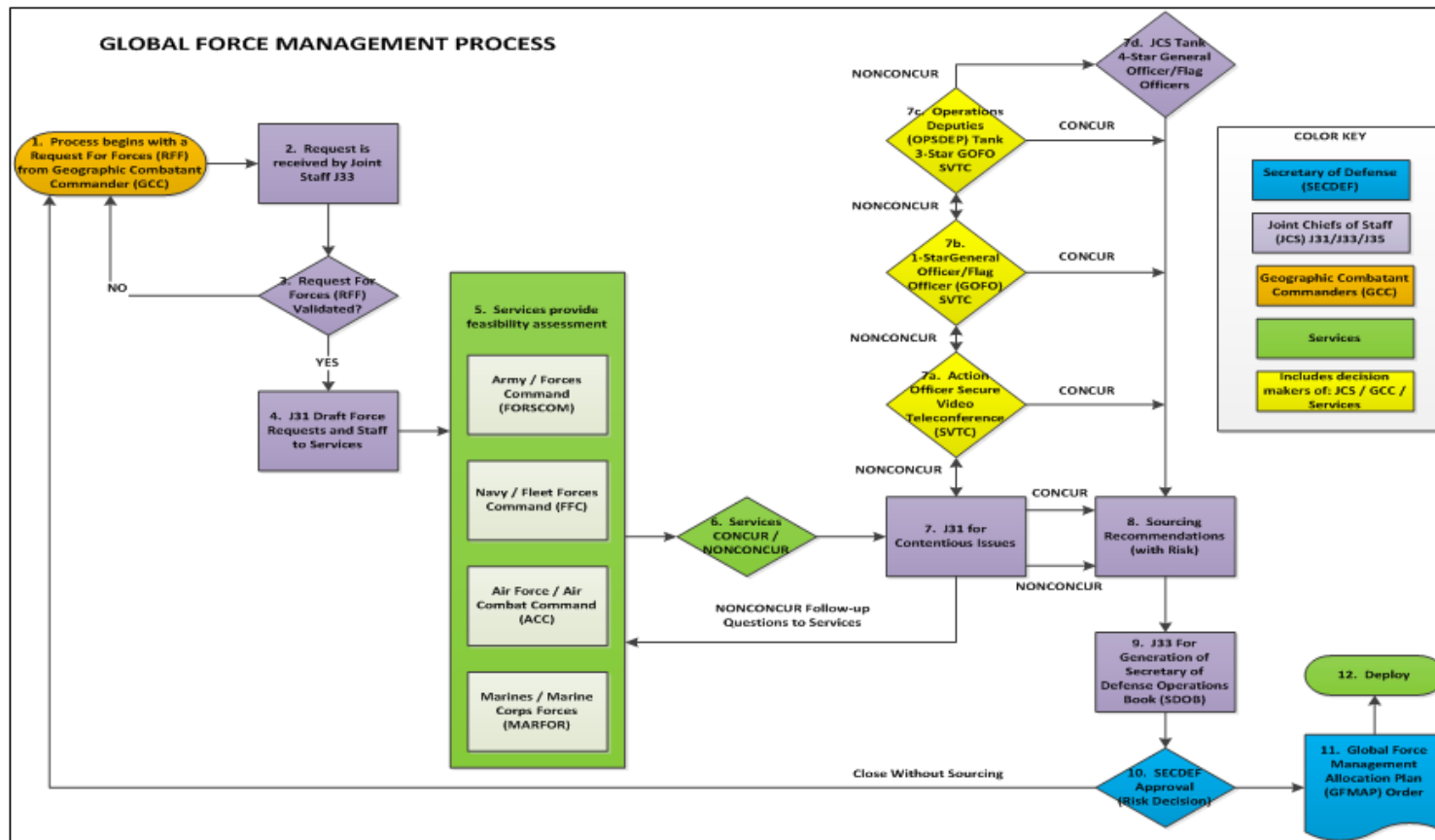


Figure 2. GFM Process Diagram Shows how the CCDRs Request Forces, the Requirement is Validated, and ultimately the SECDEF Orders the Forces.

B. CURRENT ISR ALLOCATION PROCESS DISCUSSION

The intelligence, surveillance, and reconnaissance force allocation process includes additional steps in the force allocation process. Typically, ISR capabilities such as full motion video (FMV) are in high demand by CCDRs. However, the availability of ISR platforms is severely limited. ISR capability is described as high demand and low density. Because of the ability of ISR platforms to potentially service multiple CCDRs from a common operating location and competing demands for mission critical requirements, the allocation of ISR forces includes close coordination between the Joint Staff, CCDRs, force providers, and the Joint Functional Component Command for Intelligence, Surveillance, and Reconnaissance (JFCC ISR).

JFCC ISR is responsible to the Joint Staff and the Secretary of Defense to recommend the most effective use of the limited number of ISR platforms in support of CCDR objectives. For CCDR ISR requirements, the CCDR develops Concept of Collection Operations (CONOPS). The Global Force Management Allocation Policies and Procedures, CJCSM 3130.06A, direct JFCC ISR to evaluate CCDR ISR CONOPS to establish collection priorities to support of Operations Plans (OPLAN) and Concept Plans (CONPLAN). JFCC ISR analyzes the CONOP and accounts for all ISR requirements against categorized FAM priorities and operations areas. The ISR CONOP includes descriptions that address how all ISR collection assets including CCDR theater assets, national technical means (space-based), and Coalition partner capabilities are integrated to meet intelligence collection requirements.

JFCC ISR's assessment of the ISR CONOPS includes assumptions, operational constraints such as but not limited to aircraft basing options, over flight restrictions, collection processing limitations, C4I architecture limitations, and aircraft availability. The CCDR's ISR CONOPS should include a "what cannot be accomplished" risk statement if the requirements are not sourced or partially sourced. JFCC ISR's force allocation recommendations balance ISR gaps and shortfalls with CCDR priorities and force availability. Additionally, JFCC ISR uses trend analysis for comparing (increasing, decreasing, or steady) the previous fiscal year requirements with the proposed

requirements for the current fiscal year. The analysis informs force allocation recommendations.

JFCC ISR makes the force allocation recommendation to the Joint Staff after the CCDR have submitted their ISR requirements to the Joint Staff and after the force providers have offered the available assets for allocation. The strategic priority of the FADM and previously described heuristics inform the recommendation. The proof of concept of the ISR allocation optimization model will apply similar heuristics and prioritization factors to inform both the Joint Staff and JFCC ISR in order to provide optimized recommendations to the SECDEF for the allocation of forces. Chapter III will introduce the model's objective function, which is to maximize the number of ISR capability hours provided to meet prioritized Geographic Combatant Commanders requirements.

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III. DATA PRESENTATION AND ANALYSIS

This chapter introduces the Global Force Management intelligence, surveillance, and reconnaissance allocation model. This model attempts to maximize the number of hours of ISR capability provided to the Geographic Combatant Commanders in a fiscal year to meet mission objectives. The optimization model uses a mixed integer linear programming formulation.

A. GLOBAL FORCE MANAGEMENT INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE ALLOCATION MODEL FORMULATION

1. Indices

i Full Motion Video (FMV) ISR platform type. For the purpose of this model, the following platforms will provide FMV capability to meet CCDR requirements:

- MQ-1B Predator
- MQ-1C Grey Eagle
- MQ-9 Reaper
- P-3C Orion
- Enhanced Medium Altitude Reconnaissance and Surveillance System (EMARSS)

j Combatant Commander with FMV requirements

- United States Africa Command (USAFRICOM)
- United States Central Command (USCENTCOM)
- United States European Command (USEUCOM)
- United States Northern Command (USNORTHCOM)
- United States Pacific Command (USPACOM)
- United Southern Command (USSOUTHCOM)

2. Parameters and Data

$value_{ij}$	The FADM weighted platform consideration for ISR type i provided to CDDR j
$capacity_i$	Number of ISR hours available from force provider for platform i [hours/day]
req_j	Number of total ISR hours required by CDDR j [hours/day]
lre_i	Number of LRE sorties of ISR type i available from force provider [sorties/day]
$lre_sorties_i$	Number of LRE sorties required to support one ISR type i sortie [hours/sortie]

3. Decision Variables

X_{ij}	Number of ISR FMV hours from platform i , allocated to CDDR j [hours/day]
Y_{ij}	Number of LRE sorties of type i allocated to CDDR j [sorties/day]

4. Objective Function

The goal of the ISR FMV allocation optimization model is to maximize the hours of FMV allocated to each CDDR to meet the prioritized mission requirements.

$$MAX Z = \sum_{ij} value_{ij} X_{ij} \quad (1)$$

5. Constraints

$$\sum_j X_{ij} \leq capacity_i \quad \forall i \quad (2)$$

Constraint (2) ensures that the ISR sorties allocated to all CDDRs do not exceed force provider's capacity.

$$\sum_i X_{ij} \doteq req_j \quad \forall j \quad (3)$$

Elastic constraint (3) ensures CCDR each type ISR platform requirements are met if possible.

$$X_{ij} \leq lre_sorties_i Y_{ij} \quad \forall i, j \quad (4)$$

Constraint (4) ensures that LRE are allocated to support ISR platform sorties when required.

$$\sum_j Y_{ij} \leq lre_i \quad \forall i \quad (5)$$

Constraint (5) requires that LRE sorties allocated to all CCDRs do not exceed the force provider's capacity.

$$X_{ij} \geq 0 \quad \forall ij \quad (6)$$

Constraint (6) states that ISR FMV allocation hours must be non-negative.

$$Y_{ij} \equiv \text{integer} \quad \forall ij \quad (7)$$

Constraint (7) enforces integer restrictions on all LRE platform decision variables.

This chapter introduced the equations that build the model. Chapter III goes into detail about the indices, parameters, and constraints that influence the objective function. It describes how the model is developed and discussions the assumptions used.

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IV. DATA, RESULTS, AND ANALYSES

This chapter describes in detail the indices, parameters, and constraints introduced in Chapter III using notional data and the assumptions made in the model development. The notional data provides results and informs the analysis of the model influenced by FADM and platform type. This chapter describes the analyses of the results. The model was solved using Microsoft Excel with Solver add-in.

A. HYPOTHETICAL DATA AND DEVELOPMENT

The ISR allocation optimization model applies to any of the ISR requirement capabilities, including but not limited to Full Motion Video (FMV), Signals Intelligence (SIGINT), Communications Intelligence (COMINT), and other intelligence collection capabilities. The complexity of FMV force allocation makes FMV the ideal capability to use for a proof of concept. FMV is real-time video imagery used for intelligence collection (Lockheed Martin 2016). For the purpose and scope of this thesis, FMV will be limited to airborne platforms. It does not include space-based imagery systems.

FMV is critical to the war fighter. It provides CCDRs real-time pattern of life of the battle space. It is one piece of the intelligence information puzzle. FMV combined with satellite imagery such as Google Earth and electronic warfare data provides decision makers the situational awareness required to meet mission objectives (C4ISRNET 2016). Figure 3 is a snapshot of one image of FMV. As a still image, it shows three vehicles in a single-file line along a road. Using FMV as a stream of video imagery over time, it provides point of origin of this group of vehicles and ultimate destination of these vehicles. Knowing where the trucks came from helps decision makers to distinguish if the vehicles are friendly, hostile, or potentially hostile forces on the move. This is an oversimplified example of the potential of FMV that illustrates how critical maintaining awareness of the operating area is to CCDRs. FMV combined with an armed platform allows for the rapid engagement of a time-critical target. FMV is a critical requirement to meet CCDR objectives and strategic priorities.

Hypothetical data is used to keep this thesis unclassified. The platform capabilities come from a small sampling of ISR FMV platforms that have sufficient open-source information to make the model relevant. The hypothetical CDDR requirements are derived from and loosely based on historical data from GFMAP force allocations. Actual CDDR requirements, force capacities, and FADM priorities are classified. The model uses a methodical approach using known data and informed assumptions to develop reasonable scenarios to implement in the model.

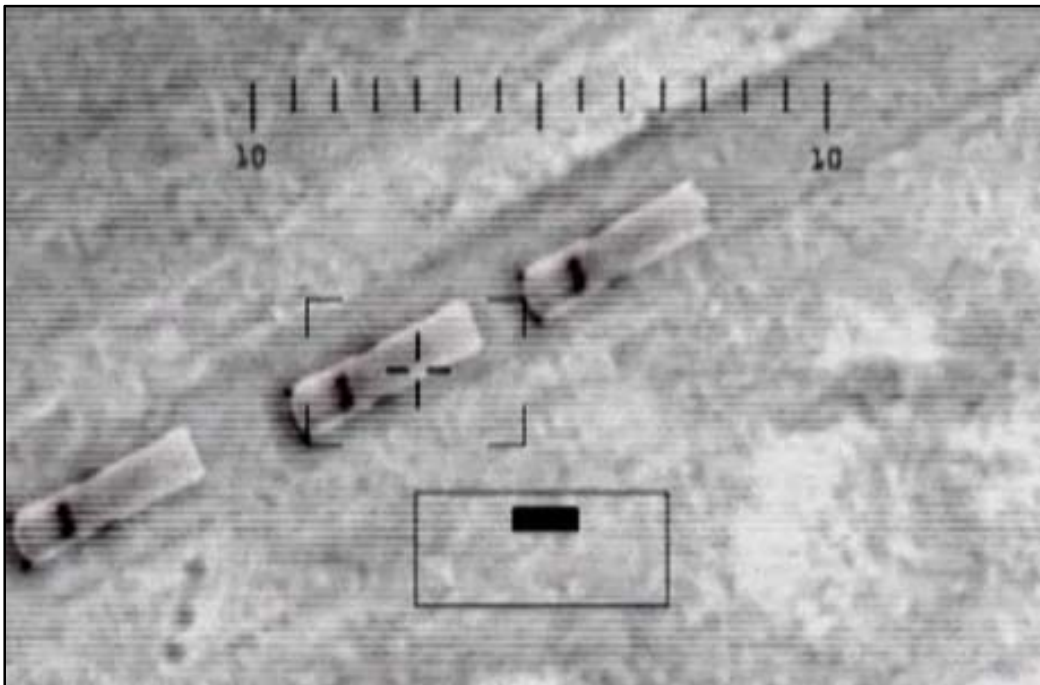


Figure 3. Full Motion Video (FMV) Example.
Source: Lockheed Martin (2016).

B. FORCE ALLOCATION MODEL DISCUSSION

This section describes in detail the formulation of the optimization model. It describes the indices of ISR platform types and CDDR requirements. The key to the understanding the optimization formulation is in the understanding of how the parameters are defined. The parameters are a combination of known objective data such as the force provider capacity of a specific platform, and an attempt to quantify heuristic data such as the importance of a particular platform type to a specific CDDR requirement.

Understanding how the parameters effect the optimized solution informs the decision influencers to which parameters influence the formulation the most. The impact is useful to the force provider, the CDDR, and the Joint Staff. The force provider may use the data to apply additional funding to the area that has the most significant gains. The force provider can also use the data to identify areas that present a risk to force and inform the decision to determine if there are significant gains to meeting CDDR requirements while accepting additional risk to force. For CCDRs, this shows objectively where the CDDR has determined how important a requirement is and how that same importance influenced the resource allocation. By looking at the results, the CDDR can see where their requirement priorities are evaluated globally across all of the CDDR's requirements. The Joint Staff can evaluate the data to verify that the results support the military objectives of the National Military Strategy. The Joint Staff can use the formulation to run recommendation scenarios to model where largest gains from risk to force and risk to mission can be made. The information can influence recommendation to the SECDEF to order a force provider to provide additional assets at the expense of long-term force readiness. This optimization model provides transparency that is not easily interpreted or understood in the current ISR force allocation process.

1. Indices

a. Full Motion Video Platform Types

The optimization model uses a sampling of FMV capable aircraft to prove the concept. Although there are many FMV capable aircraft, the aircraft types selected include platforms from each Service that have allocable ISR aircraft. The selection includes manned and remotely piloted aircraft to show that the optimization model reflects current capabilities and that it can adapt to reflect future capabilities.

(1) MQ-1B Predator

The MQ-1B Predator is a remotely piloted reconnaissance aircraft built by General Atomics Aeronautical System Inc. The United States Air Force is the force provider for USAF MQ-1B Predators. A Predator system includes four aircraft, a ground

control station, operators, and maintenance to support 24-hour missions anywhere in the world (Air Combat Command 2015). Pilots at the ground control stations fly the aircraft using data-link.

An MQ-1B carries a full motion video imaging sensor. It can either armed or unarmed with two laser-guided air to ground AGM-114 Hellfire missiles (Air Combat Command 2015). The aircraft has a range of 770 miles (Air Combat Command 2105). The combination of persistent FMV and air to ground armament allow the CCDR capability to engage time critical targets.



Figure 4. MQ-1B Predator (U.S. Air Force photo/Staff Sgt. Brian Ferguson).
Source: Air Combat Command (2015).

(2) MQ-1C Gray Eagle

The MQ-1C Gray Eagle is an unmanned aircraft system built by General Atomics Aeronautical System Inc. The United States Army is the force provider for USA MQ-1C Grey Eagles. The Army deploys the Grey Eagle platoon as part of the Combat Aviation Brigade. Four aircraft, two ground control stations and terminals, one portable ground

control station, communication equipment, ground support equipment, and 127 people make up one Gray Eagle platoon (United States Army 2016).

The Gray Eagle can carry an electro-optical sensor and up to four AGM-114 Hellfire missiles that provide FMV and strike capability to the CCDR (General Atomics Aeronautical 2016). The MQ-1C has a 2,500 miles range and an endurance profile of 27 hours (United States Army 2016). Q-1C Grey Eagle (General Atomic photo). Source: (General Atomics Aeronautical 2016)



Figure 5. MQ-1C Grey Eagle. Source: United States Army (2016)

(3) MQ-9 Reaper

The MQ-9 Reaper is a remote-piloted aircraft built by General Atomics Aeronautical Systems. The United States Air Force is the MQ-9 force provider. The MQ-9 Reaper provides combined FMV and strike capability against time-sensitive targets (Air Combat Command 2015). Reaper aircraft use multiple types of imaging sensors to provide full motion video capability (United States Air Force 2015). Like the MQ-1C, the MQ-9 can carry up to four AGM-114 Hellfire in addition to the FMV sensors.

The MQ-9 units have four aircraft, a ground control station, and communication equipment. The 1,150 miles aircraft range is significantly more than the range MQ-1B Predator (United States Air Force 2015). In some cases, CCDR prefer the MQ-9 Reaper to the MQ-1B Predator due to the additional range and armament capacity of the Reaper platform.



Figure 6. Armed MQ-9 Reaper (U.S. Air Force Photo / Lt. Col. Leslie Pratt).
Source: Air Combat Command (2015).

(4) P-3C Orion

The P-3C Orion is a U.S. Navy full motion video capable patrol aircraft built by Lockheed Martin (Lockheed Martin 2016). The P-3C Orion is a manned aircraft with multiple sensors including surface search radar and electro-optical real time video cameras. The P-3C Orion can be armed with AGM-84 Harpoon, AGM-84K SLAM-ER, AGM-65F Maverick missiles, Mk46/50/54 torpedoes, rockets, and mines (United States Navy 2016). The Orion has a range of 1,548 miles and an endurance of more than 12 hours (Janes IHS 2016). Unlike the remote piloted MQ-1B, MQ-1C, and the MQ-9 aircraft, the P-3C is a manned aircraft that can use on board real time video processing of

FMV to prosecute targets on the ground (Lockheed Martin 2016) . Additionally the P-3C Orion has the capability to deliver anti-ship and anti-submarine ordnance to meet specific over water CDR requirements.



Figure 7. P-3C Orion, captured by U.S. Navy Photo/Photographers Mate 2nd Class Elizabeth L. Burke. Source: United States Navy (2016).

(5) Enhanced Medium Altitude Reconnaissance and Surveillance System

The Enhanced Medium Altitude Reconnaissance and Surveillance System (EMARSS) is an United States Army ISR aircraft capable of providing FMV. EMARSS is an example of a successful Army program of record program that is taking former U.S. Air Force Liberty C-12 aircraft and integrating them into the Army EMARSS program (United States Army 2016). EMARSS and programs like it, are getting ISR capabilities to the warfighter through rapid acquisition authority (United States Army 2016). The number and types of platforms in the optimization model can expand and include new or adapted technologies such as EMARSS.



Figure 8. U.S. Army Enhanced Medium Altitude Reconnaissance and Surveillance System. Source: United States Army (2016).

b. Combatant Commanders

The Unified Command Plan of the United States divides the world into geographic regions and assigns responsibilities to geographic combatant commanders. Figure 3 illustrates the geographic division by CCDR.

(1) United States Africa Command

United States Africa Command (USAFRICOM) is responsible for the United States interests in Africa. It builds and strengthens military relations with African countries and the African Union to increase security and counter transnational threats (U.S. Department of Defense 2011).

(2) United States Central Command

United States Central Command (USCENTCOM) is responsible for United States military operations in 20 countries including Afghanistan, Bahrain, Egypt, Iran, Iraq, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Oman, Pakistan, Qatar, Saudi Arabia, Syria, Tajikistan, Turkmenistan, United Arab Emirates, Uzbekistan and Yemen. The mission of USCENTCOM is increasing stability in the region through international partnerships (U.S. Department of Defense 2011).

(3) United States European Command

United States European Command (USEUCOM) is responsible for building and maintaining military partnerships with European, Middle Eastern, and Eurasian nations, including the North Atlantic Treaty Organization (NATO) to increase the security in EUCOM's area of responsibility (U.S. Department of Defense 2011).

(4) United States Northern Command

United States Northern Command (USNORTHCOM) is responsible for continental United States, Alaska, Mexico, Canada, portions of the Caribbean and surrounding waters. It also oversees the North American Aerospace Defense Command (NORAD).

(5) United States Pacific Command

United States Pacific Command (USPACOM) has the largest geographic area of responsibility including 36 nations and the waters of the United States west coast extending to the western border of India, and from Antarctica to the North Pole (U.S. Department of Defense 2011). USPACOM builds and fosters military partnerships to enhance security in the region.

(6) United States Southern Command

United States Southern Command (USSOUTHCOM) is responsible for an area of 31 nations in Latin America, Central America, South America, and the Caribbean Sea. USSOUTHCOM's security efforts include promoting human rights, to deter illegal illicit trafficking and conducting multinational military exercises that build and foster partnerships (U.S. Department of Defense 2011).



Figure 9. Commander's Area of Responsibility.
Source: U.S. Department of Defense (2011).

(7) Combatant Commander Prioritization Factor Discussion

When implementing the optimization model, it is important for decision influencers to distinguish when force allocations are exclusively weighted and factored to FADM priority. For example: NORTHCOM has the responsibility to defend the United States (U.S.) against attacks to the U.S. homeland. Due to the consequences of the effects

if the U.S. is attacked, USNORTHCOM may have the highest FADM priorities for many of its requirements. However, the resource allocation may need to be balanced to provide ISR assets to a CCCR that is actively engaged in combat operations. At the time of writing this thesis, the U.S. is involved in large-scale combat operations in USCENTCOM and USAFRICOM areas of responsibility.

In further development of this model and refining the factors that influence the optimization, a refinement of how priority will factor into the risk to potential OPLANs, versus the risk to ongoing combat operations will make the optimization model more relevant.

2. Parameters

a. $value_{ij}$

The $value_{ij}$ parameter is a numerical value assigned to the priority for sourcing of each requirement of CCCR j by platform i . It is based on a prioritization derived from FADM and platform considerations. The higher the FADM priority assigned by the Joint Staff, the larger the value that will be applied to the requirement in the model. The actual FADM is classified. Table 1 is an unclassified notional example of how the FADM priority is weighted with a value. A FADM of 1.1.1 has the highest priority and weighted the most. Assigning a weight factor to FADM priority enables the objective formula to allocate FMV capability to CCCR requirements that have the highest priority. According to the fiscal years 2015 and 2016 Global Force Management Allocation Plan, this is not the case (Secretary of Defense 2015; 2016). CCCR prioritize against what they want. Not necessarily optimized against the FADM priorities. In this model, the highest FADM must receive some sourcing before lower FADM requirements.

Table 1. FADM Priority and Weight Factor

FADM	Weight Factor	FADM	Weight Factor	FADM	Weight Factor
1.1.1	100	2.1.1	60	3.1.1	30
1.1.2	99	2.1.2	59	3.1.2	29
1.1.3	98	2.1.3	58	3.1.3	28
1.1.4	97	2.1.4	57	3.1.4	27
1.1.5	96	2.1.5	56	3.1.5	26
1.1.6	95	2.1.6	55	3.1.6	25
1.1.7	94	2.1.7	54	3.1.7	24
1.2.1	93	2.2.1	53	3.2.1	23
1.2.2	92	2.2.2	52	3.2.2	22
1.2.3	91	2.2.3	51	3.2.3	21
1.2.4	90	2.2.4	50	3.2.4	20
1.2.5	89	2.2.5	49	3.2.5	19
1.2.6	88	2.2.6	48	3.2.6	18
1.2.7	87	2.2.7	47	3.2.7	17
1.3.1	86	2.3.1	46	3.3.1	16
1.3.2	85	2.3.2	45	3.3.2	15
1.3.3	84	2.3.3	44	3.3.3	14
1.3.4	83	2.3.4	43	3.3.4	13
1.3.5	82	2.3.5	42	3.3.5	12
1.3.6	81	2.3.6	41	3.3.6	11
1.3.7	80	2.3.7	40	3.3.7	10

This table is an example of how notional FADM priority assigns a weight factor used in the $value_{ij}$ parameter for each requirement. The FADM weight factor represents the “global” tradeoffs made between the competing CCDR requirements.

FADM is not the only factor that influences $value_{ij}$. In this model, each CCDR requirement is further categorized into platform i to allow platform consideration to influence the objective function. Equation (8) shows that FADM weight factor is multiplied across each CCDR's platform considerations. The platform consideration factor for CCDR i , $scale_i$, determines to what extent the objective function is influenced by specific platform preferences for each requirement. The Joint Staff and JFCC ISR with the CCDR determine the platform consideration factor for each requirement.

$$value_{ij} = \sum_i W_i(scale_i) \quad \forall j \quad (8)$$

Where,

W_i = FADM weight factor

$Scale_i$ = platform consideration factor

Table 2 illustrates how notional CCDR requirements affect $value_{ij}$. For example, USAFRICOM requirement number 118003 shows that any FMV platform is suitable by having a multiplier of 1 for each platform except MQ-9. The MQ-9 notional multiplier is 1.1, meaning the MQ-9 is preferred. As a result, the $value_{ij}$ for that requirement is influenced accordingly.

In another example, USCENTCOM requirement number 218003 has 0 as a multiplier to each platform except the P-3C AIP which is 1. This means that the preferred platform to provide capability to that requirement is the P-3C AIP.

Table 2. Example of $value_{ij}$. Table for Model Calculations

	USAFRICOM			USCENTCOM		
Requirement Tracking Number	118001	118002	118003	218001	218002	218003
Requirement Hours/Month	1100	200	300	4700	700	22100
Requirement Hours/Day	36	7	10	155	23	727
FADM	1.2.3	3.1.1	1.2.3	2.2.5	1.2.2	1.2.3
FADM Weight Factor	91	30	91	49	92	91
MQ-1B	1	1	1	1	1	0
MQ-1C	1	1	1	0	1	0
MQ-9	1	1	1.1	1	1	0
P-3 AIP	1	1	1	0	1	1
EMARSS	1	1	1	1	1	0
	USAFRICOM			USCENTCOM		
$Value_{ij}$	118001	118002	118003	218001	218002	218003
MQ-1B	91	30	91	49	92	0
MQ-1C	91	30	91	0	92	0
MQ-9	91	30	100.1	49	92	0
P-3 AIP	91	30	91	0	92	91
EMARSS	91	30	91	49	92	0

The columns contain the CCDR capability requirements. The grey rows contain the capability requirement. The light blue rows represent the FADM weight factor. The yellow rows beneath the weight factor contain the platform consideration factor. The dark blue rows represent $value_{ij}$ computed using Equation (8).

b. $capacity_i$

The $capacity_i$ parameter is the Number of ISR hours available from force provider for platform i . Provided by force provider in units of number of sorties per month for each platform type. The sorties per month are converted to sorties per day then the units are converted to hours per day for the model using the unclassified notional planning factors.

c. req_j

The req_j parameter is the numbers of ISR capability hours required by CCDR j . CCDRs provide requirements in units of hours per month of a specific capability. For this model, the unit of measurement of the capability converts from hours of FMV required per month to per day. The CCDR does not specify a particular platform such as MQ-9 or EMARSS. The requirement is for capability (Secretary of Defense 2016).

d. lre_i

The lre_i parameter is the number of Launch and Recovery Elements (LRE) of ISR type i available from force provider for platform i . MQ-1B and MQ-9 each require a LRE to support the takeoff and landing of each sortie. An LRE is platform specific. For example, a MQ-1B LRE can only support MQ-1B sorties. It cannot support MQ-9 sorties. The force provider can only support a limited number of LREs. The number of LRE crews that can operate each LRE at the location combined with the number of systems that can control the aircraft set the LRE capacity limit. Additionally, each LRE has a maximum number of sorties that a single LRE can support. For the purpose of this model, the number of sorties each LRE can support is five sorties per day for each platform type. The LRE parameter in this model only applies to MQ-1B and MQ-9. The Air Force is the force provider for the LREs and sets the limit to both how many LREs are available for force allocation and how many sorties each LRE can support. The LREs deploy to the location from where the MQ-1B and MQ-9 sorties take off and land.

e. cap_lre_i

The cap_lre_i parameter is the number of sorties per day that each LRE of platform type i can support.

f. $lre_sorties_i$

The $lre_sorties_i$ parameter is the numbers of sorties per day that support ISR of type I available from force provider. The Force Provider sets the total number of sorties that flown each day in support of CCDR. The number of Remote Piloted Aircraft (RPA) pilots, RPA sensor operators, and the Process, Exploitation, and Dissemination (PED) capacity available limit the number of RPA sorties available for allocation. Each sortie requires aircraft, RPA pilot crew, RPA sensor operator crew, and PED crew.

g. $collect_i$

The $collect_i$ parameter is the number of hours of ISR type i collection per sortie. JFCC ISR and the force provider determine the sortie length for the number of collection hours each aircraft can support.

3. Decision Variables

a. X_{ij}

X_{ij} is the number of ISR FMV hours from platform i allocated to CCDR j . The units convert from hours per month to hours per day to simplify conversion to sorties per day to align with the sortie per day limitation set by the force provider.

b. Y_{ij}

Y_{ij} is the number of LRE sorties of type i allocated to CCDR j . The units convert from hours per month to sorties per day to align with the sortie per day limitation set by the force provider.

4. Objective Function

The goal of the ISR FMV allocation optimization model is to maximize the hours of FMV allocated to each CCDR to meet the prioritized mission requirements. The optimization model uses a mixed integer linear program formulation.

$$MAX Z = \sum_{ij} value_{ij} X_{ij} \quad (1)$$

C. CONSTRAINTS

1. Sourcing Capacity Constraints

To maximize the utilization of a limited number of assets, each CCDR's requirement is equal to or greater than the sourcing recommendation. The optimized solution will not provide a CCDR more allocation of resources than what the requirement demand is.

$$\sum_j X_{ij} \leq capacity_i \quad \forall i \quad (2)$$

Constraint (2) ensures that the ISR sorties allocated to all CDDRs do not exceed force provider's capacity. However, the goal of the model is to try and allocate resources to meet and satisfy each CCDR requirement. The requirements exceed capacity. This

makes the model infeasible. To make the model feasible an elastic variable constraint (3) is applied.

$$\sum_i X_{ij} \doteq req_j \quad \forall j \quad (3)$$

Elastic constraint (3) ensures CCDR each type ISR platform requirements are met if possible.

2. Launch and Recovery Element (LRE) Constraints

$$X_{ij} \leq lre_sorties_i Y_{ij} \quad \forall i, j \quad (4)$$

Constraint (4) ensures that LREs are allocated to support ISR platform sorties when required.

$$\sum_j Y_{ij} \leq lre_i \quad \forall i \quad (5)$$

Constraint (5) requires that LRE sorties allocated to all CCDRs do not exceed the force provider's capacity.

3. Nonnegativity Constraint

$$X_{ij} \geq 0 \quad \forall ij \quad (6)$$

Constraint (6) states that ISR FMV allocation hours must be non-negative.

4. Integrality Constraint Integrality Constraint

$$Y_{ij} \equiv \text{integer} \quad \forall ij \quad (7)$$

Constraint (7) enforces integer restrictions on all LRE platform decision variables.

D. MODEL RESULTS AND ANALYSIS

This section discusses the results of the Global Force Management Intelligence, Surveillance, and Reconnaissance Allocation model. The model allocates forces to meet the most requirements using the objective function. The first sub-section describes how penalties are applied to the objective function to manage the trade-off between LRE constraints and CCCR requirement constraints. The second sub-section describes the model results of keeping the $value_{ij}$ parameter constant across all of the CCCR requirements and only applying FADM as the priority. The third sub-section describes the results of the model after adding CCCR platform consideration to each requirement. Both scenarios use the same twenty CCCR requirements and same the force provider capacities. The requirements are notional. Seven of the requirements have the same FADM priority to simulate the complexity of c CCCR's competing priorities.

1. Objective Function

The objective function (1) shows how FADM and platform consideration influences the model solution.

$$MAX Z = \sum_{ij} value_{ij} X_{ij} - \sum_{ij} (LRE_penalty) Y_{ij} - \sum_{ij} (value_{ij} _ penalty)(elastic_variable)$$

Breaking down the objective function into its three parts shows how the LRE_penalty and the value_penalty affect the model.

$$\sum_{ij} value_{ij} X_{ij}$$

The sum of the product of $value_{ij} * X_{ij}$ in the objective function encourages the model to maximize the resource allocation to the requirements that give have the highest value. The $value_{ij}$, is influenced by FADM priority and platform consideration. The parameter $value_{ij}$ is the weight factor applied to the requirement. The higher the $value_{ij}$, the more the model will allocate forces to those requirements.

$$-\sum_{ij}(LRE_penalty)Y_{ij}$$

Subtracting the sum of the product of the $LRE_penalty * Y_{ij}$ in the objective function ensures that an LRE is only allocated when necessary. A penalty factor influences when it is necessary to allocate a LRE. To minimize the penalty and drive force allocation efficiency, the $LRE_penalty$ maximizes the number of sorties at each LRE. In implementing the model, the $LRE_penalty$ can be manipulated to influence how easy it is for the model to allow an LRE allocation. The greater the penalty factor, the less likely the formula model will allocate an LRE to a requirement. The lesser the penalty factor, the more likely an LRE will be allocated to each requirement

The objective function must balance the $LRE_penalty$ with the overall intent. In this scenario CCCR's requirements are greater than the total ISR FMV capacity. Requirements need all of the available capacity allocated to CCCR requirements and we want to maximize the number of sorties that each LRE supports. If the $LRE_penalty$ is set too high, the objective function will not allocate LREs to the requirements. If the penalty is set too low, LREs are allocated without maximizing the efficiency in the number of sorties that each LRE can support.

$$-\sum_{ij}(value_{ij_penalty})(elastic_variable$$

Lastly, subtracting the sum of the product of $value_{ij_penalty}$ and its associated elastic variable ensures feasibility through the elastic constraint of equation (3). The $value_{ij_penalty}$ is the trade-off between FADM priority and CCCR's platform preference, as represented by the platform preference factor. The higher the $value_{ij_penalty}$, the greater the FADM priority influences the optimized solution. The lower the $value_{ij_penalty}$, CCCR platform preference priority influences the optimized solution.

2. Base Model—FADM Prioritized Results

As decision influencers, may want to provide an optimized recommendation strictly based on FADM priority agnostic to the consideration of the type of platform to meet each requirement. This scenario assumes any of the FMV ISR platforms can equally meet the capability requirement. Using the data developed in the previous sections, this subsection presents the initial or *base* model results. The lower chart in Table 3 shows that the model allocates one-hundred percent of the force provider capacity. However, only 902 hours per day of the 1902 hours per day requirement are allocated. This means that 47 percent of the CCDR requirement is satisfied.

The highest thirteen FADM requirements receive FMV capacity. Twelve of those 13 requirements are fully allocated resources. Requirement number 218005 is the next highest FADM priority of 1.3.1, with a FADM weight factor of 86. As shown in Table 3 of the Hours Allocated row, the model allocates 39 hours per day.

Implementing a FADM prioritized model can inform decision makers by providing a solution that shows how forces could be allocated if the objective function is strictly enforcing GEF direction. With fewer assets available than CCDR requirements demand, this method will also show the capability gaps in force allocation. For the force providers and DOD budget personnel, the gaps highlight areas where additional resources can be committed to meet strategic objectives. Although a clearly prioritized optimization model is useful for planning purposes, it does not reflect the reality of ISR FMV force allocation. In fiscal years 2015 and 2016, the SECDEF ordered force allocation was not exclusively based on FADM priority (Secretary of Defense 2015; 2016). The GFMAP considered several additional factors including emerging strategic goals, domestic and international politics, and force provider readiness.

Table 3. Base Model -FADM Prioritized Results

Requirement Tracking Number	USAFRICOM			USCENTCOM						USEUCOM					USNORTHCOM		USPACOM		USSOUTHCOM		
	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002	
Requirement Hours/Month	1100	200	300	4700	700	22100	180	13700	8700	550	730	180	90	30	180	240	100	720	360	3000	
Requirement Hours/Day	36	7	10	155	23	727	6	450	286	18	24	6	3	1	6	8	3	24	12	99	
FADM	1.2.3	3.1.1	1.2.3	2.2.5	1.2.2	1.2.3	1.2.3	1.3.1	1.3.3	1.2.3	1.2.3	1.2.4	1.2.6	1.2.6	1.1.2	2.1.7	1.2.2	3.3.7	2.1.7	2.1.7	
FADM Weight Factor	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
MQ-1B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
MQ-1C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
MQ-9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
P-3 AIP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
EMARSS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Value _{ij}	USAFRICOM			USCENTCOM						USEUCOM					USNORTHCOM		USPACOM		USSOUTHCOM		
	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002	
MQ-1B	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
MQ-1C	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
MQ-9	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
P-3 AIP	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
EMARSS	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
Results	USAFRICOM			USCENTCOM						USEUCOM					USNORTHCOM		USPACOM		USSOUTHCOM		
	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002	
MQ-1B	0	0	0	0	12	144	0	0	0	0	24	0	0	0	0	0	0	0	0	0	
MQ-1C	0	0	0	0	0	259	6	11	0	4	0	6	3	1	6	0	3	0	0	0	
MQ-9	0	0	0	0	0	168	0	28	0	14	0	0	0	0	0	0	0	0	0	0	
P-3 AIP	0	0	0	0	0	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
EMARSS	36	0	10	0	11	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
MQ-1B LRE Allocated	0	0	0	0	1	12	0	0	0	0	2	0	0	0	0	0	0	0	0	0	
MQ-9 LRE Allocated	0	0	0	0	0	12	0	2	0	1	0	0	0	0	0	0	0	0	0	0	
Hours Allocated	36	0	10	0	23	727	6	39	0	18	24	6	3	1	6	0	3	0	0	0	
% of Requirement Met	100	0	100	0	100	100	100	9	0	100	100	100	100	100	100	0	100	0	0	0	
Force Provider Capacity				Hours/Day		Hours/Day Allocated		% Allocated													
MQ-1B				180		180		100													
MQ-1C				300		300		100													
MQ-9				210		210		100													
P-3 AIP				112		112		100													
EMARSS				100		100		100													
LRE Capacity				Sorties/Day		Sorties/Day Allocated		% Allocated													
MQ-1B LREs				15		15		100													
MQ-1C LREs				15		15		100													

The upper chart shows the complete set CCDR requirements used in the (base) model and what platforms were allocated to meet those requirements. In this (base) model platform consideration is the same for all requirements. The lower chart contains the force provider capacity by platform and how many hours and the percentage of the capacity is allocated by platform.

3. CCDD Platform Consideration Sensitivity Analysis

Combatant Commanders have the best insight to what specific platforms can best meet their requirements. However, coordination is required that looks across the whole ISR enterprise for capabilities. JFCC ISR is responsible for providing that coordination. For example, a partner nation may not allow remotely-piloted aircraft flown from their country. In order to mitigate those external factors and meet the mission requirement, the CCDD or JFCC-ISR may prioritize a manned platform type. Additionally, certain platforms are better equipped for particular missions. This section conducts some sensitivity analysis by changing input data from our base model presented in section IV.D.2.

With no other changes to the base model, Table 4 shows how sensitive the model is to a change of $value_{ij}$ parameter for a particular platform. This change may represent when the platform consideration is modified based on new information or just to examine model sensitivity. In this example, the scale associated with requirement number 218003 changes for ISR platforms of EMARSS and P-3 AIP from 1 to 1.5 and which results in a change in the associated *scales* for remotely piloted aircraft to 0.5 from 1. The associated $value_{ij}$ changes from 91 to 136.5 and from 91 to 45.5 for the manned and remotely piloted aircraft, respectively. These changes simulate the preference for manned ISR platforms to meet the 218003 requirement.

Table 4. Combined CCDR and FADM Prioritized Model Results Example 1

Requirement Tracking Number	USAFRICOM			USCENTCOM						USEUCOM					USNORTHCOM		USPACOM		USSOUTHCOM		
	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002	
Requirement Hours/Month	1100	200	300	4700	700	22100	180	13700	8700	550	730	180	90	30	180	240	100	720	360	3000	
Requirement Hours/Day	36	7	10	155	23	727	6	450	286	18	24	6	3	1	6	8	3	24	12	99	
FADM	1.2.3	3.1.1	1.2.3	2.2.5	1.2.2	1.2.3	1.2.3	1.3.1	1.3.3	1.2.3	1.2.3	1.2.4	1.2.6	1.2.6	1.1.2	2.1.7	1.2.2	3.3.7	2.1.7	2.1.7	
FADM Weight Factor	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
MQ-1B	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
MQ-1C	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
MQ-9	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
P-3 AIP	1	1	1	1	1	1.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
EMARSS	1	1	1	1	1	1.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Value _g	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002	
MQ-1B	91	30	91	49	92	45.5	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
MQ-1C	91	30	91	49	92	45.5	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
MQ-9	91	30	91	49	92	45.5	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
P-3 AIP	91	30	91	49	92	136.5	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
EMARSS	91	30	91	49	92	136.5	91	86	84	91	91	91	88	88	99	54	92	10	54	54	
Results	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002	
MQ-1B	36	0	0	0	12	0	0	132	0	0	0	0	0	0	0	0	0	0	0	0	
MQ-1C	0	0	10	0	11	0	6	108	104	18	24	6	3	1	6	0	3	0	0	0	
MQ-9	0	0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	
P-3 AIP	0	0	0	0	0	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
EMARSS	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
MQ-1B LRE Allocated	3	0	0	0	1	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	
MQ-9 LRE Allocated	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	
Hours Allocated	36	0	10	0	23	212	6	450	104	18	24	6	3	1	0	0	0	0	0	0	
% of Requirement Met	100	0	100	0	100	29	100	100	36	100	100	100	100	100	100	0	100	0	0	0	
Force Provider Capacity		Hours/Day		Hours/Day Allocated		% Allocated															
MQ-1B		180		180		100															
MQ-1C		300		300		100															
MQ-9		210		210		100															
P-3 AIP		112		112		100															
EMARSS		100		100		100															
LRE Capacity		Sorties/Day		Sorties/Day Allocated		% Allocated															
MQ-1B LREs		15		15		100															
MQ-1C LREs		15		15		100															

Requirement number 218003 in Table 4 shows how platform consideration influences the objective formula.

The last row of Table 4 shows that the model allocates FMV capability to the fourteen highest FADM priority requirements. Twelve of the fourteen requirements receive 100 percent allocation. Requirement number 218003 and 218006 receive partial allocation. Requirement number 218006 has a FADM priority of 1.3.3 and a value, or objective function coefficient, of 84. It is the next lowest FADM prioritized requirement and the last requirement to receive the equivalent of 36 percent of its FMV requirement. Requirement number 218003 has a FADM priority of 1.2.3 and a value of 91. It received 29 percent (212 of 727 hours per day) of its requirement. The results show that the platform consideration $scale_i$ of 1.5 for manned aircraft for this requirements received some allocation, but at the expense of overall allocation of FMV ISR, because the change of remote piloted platform consideration $scale$ to 0.5 resulted in no FMV capability for that requirement. The MQ-1B, MQ-1C, and MQ-9 capacity was allocated to lower FADM priority requirements (e.g., requirement number 218005), because the value of 86 is more than twice the value of 45.5 for which requirement number 218003 receives for one hour of FMV.

The objective function manages the trade-off between FADM priority and platform consideration. Table 5 illustrates how FADM influences the objective function to a greater extent than platform consideration does. Using the same data illustrated in Table 4, in addition to changing the platform consideration of requirement number 418002 from 1 to 1.5, the objective function did not allocate any MQ-1B or MQ-1C capability to fulfill this requirement.

Table 5. Combined CCDR and FADM Prioritized Model Results Example 2

Requirement Tracking Number	USAFRICOM			USCENTCOM						USEUCOM					USNORTHCOM		USPACOM		USSOUTHCOM	
	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002
Requirement Hours/Month	1100	200	300	4700	700	22100	180	13700	8700	550	730	180	90	30	180	240	100	720	360	3000
Requirement Hours/Day	36	7	10	155	23	727	6	450	286	18	24	6	3	1	6	8	3	24	12	99
FADM	1.2.3	3.1.1	1.2.3	2.2.5	1.2.2	1.2.3	1.2.3	1.3.1	1.3.3	1.2.3	1.2.3	1.2.4	1.2.6	1.2.6	1.1.2	2.1.7	1.2.2	3.3.7	2.1.7	2.1.7
FADM Weight Factor	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54
MQ-1B	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1.5	1	1	1	1
MQ-1C	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1.5	1	1	1	1
MQ-9	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
P-3 AIP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
EMARSS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Value _z	USAFRICOM			USCENTCOM						USEUCOM					USNORTHCOM		USPACOM		USSOUTHCOM	
	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002
MQ-1B	91	30	91	49	92	0	91	86	84	91	91	91	88	88	99	81	92	10	54	54
MQ-1C	91	30	91	49	92	0	91	86	84	91	91	91	88	88	99	81	92	10	54	54
MQ-9	91	30	91	49	92	0	91	86	84	91	91	91	88	88	99	54	92	10	54	54
P-3 AIP	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54
EMARSS	91	30	91	49	92	91	91	86	84	91	91	91	88	88	99	54	92	10	54	54
Results	USAFRICOM			USCENTCOM						USEUCOM					USNORTHCOM		USPACOM		USSOUTHCOM	
	118001	118002	118003	218001	218002	218003	218004	218005	218006	318001	318002	318003	318004	318005	418001	418002	518001	518002	618001	618002
MQ-1B	36	0	0	0	12	0	0	132	0	0	0	0	0	0	0	0	0	0	0	0
MQ-1C	0	0	10	0	11	0	6	108	104	18	24	6	3	1	6	0	3	0	0	0
MQ-9	0	0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0
P-3 AIP	0	0	0	0	0	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EMARSS	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MQ-1B LRE Allocated	3	0	0	0	1	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
MQ-9 LRE Allocated	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0
Hours Allocated	36	0	10	0	23	212	6	450	104	18	24	6	3	1	0	0	0	0	0	0
% of Requirement Met	100	0	100	0	100	29	100	100	36	100	100	100	100	100	100	0	100	0	0	0

Force Provider Capacity	Hours/Day	Hours/Day Allocated	% Allocated
MQ-1B	180	180	100
MQ-1C	300	300	100
MQ-9	210	210	100
P-3 AIP	112	112	100
EMARSS	100	100	100
LRE Capacity	Sorties/Day	Sorties/Day Allocated	% Allocated
MQ-1B LREs	15	15	100
MQ-1C LREs	15	15	100

Requirement number 418002 in Table 5 shows that FADM influences allocation trade-off more than platform consideration.

Combining and balancing FADM and platform consideration into the optimization model allows decision makers a model that more closely resembles current allocation methods. This result is expected because the $value_{ij}$ parameter is made up of two components, the platform consideration (i.e., the $scale_i$, and FADM weight W_i). The first represents the returns to scale or consideration for a particular platform and the second represents the tradeoff among the different requirements. In other words, the former provides the regional focus to a specific geographic area or preference and the later provides more of a global influence that balances strategic priorities across all of the CCDRs.

As this chapter has shown, this model highlights the areas where there may be trade-space for additional allocation opportunities, which may not be apparent using the current process outlined in Chapter II. For example, if the only means to provide capability to a specific ISR requirement is allocating manned aircraft, the model will show what requirements will be affected to meet that limitation. Additionally, by interpreting the results, the CCDR can assess where their requirement priorities are evaluated globally across all of the CCDR's requirements. The Joint Staff can evaluate the data to verify that the results support the military objectives of the National Military Strategy. If the results do not support the strategic objectives, then the CCDR priorities and the force provider capacity must be scrutinized to mitigate the capability and requirement gaps. The impact implications are important to the Combatant Commanders for mitigation options and important to the SECDEF for accepting the risk associated with the recommendation.

V. RECOMMENDATIONS AND CONCLUSION

This thesis critically examines the Global Force Management allocation process and the factors that influence it. With the insight gained to the process, this proof of concept applies a methodical optimization formulation to a complex ISR force allocation problem that is complicated by significantly less capacity than demand. This optimization model and its methodology developed as part of this thesis uses full motion video capability and notional requirements to model the applicability of optimization, but may be easily generalized for use in other ISR capabilities (e.g., COMINT, in the Global Force Management allocation process). The data and platforms will differ; however, the basic optimization formulation will be the same.

The base model only considered FADM for allocation prioritization. Results show that with only 902 hours per day of FMV capacity to meet 1902 hours per day of requirements, the optimized solution provided 100 percent of the requirement capability to 12 of the 20 CDR requirements. Additionally, the model provided a partial allocation of 39 hours per day or nine percent of the requirement to the single next lowest FADM priority requirement. These results are useful to inform senior decision makers within the DOD of which requirements will not receive a capability allocation. The results can be compared against the actual Global Force Management Allocation Plans to highlight which lower FADM priorities are actually receiving a force allocation. The differences can show a strategic misalignment between CDR priorities and global strategic priorities. For force providers and DOD budget personnel, the gaps highlight areas where additional resources can be committed to meet strategic objectives.

Combining and balancing FADM and platform consideration into the optimization model allows decision makers a model that more closely resembles current allocation methods. The results of the combined model change if the objective function coefficient is modified (i.e., the $value_{ij}$ parameter) for a particular platform. This change may represent where the platform consideration is modified based on new information or just to examine model sensitivity. The objective function manages the trade-off between FADM priority and platform consideration. The combined model closely simulates how

the force allocations recommendations are made because it takes into account regional geographic realities while managing global strategic priorities.

The research, methodology, and analyses presented successfully prove that this optimization model will objectively inform senior decision makers in the Department of Defense for intelligence surveillance reconnaissance Global Force Management allocation.

VI. FUTURE RESEARCH

The next iteration (and a separate thesis project) would be the refinement of this model to consider risk. Risk to mission is assumed by the prioritization inherent in the FADM. The force provider assumes risk to force in the force offering. These assumptions are a good start to rotational fiscal year force allocation. However, the model can be adapted to include a risk value. For example, if the Joint Staff or JFCC ISR recommend that a force provider increase capacity to beyond what was initially offered, it would be useful to account for risk to force specifically in the formulation.

Risk can be considered in the model using a multi-objective formulation and adding risk as a consideration in the formulation. For this method to work, the model will assume that $value_{ij}$ is much greater than risk and will ignore risk initially. Then use the model to solve for $value_{ij}$. Finally, the model will use the solution for $value_{ij}$ to establish an additional constraint and solve for $risk_{ij}$. The model's objective is to compare the risk to force of adding capacity at the expense of future force readiness against the risk to mission of the CDR for not meeting a capability requirement.

A risk informed model would become the basis for an optimization model that can address emergent requirements. Emergent requirements are CDR requirements for forces within the current fiscal year. As this notional model shows, all of the force provider capacity is used. In order to allocate additional capability to new requirements, the forces would come from one of three options.

The first option would be to order additional capacity from the force providers. This option comes with a cost to future force readiness. For example, if the recommendation is that the Air Force to provide additional MQ-9 capacity, the additional qualified pilots and sensor operators needed may come from the training units. Pulling instructors from the training unit to meet the demands of operational requirements reduces the number people who are able to train the next cycle of crews. This may have significant impact to follow on rotational capacity. The risk to force would become the significant factor to the model.

The second option would recommend the reallocation of additional capacity from one CDR to a different CDR. For example, USNORTHCOM may need additional FMV capability to monitor a Russian exercise off the coast of Alaska. There is no additional force provider capacity to allocate to meet the emergent requirement. Notional reallocation options to consider include moving counter drug assets out of USSOUTHCOM or moving assets out of USCENTCOM who are supporting combat operations. In this notional scenario, the risk to USSOUTHCOM mission priority is less than the risk to combat operations in USCENTCOM. The risk to mission is the most significant factor to the model.

A third option would include contracting FMV capacity from a commercial vendor. This option has a dollar cost associated to it. Using a model that can objectively optimize recommendations while taking into account risk, may show that the dollar cost is significantly less than the cost to force readiness or the cost to the risk to mission. Not only will the model provide context for decision, it will provide transparency to the CDRs, force providers, the Joint Staff, and the Department of Defense.

Combining the optimization model described throughout this thesis with a risk informed model that can be implemented for the force allocation of all ISR capabilities is a logical evolution that optimizes the force allocation decision process that informs the SECDEF for force decisions and responsibility.

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