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OPTIMIZING AIR FORCE DEPOT PROGRAMMING TO MAXIMIZE OPERATIONAL CAPABILITY

THESIS

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AFIT-ENS-14-M-36

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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OPTIMIZING AIR FORCE DEPOT PROGRAMMING TO MAXIMIZE OPERATIONAL CAPABILITY

THESIS

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Air University

Air Education and Training Command

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OPTIMIZING AIR FORCE DEPOT PROGRAMMING TO MAXIMIZE OPERATIONAL CAPABILITY

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Abstract

The Air Force wants to improve the link between resources and weapons system readiness by reducing costs, improving risk-based decision making, and balancing costs with performance. With that in mind, RAND Project Air Force developed a linear programming model linking Depot Purchased Equipment Maintenance to operational capability. This thesis examined that model, provided an alternate model, and then developed a new model that determined the minimum cost necessary to maintain the force structure. The utility of using the models using Weapon System Sustainment (WSS) and additional sources of data for aircraft and engine inventories was evaluated and critiqued.

While every WSS requirement has a cost, the vast majority do not have quantities associated with them. Using the sources outlined for aircraft and engine inventories does not match up with WSS data. Aircraft inventory data is more specific than the WSS data requirements. Engine inventories are managed by engine type, not by aircraft. Many engines serve multiple aircraft, and many aircraft require multiple engines. The combined result is that using WSS data to process these models and obtain meaningful results is not possible at this time.

To my wonderful wife, your sacrifices, patience, and support did not go unnoticed. I am forever indebted to you. To my daughters, thank you for your understanding throughout this effort. You are together what drive me to reach my full potential.

Acknowledgments

I would like to start by thanking my thesis advisor, Dr. Ray Hill. I recognized early on that this research would be somewhat different than other efforts and I would not have gotten through it without your guidance and support. Dr. Hill was always waiting with a great suggestion or nudge whenever I was not quite sure where to go. Thanks also go to my other advisor, Maj (Dr.) Rob Overstreet, who was instrumental in helping me gather and acquire the requisite background and knowledge to complete this thesis. He was also very helpful in reassuring me that things would be okay when I had concerns early in this effort.

This thesis would not have been possible without assistance from the Centralized Asset Management Division at AFMC/A4F. Mr. Ray Gaier and his team of Mr. Rick Bryan, Mr. Charles Weeks, and Mr. Chris Hillard were able to explain how Depot Programmed Equipment Maintenance operated, without which I would have been dead in the water. In particular, Mr. Hillard went above and beyond in explaining to me the nuances of weapons systems sustainment data, which was my primary source of data.

I want to give some special thanks to the program chairs for Engineering Management, Dr. Al Thal and Lt Col Tay Johannes, who encouraged all of us not to limit our thesis topic to any particular field, and then supported me once I chose a topic outside of the department. Finally, thank you to Dr. James Chrisis for introducing me to linear programming and helping me find a thesis topic within that field. I greatly appreciate your efforts.

James D. Rhoads Jr.

Table of Contents

Table of Figures

Table of Tables

Page

OPTIMIZING AIR FORCE DEPOT PROGRAMMING TO MAXIMIZE OPERATIONAL CAPABILITY

I. INTRODUCTION

Background

Throughout the cold war, the United States military built their requirements based on the needs of the individual services, as determined by the individual services, in order to ensure the security of America and its Allies. There was a clear enemy that the United States could prepare for, and, in planning for this threat, senior leadership of each of the services planned for large expenditures devoted towards each of their own vital programs, often at the expense of the other services' needs. In the wake of the Soviet Union's collapse, that planning system was viewed as too inflexible to provide the necessary force balance and effectiveness. The acquisition system became burdened with large, complex, and costly programs that significantly slowed down the process while more traditional programs, such as funding for infantry, were slashed to pay for these massive acquisition programs (Jones & Herslow, 2005). With that in mind, the United States transitioned to a capabilities-based approach to defense planning (Jones & Herslow, 2005). In regard to planning for future threats, Secretary of Defense at the time, Donald Rumsfeld stated that America should be "focusing not only on who might threaten us, or where, or when – but more on how we might be threatened, and what portfolio of capabilities we will need to deter and defend against those new threats (Rumsfeld, 2004)."

Weapon system sustainment (WSS) is a crucial component of our readiness (Donley & Welsh III, 2013). Combat demands over the years have taken a toll across many weapons systems, and WSS requirements continue to increase in cost. With recent force structure reductions, these resources must be carefully managed in order to avoid availability shortfalls.

WSS funding requirements, which include Depot Purchase Equipment Maintenance (DPEM), have consistently increased at a rate double that of DoD inflation planning factors (Donley & Welsh III, 2013). As a result, the Air Force wants to improve the link between resources and weapons system readiness by reducing costs, improving risk-based decision making, and balancing costs with performance. The 2014 Air Force posture statement indicates the Air Force will "… leverage risk-based strategies and evaluate maintenance schedules to maximize aircraft availability and apply performance-based logistics solutions to balance total sustainment costs with performance (Donley & Welsh III, 2013)."

The principal goal of the defense budget is to deliver a collection of capabilities to meet a wide-range of uncertain future security environments (Snyder, et al., 2009). Over the past decade, the Air Force has made advances in creating a process for analyzing and evaluating capabilities and then integrating these analyses into budgetary programming (Snyder, et al., 2009). Despite these advances, many limitations still exist, and there are many disconnects between capability assessments and programming. Perhaps the greatest of those disconnects are that capability assessments remain anchored in subjective judgments, and it is often difficult to make the connection from the defined capabilities and resources to be allocated (Snyder, et al., 2009).

Unfortunately, there is no one size fits all solution linking the funding of a requirement to capabilities across the entire enterprise. However by examining two RAND Project Air Force developed models, this research developed a methodology to connect resources with capabilities. The first model is presented in their report Assessing Capabilities and Risks in Air Force Programming: Framework, Metrics, and Methods (Snyder, et al., 2009) which examined deployed combat support. Subsequently, the second mathematical model maximizes operational capability for DPEM (Snyder, et al., 2012). This thesis critically examines the latter method.

Problem Statement

RAND Project Air Force introduced a model intended to link resources to operational capabilities for DPEM. Unknown is how practical it is to implement the model with provided weapon systems sustainment data. Applying the model rests on the ability to determine its necessary parameters from given WSS data. With that in mind, a method for manipulating the WSS data to produce the necessary parameters is required, along with an explanation of any limitations that arise from using the WSS data and the RAND model in this manner.

In addition, a prototype tool is needed to assist programmers and decision makers in applying the model. The prototype should produce optimized funding decisions and express not only a set of requirements to fund, but must also identify requirements that are not recommend for funding. The expectation is not that the prototype will make programming decisions, but rather it will provide additional information to programmers and decision makers so that they may make the most informed decisions possible.

In order to address those problems, three questions had to be answered. The first question was how sound is the RAND Project Air Force DPEM linear programming model? Next, if there are any issues with the model, how can they be corrected? Finally, what are the procedures for manipulating the WSS data for use within the model?

Research Objectives

The goal of this thesis is to examine the RAND model for DPEM in a number of ways. One way is determining how feasible it is to take real world data and apply it to the model. This is done by collecting the data, examining the data manipulation necessary to provide the parameters needed for the model, and identifying the limitations of preparing this data based on current practice. This thesis also expands upon the RAND Project Air Force DPEM effort. The RAND Project Air Force model to optimize operational capability is evaluated for possible improvements from which three other models are developed. The first model minimizes DPEM costs while still meeting a set of objectives. The second model maximizes operational capability given a series of uncertain futures. The third model optimizes for operational capability, but does for an uncertain future by evaluating multiple scenarios with probabilities assigned to each.

Assumptions/Limitations

While there are assumptions and limitations addressed throughout the remainder of the thesis, there are some general assumptions and limitations that are worthwhile to mention upfront. First, the metrics developed or selected by RAND link resources to operational capability. There is no analysis concerning whether the chosen metrics are appropriate. Next is the assumption that all task requirements listed in the WSS data are valid. Third, the WSS data provided by AFMC is the source of all indices and parameters that can be derived from it. And finally, production tasks can only be deferred for one year.

There are two key limitations. First, the RAND research only addressed the DPEM commodity Aircraft within its mathematical model. As such, this effort is limited to Aircraft as well. Second, there are issues with some of the data selected for use in the models. While that is recognized, the greatest benefit of this effort is not how accurate the results may or may not be, but rather it is describing the level of difficulty with which the model may be implemented using available data sources.

Thesis Organization

The remainder of this thesis contains five additional chapters. Chapter II provides a literature review of capabilities-based programming and the previous RAND research. In Chapter III, the requirements for the models are examined to include what data are necessary, where that data can be obtained, and how the data are manipulated for model use. Chapter IV examines each of the linear programming models. Chapter V examines the development of the prototype tool to include both the Excel based graphical user interface and the Lingo code which processes the models. Chapter VI concludes the thesis effort examining the limitations with the models, feasibility of using the models, and opportunities for further research.

II. LITERATURE REVIEW

Overview

This chapter reviews the relevant literature, focusing mainly on capabilities-based programming and the previous research conducted by RAND Air Force (Snyder, et al., 2009). The research mentioned herein is not exhaustive, but provides a general understanding of capabilities-based programming and the RAND Air Force effort (Snyder, et al., 2009).

RAND Project Air Force Research

The RAND Project Air Force research had three main components. The first component began with developing a suitable set of capability metrics relating programming directly to DoD-level planning guidance (Snyder, et al., 2009). RAND expressed those metrics in terms of programmable entities, such as program elements or identifiable subsets of program elements that could apply across a wide range of program elements. By expressing capabilities in this manner, the overall capability of programming decisions is immediately expressible in terms of the ability to achieve national objectives, is usable by programmers, and enables programming trades among disparate programming areas. The second component of the method quantifies the resources needed to achieve the goals measured by the metrics. In the case of combat support resources, the objective is to determine which resources and how much of those resources are required by each contingency, operation, and vignette in the Defense Planning Scenarios (Snyder, et al., 2009). RAND recommended compiling a set of rules to automate the process as much as possible and to enable rapid assessment of multiple scenario sets. The feasibility of this approach has been previously established (Snyder, et al., 2012). The third component was an analytical tool combining the objectives set by the Department of Defense (DoD) plans with the requirements determined by a rule set to nominate a program objective memorandum (POM) for the programmer to take to the decision maker (Snyder, et al., 2009). This tool also assessed that POM's success in achieving DoD-level plans and quantified the risks incurred. The tool developed operates in multiple modes. One mode determines the resources needed at minimal cost to achieve the planning objectives across the Future Years Defense Program (FYDP). Another mode determines the funding allocation to maximize capability as measured against a set of planning objectives, given fiscal guidance across the FYDP (Snyder, et al., 2009). These assessments can be done against a single, deterministic future or against a portfolio of possible futures. The latter yields a POM that is more robust in light of uncertain future security threats.

As RAND discussed in their paper, developing a linear program across DPEM presents complications that were not confronted in their previous work on expeditionary combat support resources (Snyder, et al., 2012). The nature of expeditionary combat support resources lent itself more easily to a linear program due to the requirements being easily quantifiable. Combat support resources examined procurement costs for the resources and then costs to sustain and later reconstitute those resources. Once these parameters were determined, developing models to maximize capability or minimize cost was relatively straight-forward.

Conversely, developing a model which encompasses all eight DPEM commodities is highly problematic because, among other things, it is not readily apparent how funding in any particular commodity results in operational capability relative to the other commodities. Depot-level activities are maintenance activities required for capital assets already procured. Maintenance activities include (but are not limited to) repairing broken parts, performing inspections, modifying and upgrading hardware and software, and sustaining engineering. These activities are performed on the full spectrum of sustained resources, including aircraft, missiles, munitions, software, and a wide range of ground equipment and vehicles. Not performing necessary maintenance, or performing that maintenance inefficiently, causes resource unavailability due to their not being mission capable. For assets of high capital investment, such as aircraft and missiles, deferring maintenance is not a viable long-term programming option (Snyder, et al., 2012).

Despite the additional complexity of the DPEM model, the three goals for developing the linear program remained the same as from previous RAND work. Their first order of business was to establish appropriate metrics (Snyder, et al., 2012). Next, determine the requirements to meet plans in terms of those metrics. Finally, develop appropriate tools that nominate programming strategies to the programmer, whether that be meeting plans at minimal cost or maximizing capability against plans, given fiscal constraints. The takeaway is that there are a number of diverse activities included under DPEM and that the connecting of funding for those activities to operational capability is more tenuous than was the RAND research for deployed combat support forces.

RAND’s plan to implement capabilities-based planning and programming for depot-level activities was to first establish metrics for performance goals that related to Office of the Secretary of Defense (OSD)–level planning objectives, then to define and validate anticipated requirements to meet those objectives, and finally to set priorities among these requirements (Snyder, et al., 2012). To establish capability metrics, there are three areas of metrics to address: capability metrics that express impacts on operational performance, are directly related to national-level planning guidance, and, as much as possible, apply across multiple weapon systems and business areas to facilitate tradeoffs among various programming areas, while retaining linkages between the supported system and some operationally relevant performance measure.

There are three challenges in selecting metrics. The first is to identify the metrics that best characterize the operational performance. A widely used metric is weapon system availability (Snyder, et al., 2012). Availability is well defined for aircraft, and, in that context, captures the proportion of time that the total aircraft inventory is mission capable or partial mission capable. In practice, this means computing the time aircraft in the fleet were mission capable or partial mission capable and dividing this number by the total time that the aircraft were in this status or were not mission capable, were depot possessed, or were unit possessed and not reported (Secretary of the Air Force, 2005).

In isolation, weapon system availability expresses the primary goal of sustainment, which is to maximize the time that a system can perform its designed operational role, but availability does have shortcomings. Availability fails to reveal the interdependencies of investments in various business areas (Snyder, et al., 2012). For example, an operator needs to deliver a precision-guided bomb to a particular point of impact. An F-16 available to do this partially enables that mission, but, if other supporting capabilities, such as munitions, fueling support, and so forth, are not present, the mission fails. Availability metrics also present a challenge in linking many funding areas to the performance metric (Snyder, et al., 2012). Software maintenance is a prominent example within DPEM as it has no clear link to any current measure of weapon system availability but can play a crucial role in determining whether a system can perform. A final point is that availability, as defined for aircraft, does not always transfer adequately to other systems (Snyder, et al., 2012). One example is ICBMs, where the alert rate is a more suitable measure. Figure 1 below depicts schematically a partial mapping RAND used to develop appropriate operational capability metrics for DPEM. It illustrates how the DPEM commodity groups contribute to two different capabilities. It also clarifies why weapon system availability is a good metric for "Generate AEF and training sorties", but not necessarily for "Minuteman III availability."

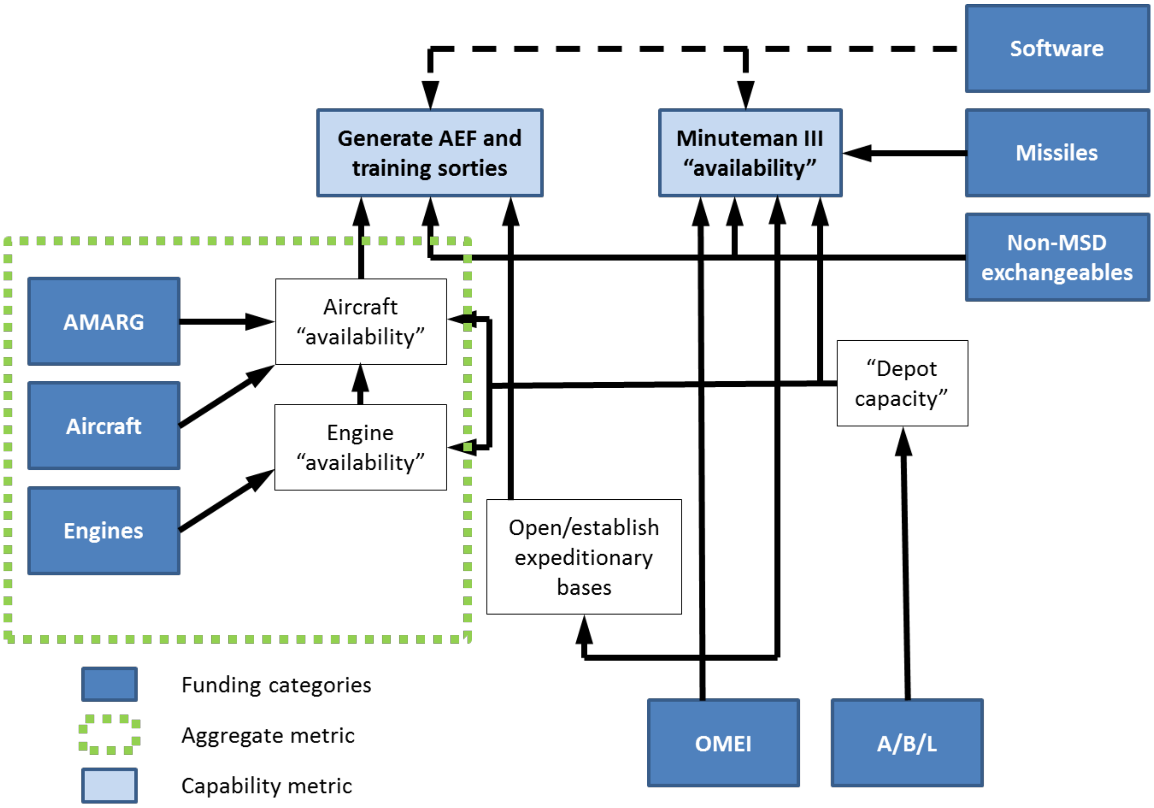


Figure 1, Schematic Partial Mapping of DPEM Operational Capabilities (Snyder, et al., 2012)

The second challenge with metrics is to balance sustainment funding in business areas that directly affect the operational performance with those that indirectly affect performance. Even though a metric may capture the linkage to operational performance, it is not helpful for programming if it gives an undesired bias toward some business area(s) at the expense of others (Snyder, et al., 2012). Funding tends to be more protected for business areas that lie closer to the combat mission. For example, it may be easier to defend spending on sustaining a combat aircraft than to defend spending on sustainment for training aircraft, or for supporting systems, such as vehicles and software. This perceived higher proximity to the mission is potentially dangerous.

Failure to meet sustainment needs in any area will eventually affect the ability to perform missions (Snyder, et al., 2012). For example, failure to perform sustainment perceived as indirect, or that might only have future impact, will eventually have a direct impact on the ability to perform the operational mission. An example would be the failure to address aging-aircraft issues, such as the identification and repair of fatigue cracks and corrosion. This oversight might not have near term impacts, but an unaddressed fatigue issue could ground the entire fleet in the future. Metrics should not unduly bias performance evaluation in favor of near-term effects to the detriment of addressing longer-term effects.

The third challenge is to determine the optimal target value for each metric. Merely attempting to maximize each performance measure risks improper balance of capabilities across systems and risks funding some areas at too high a level, where large increases in funding return only small marginal gains in capability.

While addressing each of the challenges, RAND developed a linear programming model which focused on maximizing operational capability based on both aircraft and engine availability. With that in mind, the next chapter explains how the WSS data, the source of production requirements for this research, was obtained and manipulated for use in processing not only the RAND model, but two additional models as well.

III. DATA REDUCTION

Overview

This chapter outlines the data requirements for the models, identifies the sources of that data, and then details the methods used to manipulate the data so it can be applied within each of the models. An explanation of each of the data requirements is included to help understand the logic for the models. There are several differences in the sources of data identified in the RAND effort and the sources of data used for this thesis, so a brief explanation of those differences is also included.

Model Data Requirements

Each of the models produces a list a production requirements to accomplish by aircraft and year. It follows then that indices for aircraft, production tasks, and program years are necessary. The parameters needed for each aircraft include total aircraft inventory, primary aircraft inventory, minimum aircraft availability, mission capability goal, on-hand engine stock, base peacetime operating stock engine quantity, war reserve engine quantity, and an aircraft weighting factor. The total aircraft inventory is the sum of the primary and backup aircraft assigned to meet the total active aircraft authorization, while the primary aircraft inventory is the aircraft assigned to meet the primary aircraft authorization. The total aircraft inventory is used to ensure planning requirements are met, while the primary aircraft inventory, in conjunction with production task deferrals, are used to set a cap on available aircraft. The minimum aircraft availability and mission capability goal are both user defined parameters. The three engine parameters are used to establish another cap for available aircraft, similar to the total aircraft inventory, since all operational aircraft require operational engines.

The parameters required for each aircraft-production requirement-year combination are as follows: production task cost, additional deferral cost, production requirement, maximum deferral rate, and utilization fraction of production capacity. The production task cost is the cost of each production task by aircraft and year. The additional deferral cost is the additional cost associated with conduction a production task on an aircraft that was deferred the previous year. The production requirement is the number of aircraft required to undergo a production task by aircraft and year. The utilization fraction of production capacity helps to establish the maximum production of a production task in a given year.

The final necessary parameters are the annual budgets, the number of years in the Future Years Development Plan (FYDP), and a parametric weighting factor. . The annual budgets establish the limit for spending. The number of years in the FYDP establishes the length of the planning horizon. The parametric weighting factor is included so that the models can balance deferrals across all aircraft platforms. The product of the parametric weighting factor and the maximum deferral rate among all of the aircraft is used as a negative term in the objective function. If the parametric weighting factor is small then the term is dominated in the objective function. Conversely, the larger the parametric weighting factor is, the more weight the term has within the objective function. The larger this term becomes, the more the models favor balancing deferrals across all of the systems as any single large deferral rate will disproportionately decrease the objective functions' value. The parametric weighting factor was not utilized in the cost minimization model.

Sources of Data

Unfortunately, the necessary data is not contained in a single location. In fact, it comes from a variety of many different locations. Table 1 lists each of the model requirements, what RAND identified as the parameter source, and where the parameters are found.

Table 1, Data Sources

Data	Symbol	RAND Data Source	Thesis Data Source
Index of aircraft	i	Not specifically mentioned	WSS data file
Index of production tasks	j	Not specifically mentioned	WSS data file
Index of years in FYDP	k	Not specifically mentioned	Assumed 5-year planning horizon
Total aircraft inventory	a	PDS	D200F API database
Annual budgets	b	Management-of-funds-spreadsheet	Used 90% of annual requirements
Production task cost	c	Management-of-funds-spreadsheet	WSS data file
Production demand levels	d	Management-of-funds-spreadsheet	WSS data file
Parametric weighting factor	e	Not specifically mentioned	User adjustable
Maximum fraction of deferrals	f	Not specifically mentioned	User adjustable
Extra deferral cost	g	User adjustable; default = 5%	User adjustable
Minimum aircraft availability	h	Not specifically mentioned	User adjustable
Mission-capability goal	m	User adjustable	User adjustable
Primary aircraft inventory	p	PDS	D200F API database
Utilization fraction of production capacity	q	User adjustable; default = 93%	User adjustable
Engine on-hand stocks	s	LIMS-EV	LIMS-EV
Aircraft weighting factors	w	Not specifically mentioned	User adjustable
Authorized BPOS engines	α	LIMS-EV	LIMS-EV
War-reserve engines	β	LIMS-EV	LIMS-EV

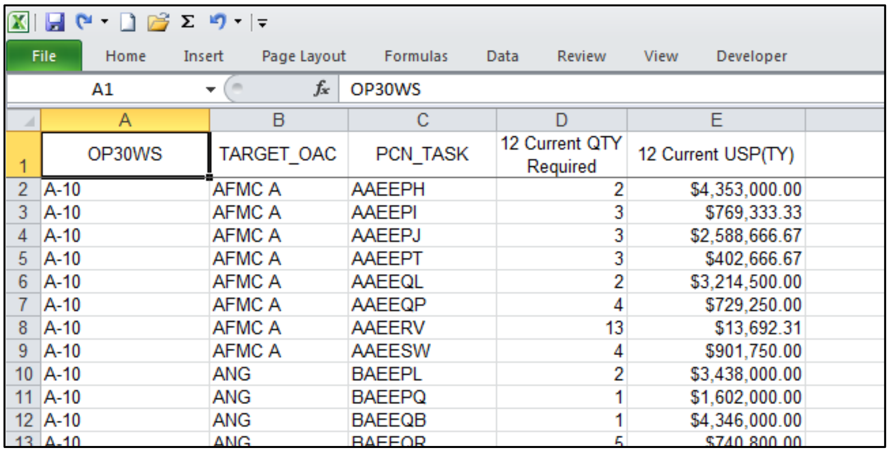
The reasons for the differences between sources for the parameters were varied. WSS data was provided by the primary sponsor of this research, AF/A4, so that was the source for much of the data. RAND suggested using the program data system (PDS) for aircraft inventories, but PDS proved too nonspecific to locate the required parameters. After an extensive search effort, the parameters were found in the D200F Applications, Programs, and Indentures database. RAND also suggested using the management-of-funds spreadsheet for some of the data, but it could not be located. However, that data from the management-of-funds spreadsheet was derived from the WSS data. Finally, the engine parameters came from Logistics Installations and Mission Support - Enterprise View (LIMS-EV), as noted by RAND.

Data Manipulation

The 2012 WSS data were provided in Microsoft Excel® format with 4,496 rows and 60 columns with one requirement listed per row. Many of those requirements did not pertain to DPEM, and many of the DPEM requirements did not pertain to aircraft. The data required manual manipulation to remove the unnecessary information. First, the requirements were sorted by column S, “Process”, to identify DPEM requirements. The non-DPEM requirements were deleted leaving 1,220 requirements. Next, the requirements were sorted by column D, “OP30WS”, which identified the weapon system each requirement belonged to. The non-aircraft requirements were removed leaving 570 remaining. Many of the remaining requirements did not list the quantities required. The quantity required served as the production demand level within the linear programming models, so those requirements without a quantity were also removed leaving 182 task requirements.

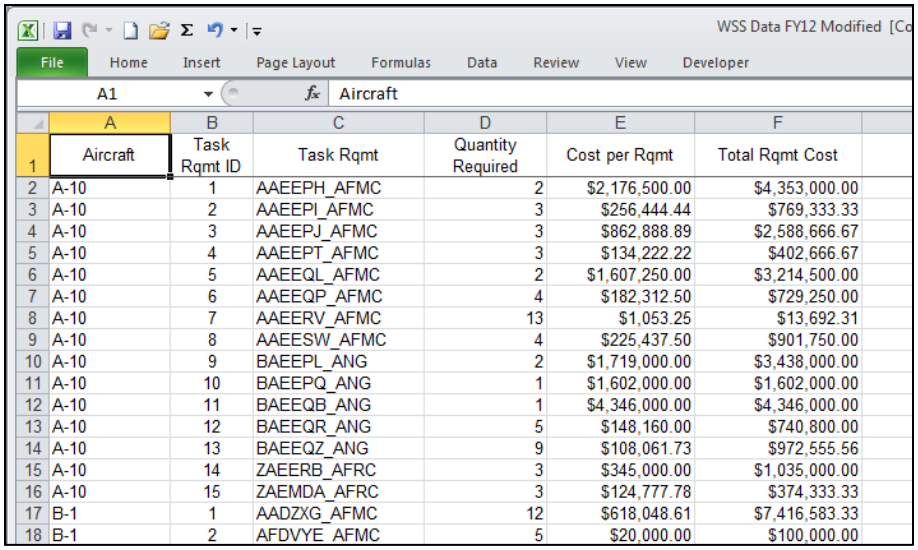
The data were also modified to remove unnecessary column data leaving only five columns of original data after the unnecessary columns were removed. The first column to remain was column D, “OP30WS”, which identified the aircraft for which the requirement belonged to. The next columns that were kept were E, “TARGET_OAC”, and AD, “PCN_TASK”. The “TARGET_OAC” identified which of three Air Force groups (AFMC, AFRC, or ANG) the requirement belonged to. The funding center identifier for the Air Force is OAC. The “PCN_TASK” is a six-character alpha-numeric program control number. While some PCN’s were repeated among the requirements, they were never repeated for different aircraft or with the same “TARGET_OAC”. This allowed combining the “TARGET_OAC” and “PCN_TASK” for each requirement to create a unique requirement identifier. The next column was AS, “(last two digits of fiscal year) Current QTY Required” which identified the number of aircraft needing this requirement. The final original column kept was BF, “12 Current USP(TY)” which was the total amount for the requirements. The last two columns helped determine the cost per requirement parameter for the model. Figure 2 illustrates the remaining columns. This data manipulation was not immediately obvious, ended up being quite time-consuming, and was conducted manually.

After removing the columns and rows that were not needed to process the models, a few new columns were created. A column labeled “Task Rqmt” was created as a text string combination of “PCN_TASK” and “TARGET_OAC”. The “PCN_TASK” and “TARGET_OAC” columns were no longer needed once the “Task Rqmt” column was created, so they were deleted. A column labeled “Task Rqmt ID” was created to assign sequential numbers to the requirement tasks by aircraft. Finally, a column labeled “Cost per Rqmt" was created as the total requirement cost divided by the quantity required. The remaining columns from the WSS data file were renamed to align with the named parameters of the model. The process was then repeated for each of the five years in the five-year planning horizon. Figure 3 provides a screenshot of the updated columns.



	A	B	C	D	E
1	OP30WS	TARGET_OAC	PCN_TASK	12 Current QTY Required	12 Current USP(TY)
2	A-10	AFMC A	AAEEPH	2	$4,353,000.00
3	A-10	AFMC A	AAEEPI	3	$769,333.33
4	A-10	AFMC A	AAEEPJ	3	$2,588,666.67
5	A-10	AFMC A	AAEEPT	3	$402,666.67
6	A-10	AFMC A	AAEEQL	2	$3,214,500.00
7	A-10	AFMC A	AAEEQP	4	$729,250.00
8	A-10	AFMC A	AAEERV	13	$13,692.31
9	A-10	AFMC A	AAEESW	4	$901,750.00
10	A-10	ANG	BAEEPL	2	$3,438,000.00
11	A-10	ANG	BAEEPQ	1	$1,602,000.00
12	A-10	ANG	BAEEQB	1	$4,346,000.00
13	A-10	ANG	BAEEQR	5	$740,800.00

Figure 2, Screenshot of Remaining Columns of WSS Data



	A	B	C	D	E	F
1	Aircraft	Task Rqmt ID	Task Rqmt	Quantity Required	Cost per Rqmt	Total Rqmt Cost
2	A-10	1	AAEEPH_AFMC	2	$2,176,500.00	$4,353,000.00
3	A-10	2	AAEEPI_AFMC	3	$256,444.44	$769,333.33
4	A-10	3	AAEEPJ_AFMC	3	$862,888.89	$2,588,666.67
5	A-10	4	AAEEPT_AFMC	3	$134,222.22	$402,666.67
6	A-10	5	AAEEQL_AFMC	2	$1,607,250.00	$3,214,500.00
7	A-10	6	AAEEQP_AFMC	4	$182,312.50	$729,250.00
8	A-10	7	AAEERV_AFMC	13	$1,053.25	$13,692.31
9	A-10	8	AAEESW_AFMC	4	$225,437.50	$901,750.00
10	A-10	9	BAEEPL_ANG	2	$1,719,000.00	$3,438,000.00
11	A-10	10	BAEEPQ_ANG	1	$1,602,000.00	$1,602,000.00
12	A-10	11	BAEEQB_ANG	1	$4,346,000.00	$4,346,000.00
13	A-10	12	BAEEQR_ANG	5	$148,160.00	$740,800.00
14	A-10	13	BAEEQZ_ANG	9	$108,061.73	$972,555.56
15	A-10	14	ZAEERB_AFRC	3	$345,000.00	$1,035,000.00
16	A-10	15	ZAEMDA_AFRC	3	$124,777.78	$374,333.33
17	B-1	1	AADZXG_AFMC	12	$618,048.61	$7,416,583.33
18	B-1	2	AFDVYE_AFMC	5	$20,000.00	$100,000.00

Figure 3, Screenshot of Updated Columns

Summary

There are a number of parameters needed to process the models and the reasoning for needing each of those parameters was explained. Those parameters came primarily from the WSS data, but some were found in the Logistics Installations and Mission Support and D200F Applications, Programs, and Indentures databases as detailed in Table 1. Table 1 also identified the differences between research sources for the data and those sources listed in the RAND paper. Differences in data sources used in the RAND research and this effort were noted and explained. Finally, a detailed account of how the WSS data was manipulated for use in the models was included.

IV. MATHEMATICAL MODELS

Overview

This chapter presents the mathematical models used in this research. The model developed by RAND Project Air Force to maximize operational capability is presented first. Minor potential shortfalls of the model are discussed and are followed by a slightly modified model that addresses those issues. The chapter finishes with a model developed to minimize cost while meeting aircraft availability.

RAND Formulation to Maximize Operational Capability

Indices used:

i = Index of aircraft

j = Index of production tasks

k = Index of year

Decision Variables:

V = Maximum fractional production demand shortfall for all MDS

X_{ijk} = Production for aircraft i of production task j in year k

Y_{ijk} = Deferrals for aircraft i of production task j in year k

Z_{ik} = Available aircraft i in year k

Parameters:

a_{i1} = Total aircraft inventory of aircraft i

b_k = Total budget available in year k

c_{ijk} = Cost for aircraft i of production task j in year k

d_{ijk} = Production requirement for aircraft i of production task j in year k

e = Parametric weighting factor

f_{ijk} = Maximum fraction of d_{ijk} that can be deferred

g_{ijk} = Extra cost of executing a deferred task, expressed as a fraction of c_{ijk}

h_{i1} = Minimum aircraft availability for aircraft i in year 1

m_{i1} = Mission-capability goal for aircraft i in year 1

p_{i1} = Primary aircraft inventory for aircraft i in year 1

q_{ijk} = Utilization fraction of production capacity

s_{i2} = On-hand stock of engines for aircraft i in year 2

T = Number of years in the Future Years Development Plan

w_{i1} = Weighting factor for aircraft i in year 1

α_i = Number of BPOS engines for aircraft i

β_i = Number of war reserve engines for aircraft i

Mathematical Model:

The objective of the model is to maximize aircraft availability while sustaining the availability of the force.

$$Maximize\ \frac{1}{T}\sum_i \sum_k \left[\left(\frac{w_{i1}}{\sum_i w_{i1}}\right)\frac{m_{i1}Z_{ik}}{a_{i1}}\right] - eV \tag{1}$$

subject to:

$$0 \leq f_{ijk} \leq 1 \quad \forall\, i, j, k \tag{2}$$

$$0 \leq g_{ijk} \leq 1 \quad \forall\, i, j, k \tag{3}$$

$$0 \leq h_{ijk} \leq 1 \quad \forall\, i, j, k \tag{4}$$

$$0 \leq q_{ik} \leq 1 \quad \forall\, i, k \tag{5}$$

$$\sum_i \sum_j c_{ijt}\left(X_{ijk} + g_{ijk}Y_{ijk}\right) \leq b_k \quad \forall\, k \tag{6}$$

$$X_{ijk} \leq \frac{d_{ijk}}{q_{ijk}} \quad \forall\, k > 1 \tag{7}$$

$$X_{ijk} \geq 0 \quad \forall i, j, k \tag{8}$$

$$Y_{ijk} \geq 0 \quad \forall i, j, k \tag{9}$$

$$Y_{ijk} = \sum_{k' \leq k} \left(d_{ijk'} - X_{ijk'} \right) \quad \forall\, i, j \tag{10}$$

$$X_{ijk} \geq Y_{ijk-1} \quad \forall i, j, k > 1 \tag{11}$$

$$Y_{ijk} \leq f_{ijk} d_{ijk} \quad \forall i, j, k \tag{12}$$

$$Z_{ik} \leq p_{i1} - Y_{i1k} \quad \forall i, k \tag{13}$$

$$Z_{ik} \leq \frac{(s_{i2} - Y_{i2k}) p_{i1}}{\alpha_i + \beta_i} \quad \forall i, k \tag{14}$$

$$d_{ijk} V \geq d_{ijk} - X_{ijk} \quad \forall\, i, j, k \tag{15}$$

$$\frac{m_{i1} Z_{ik}}{a_{i1}} \geq h_{i1} \quad \forall i, k \tag{16}$$

$$s_{i2} \geq 0 \tag{17}$$

$$V \geq 0 \tag{18}$$

The objective function of the model (1) balances maximizing aircraft availability and sustaining the force structure. The term inside the brackets is the aircraft availability by weapon system multiplied by an associated weighting factor (in parenthesis). The eV term allows the programmer to determine how evenly distributed to spread deferrals. Because V is defined by the largest production task deferral rate (15), the larger e is the more the eV term dominates the objective function. If e is very large, the linear program will force V as small as possible, which occurs when the rate of deferrals is the same for all production tasks on all aircraft in all years. Conversely, as e approaches zero, the objective function is dominated by the weighted aircraft availability. The first group of constraints (2 through 5) ensures that the parameters f_{ijk}, g_{ijk}, h_{ijk}, and q_{ik}, are each between 0 and 1. The next constraint (6) ensures the amount spent in year k is less than or equal to the amount available in the budget, b_k. Production of a task, X_{ijk}, may need to exceed the required production demand level in any given year due to deferrals from the previous year; however, production cannot exceed production capacity, d_{ijk}/q_{ijk}, so (7) ensures that maximum production is not exceeded. The next constraints (8 and 9) ensure that production and deferrals are non-negative, respectively. Constraint (10) ensures deferrals for year k are equal to the difference between the production requirement, d_{ijk}, and actual production, X_{ijk}, in addition to any prior year deferrals. A task requirement can only be deferred for one year, so (11) ensures the production in year k, X_{ijk}, is greater than or equal to deferrals from year $k-1$. Constraint (12) ensures the amount of deferrals, Y_{ijk}, is less than the maximum allowed, $f_{ijk}d_{ijk}$. The next two constraints (13 and 14) work together to establish Z_{ik} as the minimum of the two constraints. First, (13) establishes available aircraft, Z_{ik}, as less than or equal to the amount of available airframes and then (14) ensures available aircraft, Z_{ik}, as less than or equal to the amount of available engines. In conjunction with the objective function, (15) ensures that V is the maximum fractional production demand shortfall. The next constraint (16) ensures aircraft availability is greater than the user defined parameter minimum aircraft availability, h_{i1}. The last two constraints (17 and 18) are non-negativity constraints for (17) the on-hand stock of engines, s_{i2}, and (18) the maximum fractional production demand shortfall, V.

Analysis/Critique

The RAND model has a few issues that prevent it from arriving at a true optimal solution. Constraint (13) ensures that available aircraft, Z_{ik}, does not exceed the primary aircraft inventory, p_{i1}, minus deferred aircraft, Y_{i1k}. This makes sense if Y_{i1k} is the aircraft-year combination with the greatest number of deferrals; however, this is not likely the case as there are many production requirements for each aircraft. It may be better to identify the production task with the greatest number of deferrals by aircraft-year combination. Constraint (14) ensures available aircraft do not exceed available engines. The formulation in the model does not allow three of the parameters to vary by year even though they can, and usually are, different values. Constraint (16) ensures available aircraft is greater than the required minimum. As with the previous example, the constraint as written does not allow some of the parameters to vary by year even though the values change by year. There are two constraints RAND did not include that would seem to be necessary. The first of these is for the mission capability goal parameter, m_{ik}. It is another parameter which needs a constraint to ensure it falls between 0 and 1, similar to other constraints (2 through 5). There should also be constraints to ensure the decision variables for production tasks, deferrals of production tasks, and available aircraft are integers since you cannot have fractions of any of them. While rounding the continuous linear program to an integer solution is a common practice, there is really no guarantee of rounded solution quality. Thus, the recommendation to solve this is as an integer program. Finally, the parameter for the number of years in the Future Year Development Plan has no effect on the outcome of the model. It does make the magnitude of the objective function smaller as years in the plan increase, but it has no impact on the decision variables selected by the model. All of these issues are addressed in the modified formulation to maximize operational capability.

Modified Formulation to Maximize Operational Capability

The modified formulation seeks to maximize operational capability and to incorporate the changes previously noted in the analysis of the RAND model. There are new constraints to account for the mission capability goal (5) and for the identification of the greatest number of deferrals by aircraft-year combination (14). The constraint which ensures that available aircraft do not exceed the primary aircraft inventory minus deferred aircraft (13 in the RAND model and 15 in this model) has been modified to use the result from item 14 in the constraint.

Indices used:

i = Index of aircraft

j = Index of production tasks

k = Index of year

Decision Variables:

T_k = Total cost of production tasks completed in year k

V = Maximum fractional production demand shortfall for all MDS

X_{ijk} = Production for aircraft i of production task j in year k

Y_{ijk} = Deferrals for aircraft i of production task j in year k

Z_{ik} = Available aircraft i in year k

Parameters:

a_{ik} = Total aircraft inventory of aircraft i in year k

b_k = Total budget available in year k

c_{ijk} = Cost for aircraft i of production task j in year k

d_{ijk} = Production requirement for aircraft i of production task j in year k

e = Parametric weighting factor

f_{ijk} = Maximum fraction of d_{ijk} that can be deferred

g_{ijk} = Extra cost of executing a deferred task, expressed as a fraction of c_{ijk}

h_{ik} = Minimum aircraft availability for aircraft i in year k

m_{ik} = Mission-capability goal for aircraft i in year k

p_{ik} = Primary aircraft inventory for aircraft i in year k

q_{ijk} = Utilization fraction of production capacity for a/c i of task j in year k

s_{ik} = On-hand stock of engines for aircraft i in year k

w_{ik} = Weighting factor for aircraft i in year k

α_i = Number of BPOS engines for aircraft i

β_i = Number of war reserve engines for aircraft i

Mathematical Model:

The objective of the model is to maximize aircraft availability while sustaining the availability of the force.

$$Maximize\ \sum_i \sum_k \left[\left(\frac{w_{ik}}{\sum_i w_{ik}}\right)\frac{m_{ik}Z_{ik}}{a_{ik}}\right] - eV \qquad (1)$$

subject to:

$$0 \le f_{ijk} \le 1 \quad \forall\, i, j, k \qquad (2)$$

$$0 \le g_{ijk} \le 1 \quad \forall\, i, j, k \qquad (3)$$

$$0 \le h_{ijk} \le 1 \quad \forall\, i, j, k \qquad (4)$$

$$0 \leq m_{ik} \leq 1 \quad \forall\, i,k \tag{5}$$

$$0 \leq q_{ik} \leq 1 \quad \forall\, i,k \tag{6}$$

$$T_k = \sum_i \sum_j c_{ijk}\big(X_{ijk} + g_{ijk}Y_{ijk}\big) \quad \forall\, k \tag{7}$$

$$T_k \leq b_k \quad \forall\, k \tag{8}$$

$$X_{ijk} \leq \frac{d_{ijk}}{q_{ijk}} \quad \forall\, i,j,k > 1 \tag{9}$$

$$X_{ijk} \geq 0 \quad \forall\ i,j,k \tag{10}$$

$$Y_{ijk} \geq 0 \quad \forall\ i,j,k \tag{11}$$

$$Y_{ijk} = \sum_{k' \leq k}\big(d_{ijk'} - X_{ijk'}\big) \quad \forall\ i,j \tag{12}$$

$$X_{ijk} \geq Y_{ijk-1} \quad \forall\ i,j,k > 1 \tag{13}$$

$$Y_{ijk} \leq f_{ijk}d_{ijk} \quad \forall\ i,j,k \tag{14}$$

$$Z_{ik} \leq p_{ik} - Y_{ijk} \quad \forall\ i,j,k \tag{15}$$

$$Z_{ik} \leq \frac{(s_{ik} - Y_{ijk})p_{ik}}{\alpha_i + \beta_i} \quad \forall\ i,j,k \tag{16}$$

$$\frac{m_{ik}Z_{ik}}{a_{ik}} \geq h_{ik} \quad \forall\, i,k \tag{17}$$

$$d_{ijk}V \geq d_{ijk} - X_{ijk} \quad \forall\, i,j,k \tag{18}$$

$$s_{ik} \geq 0 \quad \forall\, i,k \tag{19}$$

$$V \geq 0 \tag{20}$$

$$X_{ijk} \in \mathbb{Z} \quad \forall\, i,j,k \tag{21}$$

$$Z_{ik} \in \mathbb{Z} \quad \forall\, i,k \tag{22}$$

The objective function of the model (1) uses the modified formulation to balance between maximizing aircraft availability and sustaining the force structure. The term inside the brackets is the aircraft availability by weapon system multiplied by an associated weighting factor (in parenthesis). The eV term allows the programmer to determine how evenly distributed they want deferrals. Because V is defined by the largest production task deferral rate (18), the larger e is the more the eV term dominates the objective function. So if e is very large, the linear program will force V as small as possible, which occurs when the rate of deferrals is the same for all production tasks on all aircraft in all years. Conversely, as e approaches zero, the objective function is dominated by the weighted aircraft availability. The first group of constraints (2 through 6) ensures that the parameters f_{ijk}, g_{ijk}, h_{ijk}, m_{ik}, and q_{ik}, are each between 0 and 1, respectively. The next constraint (7) defines the total cost of all production tasks to be completed, X_{ijk}, for each year k as T_k. Constraint (8) then guarantees that the amount spent in each year k, T_k, is less than or equal to the amount available in the budget, b_k. Production of a task, X_{ijk}, may need to exceed the required production demand level in any given year due to deferrals from the previous year; however, production cannot exceed production capacity, d_{ijk}/q_{ijk}, so (9) ensures that maximum production is not exceeded. The next constraints (10 and 11) ensure that production and deferrals are non-negative, respectively. Constraint (12) ensures deferrals for year k are equal to the difference between the production requirement, d_{ijk}, and actual production, X_{ijk}, in addition to any prior year deferrals. A task requirement can only be deferred for one year, so (13) ensures the production in year k, X_{ijk}, is greater than or equal to deferrals from year $k-1$. Constraint (14) ensures the amount of deferrals, Y_{ijk}, is less than the maximum allowed, $f_{ijk}d_{ijk}$. The next three constraints (15 through 17) work together to establish the upper and lower bounds for available aircraft, Z_{ik}. First, (15) establishes available aircraft, Z_{ik}, is less than or equal to the amount of available airframes and then (16) ensures available aircraft, Z_{ik}, is less than or equal to the amount of available engines. Constraint (17) establishes a minimum for available aircraft by ensuring aircraft availability is greater than the user defined parameter h_{ik}. In conjunction with the objective function, (18) ensures that V is the maximum fractional production demand shortfall. The next two constraints (19 and 20) are non-negativity constraints for (19) the on-hand stock of engines, s_{ik}, and (20) the maximum fractional production demand shortfall, V, respectively. The final two constraints (21 and 22) ensure all production tasks completed, X_{ijk}, and available aircraft, Z_{ik}, are integers, respectively. Forcing production tasks completed to be integers will result in production tasks deferred, Y_{ijk}, also being integers without explicitly requiring it.

Formulation to Minimize Cost

The purpose of the formulation to minimize cost is to determine the minimum amount of funding necessary to still meet aircraft availability requirements. While it may not be wise to simply program funding to meet minimum requirements, this model provides programmers and decision makers an understanding of how much funding is essential to meet minimum aircraft availability requirements. The major difference between this model and the modified formulation to maximize operational capability lies in objective function. However, the maximum fractional production demand shortfall decision variable V and parametric weighting factor e are not required, so that eliminates two constraints.

Indices used:

i = Index of aircraft

j = Index of production tasks

k = Index of year

Decision Variables:

T_k = Total cost of production tasks completed in year k

X_{ijk} = Production for aircraft i of production task j in year k

Y_{ijk} = Deferrals for aircraft i of production task j in year k

Z_{ik} = Available aircraft i in year k

Parameters:

a_{ik} = Total aircraft inventory of aircraft i in year k

b_k = Total budget available in year k

c_{ijk} = Cost for aircraft i of production task j in year k

d_{ijk} = Production requirement for aircraft i of production task j in year k

f_{ijk} = Maximum fraction of d_{ijk} that can be deferred

g_{ijk} = Extra cost of executing a deferred task, expressed as a fraction of c_{ijk}

h_{ik} = Minimum aircraft availability for aircraft i in year k

m_{ik} = Mission-capability goal for aircraft i in year k

p_{ik} = Primary aircraft inventory for aircraft i in year k

q_{ijk} = Utilization fraction of production capacity for a/c i of task j in year k

s_{ik} = On-hand stock of engines for aircraft i in year k

w_{ik} = Weighting factor for aircraft i in year k

α_i = Number of BPOS engines for aircraft i

β_i = Number of war reserve engines for aircraft *i*

Mathematical Model:

The objective of the model is to minimize costs while sustaining the necessary aircraft availability.

$$Minimize\ \sum_k T_k - \sum_i \sum_k Z_{ik} \tag{1}$$

subject to:

$$0 \leq f_{ijk} \leq 1 \quad \forall\, i, j, k \tag{2}$$

$$0 \leq g_{ijk} \leq 1 \quad \forall\, i, j, k \tag{3}$$

$$0 \leq h_{ijk} \leq 1 \quad \forall\, i, j, k \tag{4}$$

$$0 \leq m_{ik} \leq 1 \quad \forall\, i, k \tag{5}$$

$$0 \leq q_{ik} \leq 1 \quad \forall\, i, k \tag{6}$$

$$T_k = \sum_i \sum_j c_{ijk}\left(X_{ijk} + g_{ijk} Y_{ijk}\right) \quad \forall\, k \tag{7}$$

$$T_k \leq b_k \quad \forall\, k \tag{8}$$

$$X_{ijk} \leq \frac{d_{ijk}}{q_{ijk}} \quad \forall\, i, j, k > 1 \tag{9}$$

$$X_{ijk} \geq 0 \quad \forall\ i, j, k \tag{10}$$

$$Y_{ijk} \geq 0 \quad \forall\ i, j, k \tag{11}$$

$$Y_{ijk} = \sum_{k' \leq k}\left(d_{ijk'} - X_{ijk'}\right) \quad \forall\ i, j \tag{12}$$

$$X_{ijk} \geq Y_{ijk-1} \quad \forall\ i, j, k > 1 \tag{13}$$

$$Y_{ijk} \leq f_{ijk} d_{ijk} \quad \forall\ i, j, k \tag{14}$$

$$Z_{ik} \leq p_{ik} - Y_{ijk} \quad \forall\ i, j, k \tag{15}$$

$$Z_{ik} \leq \frac{(s_{ik} - Y_{ijk}) p_{ik}}{\alpha_i + \beta_i} \quad \forall\ i, j, k \tag{16}$$

$$\frac{m_{ik}Z_{ik}}{a_{ik}} \geq h_{ik} \quad \forall\, i,k \tag{17}$$

$$s_{ik} \geq 0 \quad \forall\, i,k \tag{18}$$

$$X_{ijk} \in \mathbb{Z} \quad \forall\, i,j,k \tag{19}$$

$$Z_{ik} \in \mathbb{Z} \quad \forall\, i,k \tag{20}$$

The objective function of the model (1) is the minimum sum of annual costs, T_k, minus the sum of available aircraft, Z_{ik}. While minimum cost is the ultimate goal, it is necessary to subtract available aircraft to ensure that greatest value of available aircraft is selected in defining the decision variables. The first group of constraints (2 through 6) ensures that the parameters f_{ijk}, g_{ijk}, h_{ijk}, m_{ik}, and q_{ik}, are each between 0 and 1, respectively. The next constraint (7) defines the total cost of all production tasks to be completed, X_{ijk}, for each year k as T_k. Constraint (8) then guarantees that the amount spent in each year k, T_k, is less than or equal to the amount available in the budget, b_k. Production of a task, X_{ijk}, may need to exceed the required production demand level in any given year due to deferrals from the previous year; however, production cannot exceed production capacity, d_{ijk}/q_{ijk}, so (9) ensures that maximum production is not exceeded. The next constraints (10 and 11) ensure that production and deferrals are non-negative, respectively. Constraint (12) ensures deferrals for year k are equal to the difference between the production requirement, d_{ijk}, and actual production, X_{ijk}, in addition to any prior year deferrals. A task requirement can only be deferred for one year, so (13) ensures the production in year k, X_{ijk}, is greater than or equal to deferrals from year $k-1$. Constraint (14) ensures the amount of deferrals, Y_{ijk}, is less than the maximum allowed, $f_{ijk}d_{ijk}$. The next three constraints (15 through 17) work together to establish the upper and lower bounds for available aircraft, Z_{ik}. First, (15) establishes available aircraft, Z_{ik}, is less than or equal to the amount of available airframes and then (16) ensures available aircraft, Z_{ik}, is less than or equal to the amount of available engines. Constraint (17) establishes a minimum for available aircraft by ensuring aircraft availability is greater than the user defined parameter h_{i1}. Constraint (18) is a non-negativity constraint for the on-hand stock of engines, s_{ik}. The final two constraints (19 and 20) ensure all production tasks completed, X_{ijk}, and available aircraft, Z_{ik}, are integers, respectively. Forcing production tasks completed to be integers will result in production tasks deferred, Y_{ijk}, also being integers without explicitly requiring it.

V. METHODOLOGY

Overview

An initial goal of the research was to develop a prototype tool that utilized the RAND model so that programmers could use it as a decision support tool. However, as the research effort progressed, it became apparent that implementing the RAND model with the provided WSS data and from the other sources as outlined in previous chapters is premature. This was due to limitations with the WSS data itself. As explained in prior chapters, the WSS data was significantly manipulated to allow the models to run. However, due to a major assumption made while manipulating the data, the output from the models are not sufficiently reliable for making actual programming decisions. The major assumption referred to is the elimination of production tasks that do not have a quantity associated with them. It is reasonable to believe that each production task is a valid requirement, but without assigned quantities, the tasks cannot be evaluated by the models. That said, the details of the development of the Excel and LINGO components are included in this chapter, along with an explanation of how a user would process the models given both the Excel and Lingo components.

LINGO Component

The LINGO component was developed in three phases. The first phase was the development of the LINGO code for use with notional sets and data. The notional sets data were included within the LINGO files. Initial code was developed and tested for each of the three models. The LINGO code for each of the model is included in Appendix A. The second phase tested the link between Excel and LINGO. For the

LINGO component, the data from the LINGO file was removed and placed within an Excel file to ensure that the data could be pulled into LINGO and processed from Excel. The resulting LINGO output from the second phase was then compared to that of the first phase to ensure consistency between the two methods. The final phase was utilizing the WSS data Excel files with the LINGO models. The final code for these LINGO models is in Appendix B.

Excel Component

The Excel component consists of an Excel workbook with six spreadsheets. The first three sheets contain all of the parameter data necessary for the models. The first sheet, labeled "Production_Tasks", contains all of the production task data. It was created from the WSS data and includes all of the parameters that cross all three indices. It was sorted by "Aircraft", Task Rqmt ID", and "Year" to be properly read by the LINGO models. Table 2 below is a copy of a section of the Production Tasks sheet.

Table 2, Production_Tasks Spreadsheet

Year	Aircraft	Task Rqmt ID	Task Rqmt	Quantity Required	Cost per Rqmt ($K)	Maximum Deferred	Extra Deferral Cost Rate	Prod Cap Util Rate
2012	A-10	1	AAEEPH_AFMC	2	$2,176.50	0.50	0.15	0.85
2013	A-10	1	AAEEPH_AFMC	2	$2,222.21	0.50	0.15	0.85
2014	A-10	1	AAEEPH_AFMC	2	$2,268.87	0.50	0.15	0.85
2015	A-10	1	AAEEPH_AFMC	2	$2,316.52	0.50	0.15	0.85
2016	A-10	1	AAEEPH_AFMC	2	$2,365.17	0.50	0.15	0.85
2012	A-10	2	AAEEPI_AFMC	3	$256.44	0.50	0.15	0.85
2013	A-10	2	AAEEPI_AFMC	2	$261.83	0.50	0.15	0.85
2014	A-10	2	AAEEPI_AFMC	3	$267.33	0.50	0.15	0.85
2015	A-10	2	AAEEPI_AFMC	5	$272.94	0.50	0.15	0.85
2016	A-10	2	AAEEPI_AFMC	7	$278.67	0.50	0.15	0.85
2012	A-10	3	AAEEPJ_AFMC	3	$862.89	0.50	0.15	0.85
2013	A-10	3	AAEEPJ_AFMC	2	$881.01	0.50	0.15	0.85
2014	A-10	3	AAEEPJ_AFMC	3	$899.51	0.50	0.15	0.85
2015	A-10	3	AAEEPJ_AFMC	2	$918.40	0.50	0.15	0.85
2016	A-10	3	AAEEPJ_AFMC	2	$937.69	0.50	0.15	0.85
2012	A-10	4	AAEEPT_AFMC	3	$134.22	0.50	0.15	0.85
2013	A-10	4	AAEEPT_AFMC	3	$137.04	0.50	0.15	0.85
2014	A-10	4	AAEEPT_AFMC	3	$139.92	0.50	0.15	0.85

The second sheet, named "Yearly_Parameters", contains all of the parameter data that utilize the aircraft and year indices. It was sorted by "Aircraft" and "Year" and read in by the LINGO models. Table 3 shows a section of the Yearly Tasks sheet. The third sheet is titled “Universal_Parameters” and contains all of the remaining parameters. Table 4 below illustrates this data. Ranges were named on all three sheets to facilitate the transfer of data from Excel to LINGO and then back to Excel.

Table 3, Yearly_Parameters Spreadsheet

Year	Aircraft	Min A/C Availability	Mission Capability Goal	A/C Weighting Factor	On-hand Engine Stock	PAI	TAI
2012	A-10	0.70	0.95	1.00	746	310	345
2013	A-10	0.70	0.95	1.00	746	282	294
2014	A-10	0.70	0.95	1.00	746	243	283
2015	A-10	0.70	0.95	1.00	746	150	173
2016	A-10	0.70	0.95	1.00	746	102	119
2012	B-1	0.70	0.95	1.00	351	53	65
2013	B-1	0.70	0.95	1.00	351	53	63
2014	B-1	0.70	0.95	1.00	351	53	63
2015	B-1	0.70	0.95	1.00	351	52	62
2016	B-1	0.70	0.95	1.00	351	51	61
2012	B-2	0.70	0.95	1.00	109	16	20
2013	B-2	0.70	0.95	1.00	109	16	20
2014	B-2	0.70	0.95	1.00	109	16	20
2015	B-2	0.70	0.95	1.00	109	16	20

Table 4, Universal Parameter Data

Aircraft	BPOS Engines	War Reserve Engines
A-10	44	0
B-1	63	23
B-2	14	2
B-52	51	13
C-130	50	30
C-5	101	21
E-3	36	10
E-8	12	0
F-15	50	30
F-16	50	30
HH-60	76	55
KC/C-135	81	33
KC-10	27	27
RC/OC-135	18	4
UH-1	34	5

Parameters	
Parametric Weighting Factor	1
FYDP Years	5

Years	Budget ($K)
2012	$443,850
2013	$460,111
2014	$455,157
2015	$460,737
2016	$517,686

The final three sheets in the workbook contain the processed data from each of the three models. The sheets are named “RAND_Model”, “Modified_Model”, and “Minimization_Model” respectively. Each of the sheets has their respective LINGO model embedded within it. The models are processed from within Excel by activating the embedded LINGO code and solving the model. After the model processes, the spreadsheet updates with the solution. The data is transferred between Excel and LINGO and then back to Excel using object linking and embedding (OLE) functions.

Testing Results

RAND Model:

Table 5, RAND Model – Available Aircraft

Available Aircraft					
Aicraft	**2012**	**2013**	**2014**	**2015**	**2016**
A-10	310	310	310	310	310
B-1	53	53	53	53	53
B-2	16	16	16	16	16
B-52	63	63	63	63	63
C-130	312	312	312	312	312
C-5	70	70	70	70	70
E-3	28	28	28	28	28
E-8	14	14	14	14	14
F-15	409	409	409	409	409
F-16	911	911	911	911	911
HH-60	85	85	85	85	85
KC/C-135	377	377	377	377	377
KC-10	51	51	51	51	51
RC/OC-135	19	19	19	19	19
UH-1	63	63	63	63	63

Table 6, RAND Model - Budget Info

Budget Information		
Year	**Spent**	**Budget**
2012	$ 493,003,747	$ 493,166,881
2013	$ 491,662,896	$ 511,234,678
2014	$ 486,530,450	$ 505,729,489
2015	$ 443,980,792	$ 511,930,029
2016	$ 555,842,242	$ 575,206,993

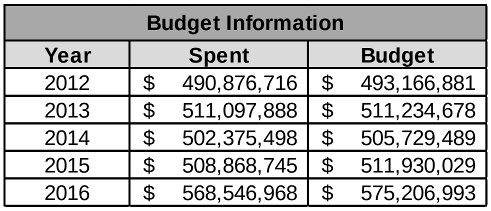
The RAND Model results have some errors due to some of the problems noted previously. What is immediately apparent in looking at the available aircraft results is that the available aircraft is the same for each of the years. This is caused by one of the constraints using the primary aircraft inventory from the first year in each of the following years as well. The model does a fairly good job expending available resources in FY12 as it allocated nearly 100% of the budget, but does nearly reach this same level of utilization for future years. This is interesting considering this model resulted in many deferrals. The complete productions task results for each of the models can be viewed in Appendix C.

Modified Model:

Table 7, Modified Model – Available Aircraft

Available Aircraft					
Aicraft	**2012**	**2013**	**2014**	**2015**	**2016**
A-10	310	282	243	150	102
B-1	53	53	53	52	51
B-2	16	16	16	16	16
B-52	63	63	63	63	63
C-130	312	307	290	269	270
C-5	70	54	50	50	50
E-3	28	27	27	22	22
E-8	14	14	14	14	10
F-15	408	470	402	356	356
F-16	911	923	818	818	818
HH-60	85	85	27	27	27
KC/C-135	377	375	307	313	321
KC-10	51	51	14	14	14
RC/OC-135	19	19	17	17	17
UH-1	63	56	51	54	54

Table 8, Modified Model - Budget Info



Budget Information		
Year	**Spent**	**Budget**
2012	$ 490,876,716	$ 493,166,881
2013	$ 511,097,888	$ 511,234,678
2014	$ 502,375,498	$ 505,729,489
2015	$ 508,868,745	$ 511,930,029
2016	$ 568,546,968	$ 575,206,993

The results from the modified model have available aircraft based on different primary aircraft inventories unlike the RAND model results in Table 4. The modified model also does a much better job at utilizing the available budgets across the planning horizon, as the lowest resource utilization rate was still 98.8% (in 2016). Aircraft and engine inventory parameters are preventing the model from full resource utilization.

Minimization Model:

Table 9, Minimization Model – Available Aircraft

Available Aircraft					
Aicraft	**2012**	**2013**	**2014**	**2015**	**2016**
A-10	306	280	243	150	102
B-1	47	51	53	52	51
B-2	12	16	16	12	16
B-52	49	43	45	43	43
C-130	288	283	278	249	255
C-5	63	44	38	38	35
E-3	20	19	18	14	17
E-8	10	12	14	14	10
F-15	391	456	396	352	351
F-16	893	909	800	806	808
HH-60	82	81	18	27	22
KC/C-135	359	361	277	305	301
KC-10	46	43	11	10	14
RC/OC-135	18	19	17	17	17
UH-1	59	52	51	54	54

Table 10, Minimization Model – Budget Info

Budget Information		
Year	**Spent**	**Budget**
2012	$ 348,982,728	$ 493,166,881
2013	$ 479,773,483	$ 511,234,678
2014	$ 492,218,684	$ 505,729,489
2015	$ 503,259,402	$ 511,930,029
2016	$ 563,440,768	$ 575,206,993

The minimization model results in fewer available aircraft than the previous two models. The magnitude of this difference is relatively small, but that is due to the quantities within the task requirements being small when compared to the primary aircraft inventory. Even though this model minimizes cost, there are still several constraints that limit the amount of deferrals. Production tasks can essentially only be cut in a single year because they must be completed the following year if deferred, there are production limits for every task, and available aircraft must still meet the mission-capability goal. This is reflected in the amount spent each year. There are significant savings in FY12, but a much greater percentage of the budget is spent in following years.

VI. CONCLUSIONS AND RECOMMENDATIONS

Overview

The utility of mathematical models linking resources to operational capabilities is very well founded. Optimization models have the ability to provide a great deal of information to programmers and decision makers when recommending how to best utilize funding, particularly with budgets shrinking across the federal government. Both this and the RAND research identified several issues that make using any of the models proposed research problematic at this time. There are limitations with the actual models, but even more so with the data used to process them.

Model Limitations

The RAND model to maximize operational capability does not accurately calculate the number of aircraft available. To determine the amount of available aircraft, the model must determine the aircraft-production task combination with the greatest number of deferrals. Instead of identifying the necessary pairing, the model ends up with a coupling of aircraft and first production task. The model also does not adequately ensure that aircraft will not exceed available engines. The result is an overestimation of available aircraft. Both the modified model to maximize operational capability and the model to minimize costs attempt to build on what RAND developed while eliminating the issues with the formulation. A potential issue within all of the models is that they assume no deferrals in the year before the planning horizon. More problematic than any issues with the actual models is with the data used to process the models.

Real-World Applicability

In manipulating the data for use with the models, there was a necessary assumption made to use the WSS data. The assumption involved discarding task production requirements without a quantity required. This was necessary because the quantity required is a necessary parameter for the models. However, this is highly problematic since only 230 of a total 1,220 task requirements had a quantity required associated with them. If it is assumed that all of the task requirements are valid, then data manipulation eliminated 81% of all valid task requirements before they could be evaluated.

The aircraft and engine inventory data used are also a concern. The aircraft inventory data is more specific than the aircraft identified in the WSS data. For example, the WSS data has requirements for the F-16, but the aircraft inventory further divides the F-16 into A-16A, F-16B, F-16C, and F-16D. That issue could probably be addressed in a number of ways, but engine inventory data concerns are more complicated. The models all assume there is one engine per aircraft. However, several aircraft require multiple engines such as the B-52, which uses eight, and the E-3, which uses four. The result is that the constraint ensuring there are available engines is not nearly as restrictive as it should be. Another issue is that engines are not necessarily unique to a particular weapon system. There are multiple engines that are used by more than one aircraft. There are also aircraft that use more than one specific engine. The result is that there is currently no way to pair aircraft in the WSS data to engine inventory data. Finally, while aircraft inventory data is available for current and future years, engine data is not, at least not in

LIMS-EV. It would seem that if aircraft inventories are allowed to change, then so should engine inventories. However, all that is currently available is present stocks of engines. Using the quantity of engines available today as a constraint potentially five years in the future does not seem wise.

Opportunities for Extension of Research

Assuming the data issues addressed above are corrected, there are several avenues available for future research. This research effort only evaluated aircraft, yet there are other weapon systems that fall under DPEM that could be evaluated. Models could also be developed for the entirety of the task requirements within the WSS data, not just those that are DPEM requirements. RAND discusses, but does not provide, a robust optimization solution for this model. A robust optimization model provides solutions given uncertainty, which is often the case with budgetary programming. Finally, looking outside the immediate scope of this thesis, there are opportunities to maximize operational capability in any number of program areas.

Conclusion

There are msny opportunities to use optimization to assist in making better decisions across the entire Air Force enterprise. RAND Project Air Force's effort to develop a linear program for DPEM is a great step in that direction. There are some problems with their formulation, but even formulations that have those problems addressed would be extremely limited in providing useful information to programmers and decision makers. The sources of data used by the models in this research are not reliable enough to provide beneficial results. However, this is an area of research that can provide tremendous benefits in the future, particularly in an increasingly constrained fiscal environment.

Appendix A – Initial LINGO Code with Notional Data by Model

RAND Formulation to Maximize Operational Capability

```
SETS:
      AC/ B52 C130 C17/: BPOS, WRE;
      PT/ A B C/;
      YR/ 13 14/: BUD, T;
      AC_YR( AC, YR): MAA, MCG, OES, PAI, TAI, WF, Z, MAX_Y;
      AC_PT_YR( AC, PT, YR): CST, P_RQ, P_RQ_MD, DTC, UFPC, X, Y;
ENDSETS

DATA:
      BPOS = 5    5    5;
      WRE =  5    5    5;
      BUD = 1400000 1540000; ! 100% funding is 1600000 and 1740000;
      MAA = .75 .75  .75  .75   .75  .75;
      MCG =  1   .9 .975    1    .9 .975;
      OES = 25   70   60   25    70   60;
      PAI = 25   70   60   25    70   60;
      TAI = 30   75   60   30    75   60;
      WF =  .8    1   .6   .8     1   .6;
      CST = 18000 15000 12000 14000 8000 7500 11000 2000 1000 12000
            11000 10000 5000 4000 6000 7500 8000 15000;
      DTC = .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1;
      P_RQ = 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20;
      P_RQ_MD = .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5;
      UFPC = .93 .93 .85 .93 .93 .93 .93 .93 .93 .93 .93 .93 .93 .93
             .93 .93 .93 .93;
      PWF =       1;
      FYDP_YRS =  2;
      E =        .5;
ENDDATA

MAX = (1/FYDP_YRS) * (@SUM(AC_YR(I,K): ((WF(I,1) / @SUM(AC_YR(I,K):
WF(I,1)))) * ((MCG(I,1) * Z) / TAI))) - (PWF * V);

@FOR(AC_PT_YR(I,J,K): DTC > 0);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD > 0);
@FOR(AC_PT_YR(I,J,K): UFPC > 0);
@FOR(AC_YR(I,K): MAA > 0);
@FOR(AC_PT_YR(I,J,K): DTC < 1);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD < 1);
@FOR(AC_PT_YR(I,J,K): UFPC < 1);
@FOR(AC_YR(I,K): MAA < 1);
! Ensures fractional parameters are between 0 and 1;

@FOR(YR(K): T = @SUM(AC_PT_YR(I,J,K): CST * (X + DTC * Y)));
! Produces values for the total spent each year;

@FOR(YR(K): BUD > T);
! Ensures the amount spent in year k is less than the available budget
   that year;
```

```
@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X < P_RQ / UFPC);
! Ensures production does not exceed capacity;

@FOR(AC_PT_YR(I,J,K): X > 0);
! Ensures aircraft production is non negative;

@FOR(AC_PT_YR(I,J,K): Y > 0);
! Ensures aircraft deferrals are non negative;

@FOR(AC_PT_YR(I,J,K): Y(I,J,K) = @SUM(AC_PT_YR(I,J,L)| L #LE# K :
P_RQ(I,J,L) - X(I,J,L)));
! Ensures deferrals for year k are equal to sum of the differences
between the production requirement, P_RQ, and actual production, X, in
year k and each year prior. Serves as a linking constraint;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X(I,J,K) > Y(I,J,K-1));
! Ensures the production in year k is greater than or equal to
deferrals from year k-1;

@FOR(AC_PT_YR(I,J,K): Y < P_RQ * P_RQ_MD);
! Ensures the amount of deferrals are less than the maximum allowed;

@FOR(AC_YR(I,K): Z < PAI(I,1) - Y(I,1,K));
! Ensures available aircraft does not exceed primary aircraft inventory
minus deferred aircraft;

@FOR(AC_YR(I,K): Z < ((OES(I,2) - Y(I,2,K)) * PAI(I,1)) / (BPOS +
WRE));
! Ensures available aircraft does not exceed available engines;

@FOR(AC_PT_YR(I,J,K): P_RQ * V < P_RQ - X);
! Along with the objective function, ensures that V is the maximum
fractional production demand shortfall;

@FOR(AC_YR(I,K): MCG(I,1) * Z / TAI(I,1) > MAA);
! Ensures aircraft availability is greater than user than the mission-
capability goal;

@FOR(AC_YR(I,K): OES > 0);
! Ensures on-hand engine stock is non-negative;

V > 0;
! Ensures maximum fractional production demand shortfall is non-
negative;
```

Modified Formulation to Maximize Operational Capability

```
SETS:
      AC/ B52 C130 C17/: BPOS, WRE;
      PT/ A B C/;
      YR/ 13 14/: BUD, T;
      AC_YR( AC, YR): MAA, MCG, OES, PAI, TAI, WF, Z, MAX_Y;
      AC_PT_YR( AC, PT, YR): CST, P_RQ, P_RQ_MD, DTC, UFPC, X, Y;
ENDSETS

DATA:
      BPOS = 5    5    5;
      WRE =  5    5    5;
      BUD =  1230000 1370000; ! 100% funding is 1600000 and 1740000;
      MAA = .75 .75  .75  .75   .75  .75;
      MCG =  1   .9 .975    1    .9 .975;
      OES = 25   70   60   25    70   60;
      PAI = 25   70   60   25    70   60;
      TAI = 30   75   60   30    75   60;
      WF =  .8    1   .6   .8     1   .6;
      CST = 18000 15000 12000 14000 8000 7500 11000 2000 1000
      12000 11000 10000 5000 4000 6000 7500 8000 15000;
      DTC = .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1;
      P_RQ = 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20;
      P_RQ_MD = .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5;
      UFPC = .93 .93 .85 .93 .93 .93 .93 .93 .93 .93 .93 .93 .93 .93
      .93 .93 .93 .93;
      PWF = 1;
      FYDP_YRS = 2;
      E = .5;
ENDDATA

MAX = (@SUM(AC_YR(I,K): ((WF / @SUM(AC_YR(I,K): WF))) * ((MCG * Z) /
TAI))) - (PWF * V);

@FOR(AC_PT_YR(I,J,K): DTC > 0);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD > 0);
@FOR(AC_PT_YR(I,J,K): UFPC > 0);
@FOR(AC_YR(I,K):      MAA > 0);
@FOR(AC_YR(I,K):      MCG > 0);
@FOR(AC_PT_YR(I,J,K): DTC < 1);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD < 1);
@FOR(AC_PT_YR(I,J,K): UFPC < 1);
@FOR(AC_YR(I,K):      MAA < 1);
@FOR(AC_YR(I,K):      MCG < 1);
! Ensures fractional parameters are between 0 and 1;

@FOR(YR(K): T = @SUM(AC_PT_YR(I,J,K): CST * (X + DTC * Y)));
! Calculates the total cost in year k;

@FOR(YR(K): BUD > T);
! Ensures the amount spent in year k is less than the available budget
   that year;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X < P_RQ / UFPC);
```

```
! Ensures production does not exceed capacity;

@FOR(AC_PT_YR(I,J,K): X > 0);
! Ensures aircraft production is non negative;

@FOR(AC_PT_YR(I,J,K): Y > 0);
! Ensures aircraft deferrals are non negative;

@FOR(AC_PT_YR(I,J,K): Y(I,J,K) = @SUM(AC_PT_YR(I,J,L)| L #LE# K :
P_RQ(I,J,K) - X(I,J,K)));
! Ensures deferrals for year k are equal to sum of the differences
between the production requirement, P_RQ, and actual production, X, in
year k and each year prior. Serves as a linking constraint;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X > Y(I,J,K-1));
! Ensures the production in year k is greater than or equal to
deferrals from year k-1;

@FOR(AC_PT_YR(I,J,K): Y < P_RQ * P_RQ_MD);
! Ensures the amount of deferrals are less than the maximum allowed;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < PAI(I,K) - Y);
! Ensures available aircraft does not exceed primary aircraft inventory
minus deferred aircraft;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < ((OES(I,K) - ENG_RQ(I) * Y) * PAI(I,K))
/ (BPOS(I) + WRE(I)));
! Ensures available aircraft does not exceed available engines;

@FOR(AC_PT_YR(I,J,K): P_RQ * V < P_RQ - X);
! Along with the objective function, ensures that V is the maximum
fractional production demand shortfall;

@FOR(AC_YR(I,K): MCG * Z / TAI > MAA);
! Ensures aircraft availability is greater than the mission-capability
goal;

@FOR(AC_YR(I,K): OES > 0);
! Ensures on-hand engine stock is non-negative;

V > 0;
! Ensures maximum fractional production demand shortfall is non-
negative;

@FOR(AC_PT_YR(I,J,K): @GIN(X));
! Ensures aircraft production are integers;

@FOR(AC_PT_YR(I,J,K): @GIN(Z));
! Ensures available aircraft are integers;
```

Formulation to Minimize Cost

```
SETS:
      AC/ B52 C130 C17/: BPOS, WRE;
      PT/ A B C/;
      YR/ 13 14/: T;
      AC_YR( AC, YR): MAA, MCG, OES, PAI, TAI, WF, Z, MAX_Y;
      AC_PT_YR( AC, PT, YR): CST, P_RQ, P_RQ_MD, DTC, UFPC, X, Y;
ENDSETS

DATA:
      BPOS =  5    5    5;
      WRE =   5    5    5;
      MAA = .75 .75  .75  .75   .75  .75;
      MCG =  1   .9 .975    1    .9 .975;
      OES = 25   70   60   25    70   60;
      PAI = 25   70   60   25    70   60;
      TAI = 30   75   60   30    75   60;
      WF =  .8    1   .6   .8     1   .6;
      CST = 18000 15000 12000 14000 8000 7500 11000 2000 1000 12000
      11000 10000 5000 4000 6000 7500 8000 15000;
      DTC = .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1 .1;
      P_RQ = 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20;
      P_RQ_MD = .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5 .5;
      UFPC = .93 .93 .85 .93 .93 .93 .93 .93 .93 .93 .93 .93 .93 .93
      .93 .93 .93 .93;
ENDDATA

MIN = @SUM(YR(K): T) - @SUM(AC_YR(I,K): Z);

@FOR(AC_PT_YR(I,J,K): DTC > 0);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD > 0);
@FOR(AC_PT_YR(I,J,K): UFPC > 0);
@FOR(AC_YR(I,K):      MAA > 0);
@FOR(AC_YR(I,K):      MCG > 0);
@FOR(AC_PT_YR(I,J,K): DTC < 1);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD < 1);
@FOR(AC_PT_YR(I,J,K): UFPC < 1);
@FOR(AC_YR(I,K):      MAA < 1);
@FOR(AC_YR(I,K):      MCG < 1);
! Ensures fractional parameters are between 0 and 1;

@FOR(YR(K): T = @SUM(AC_PT_YR(I,J,K): CST * (X + DTC * Y)));
! Calculates the total cost in year k;

@FOR(YR(K): BUD > T);
! Ensures the amount spent in year k is less than the available budget
   that year;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X < P_RQ / UFPC);
! Ensures production does not exceed capacity;

@FOR(AC_PT_YR(I,J,K): X > 0);
! Ensures aircraft production is non negative;
```

```
@FOR(AC_PT_YR(I,J,K): Y > 0);
! Ensures aircraft deferrals are non negative;

@FOR(AC_PT_YR(I,J,K): Y(I,J,K) = @SUM(AC_PT_YR(I,J,L)| L #LE# K :
P_RQ(I,J,K) - X(I,J,K)));
! Ensures deferrals for year k are equal to sum of the differences
between the production requirement, P_RQ,
and actual production, X, in year k and each year prior. Serves as a
linking constraint;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X > Y(I,J,K-1));
! Ensures the production in year k is greater than or equal to
deferrals from year k-1;

@FOR(AC_PT_YR(I,J,K): Y < P_RQ * P_RQ_MD);
! Ensures the amount of deferrals are less than the maximum allowed;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < PAI(I,K) - Y);
! Ensures available aircraft does not exceed primary aircraft inventory
minus deferred aircraft;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < ((OES(I,K) - ENG_RQ(I) * Y) * PAI(I,K))
/ (BPOS(I) + WRE(I)));
! Ensures available aircraft does not exceed available engines;

@FOR(AC_YR(I,K): MCG * Z / TAI > MAA);
! Ensures aircraft availability is greater than the mission-capability
goal;

@FOR(AC_YR(I,K): OES > 0);
! Ensures on-hand engine stock is non-negative;

@FOR(AC_PT_YR(I,J,K): @GIN(X));
! Ensures aircraft production are integers;

@FOR(AC_PT_YR(I,J,K): @GIN(Z));
! Ensures available aircraft are integers;
```

Appendix B –Final LINGO Code by Model

RAND Formulation to Maximize Operational Capability

```
SETS:
      AC: BPOS, WRE;
      PT;
      YR: BUD, T;
      AC_YR( AC, YR): MAA, MCG, OES, PAI, TAI, WF,Z;
      AC_PT_YR( AC, PT, YR): CST, P_RQ, P_RQ_MD, DTC, UFPC, X, Y;
ENDSETS

DATA:
      AC, PT, YR, BPOS, WRE, BUD, MAA, MCG, OES, PAI, TAI, WF, CST,
       DTC, P_RQ, P_RQ_MD, UFPC, PWF, FYDP_YRS =
        @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model Data.XLSX',
         'AC', 'PT', 'YR', 'BPOS', 'WRE', 'BUD', 'MAA', 'MCG', 'OES',
          'PAI', 'TAI', 'WF', 'CST', 'DTC', 'P_RQ', 'P_RQ_MD', 'UFPC',
           'PWF', 'FYDP_YRS');
      @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model
       Data.XLSX','X_RAND','Y_RAND','Z_RAND','T_RAND') = X, Y, Z, T;
ENDDATA

SETS:
      AC: BPOS, WRE;
      PT;
      YR: BUD, T;
      AC_YR( AC, YR): MAA, MCG, OES, PAI, TAI, WF,Z;
      AC_PT_YR( AC, PT, YR): CST, P_RQ, P_RQ_MD, DTC, UFPC, X, Y;
ENDSETS

DATA:
      AC, PT, YR, BPOS, WRE, BUD, MAA, MCG, OES, PAI, TAI, WF, CST,
       DTC, P_RQ, P_RQ_MD, UFPC, PWF, FYDP_YRS =
        @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model Data.XLSX',
         'AC', 'PT', 'YR', 'BPOS', 'WRE', 'BUD', 'MAA', 'MCG', 'OES',
          'PAI', 'TAI', 'WF', 'CST', 'DTC', 'P_RQ',   'P_RQ_MD',
           'UFPC', 'PWF', 'FYDP_YRS');
      @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model
       Data.XLSX','X_RAND','Y_RAND','Z_RAND','T_RAND') = X, Y, Z, T;
ENDDATA

MAX = (1/FYDP_YRS) * (@SUM(AC_YR(I,K): ((WF(I,1) / @SUM(AC_YR(I,K):
WF(I,1)))) * ((MCG(I,1) * Z) / TAI))) - (PWF * V);

@FOR(AC_PT_YR(I,J,K): DTC > 0);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD > 0);
@FOR(AC_PT_YR(I,J,K): UFPC > 0);
@FOR(AC_YR(I,K): MAA > 0);
@FOR(AC_PT_YR(I,J,K): DTC < 1);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD < 1);
@FOR(AC_PT_YR(I,J,K): UFPC < 1);
@FOR(AC_YR(I,K): MAA < 1);
! Ensures fractional parameters are between 0 and 1;
```

```
@FOR(YR(K): T = @SUM(AC_PT_YR(I,J,K): CST * (X + DTC * Y)));
! Produces values for the total spent each year;

@FOR(YR(K): BUD > T);
! Ensures the amount spent in year k is less than the available budget
   that year;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X < P_RQ / UFPC);
! Ensures production does not exceed capacity;

@FOR(AC_PT_YR(I,J,K): X > 0);
! Ensures aircraft production is non negative;

@FOR(AC_PT_YR(I,J,K): Y > 0);
! Ensures aircraft deferrals are non negative;

@FOR(AC_PT_YR(I,J,K): Y(I,J,K) = @SUM(AC_PT_YR(I,J,L)| L #LE# K :
P_RQ(I,J,L) - X(I,J,L)));
! Ensures deferrals for year k are equal to sum of the differences
between the production requirement, P_RQ, and actual production, X, in
year k and each year prior. Serves as a linking constraint;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X(I,J,K) > Y(I,J,K-1));
! Ensures the production in year k is greater than or equal to
deferrals from year k-1;

@FOR(AC_PT_YR(I,J,K): Y < P_RQ * P_RQ_MD);
! Ensures the amount of deferrals are less than the maximum allowed;

@FOR(AC_YR(I,K): Z < PAI(I,1) - Y(I,1,K));
! Ensures available aircraft does not exceed primary aircraft inventory
minus deferred aircraft;

@FOR(AC_YR(I,K): Z < ((OES(I,2) - Y(I,2,K)) * PAI(I,1)) / (BPOS +
WRE));
! Ensures available aircraft does not exceed available engines;

@FOR(AC_PT_YR(I,J,K): P_RQ * V < P_RQ - X);
! Along with the objective function, ensures that V is the maximum
fractional production demand shortfall;

@FOR(AC_YR(I,K): MCG(I,1) * Z / TAI(I,1) > MAA);
! Ensures aircraft availability is greater than user than the mission-
capability goal;

@FOR(AC_YR(I,K): OES > 0);
! Ensures on-hand engine stock is non-negative;

V > 0;
! Ensures maximum fractional production demand shortfall is non-
negative;
```

Modified Formulation to Maximize Operational Capability

```
SETS:
      AC: BPOS, WRE, ENG_RQ;
      PT;
      YR: BUD, T;
      AC_YR( AC, YR): MAA, MCG, OES, PAI, TAI, WF,Z;
      AC_PT_YR( AC, PT, YR): CST, P_RQ, P_RQ_MD, DTC, UFPC, X, Y;
ENDSETS

DATA:
      AC, PT, YR, BPOS, WRE, ENG_RQ, BUD, MAA, MCG, OES, PAI, TAI, WF,
       CST, DTC, P_RQ, P_RQ_MD, UFPC, PWF =
        @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model Data.XLSX',
         'AC', 'PT', 'YR', 'BPOS', 'WRE', 'ENG_RQ', 'BUD', 'MAA',
          'MCG', 'OES', 'PAI', 'TAI', 'WF', 'CST', 'DTC', 'P_RQ',
           'P_RQ_MD', 'UFPC', 'PWF');
       @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model
        Data.XLSX','X_MOD','Y_MOD','Z_MOD','T_MOD') = X, Y, Z, T;
ENDDATA

MAX = (@SUM(AC_YR(I,K): ((WF / @SUM(AC_YR(I,K): WF))) * ((MCG * Z) /
TAI))) - (PWF * V);

@FOR(AC_PT_YR(I,J,K): DTC > 0);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD > 0);
@FOR(AC_PT_YR(I,J,K): UFPC > 0);
@FOR(AC_YR(I,K):      MAA > 0);
@FOR(AC_YR(I,K):      MCG > 0);
@FOR(AC_PT_YR(I,J,K): DTC < 1);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD < 1);
@FOR(AC_PT_YR(I,J,K): UFPC < 1);
@FOR(AC_YR(I,K):      MAA < 1);
@FOR(AC_YR(I,K):      MCG < 1);
! Ensures fractional parameters are between 0 and 1;

@FOR(YR(K): T = @SUM(AC_PT_YR(I,J,K): CST * (X + DTC * Y)));
! Calculates the total cost in year k;

@FOR(YR(K): BUD > T);
! Ensures the amount spent in year k is less than the available budget
   that year;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X < P_RQ / UFPC);
! Ensures production does not exceed capacity;

@FOR(AC_PT_YR(I,J,K): X > 0);
! Ensures aircraft production is non negative;

@FOR(AC_PT_YR(I,J,K): Y > 0);
! Ensures aircraft deferrals are non negative;

@FOR(AC_PT_YR(I,J,K): Y(I,J,K) = @SUM(AC_PT_YR(I,J,L)| L #LE# K :
P_RQ(I,J,K) - X(I,J,K)));
```

```
! Ensures deferrals for year k are equal to sum of the differences
between the production requirement, P_RQ, and actual production, X, in
year k and each year prior. Serves as a linking constraint;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X > Y(I,J,K-1));
! Ensures the production in year k is greater than or equal to
deferrals from year k-1;

@FOR(AC_PT_YR(I,J,K): Y < P_RQ * P_RQ_MD);
! Ensures the amount of deferrals are less than the maximum allowed;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < PAI(I,K) - Y);
! Ensures available aircraft does not exceed primary aircraft inventory
minus deferred aircraft;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < ((OES(I,K) - ENG_RQ(I) * Y) * PAI(I,K))
/ (BPOS(I) + WRE(I)));
! Ensures available aircraft does not exceed available engines;

@FOR(AC_PT_YR(I,J,K): P_RQ * V < P_RQ - X);
! Along with the objective function, ensures that V is the maximum
fractional production demand shortfall;

@FOR(AC_YR(I,K): MCG * Z / TAI > MAA);
! Ensures aircraft availability is greater than the mission-capability
goal;

@FOR(AC_YR(I,K): OES > 0);
! Ensures on-hand engine stock is non-negative;

V > 0;
! Ensures maximum fractional production demand shortfall is non-
negative;

@FOR(AC_PT_YR(I,J,K): @GIN(X));
! Ensures aircraft production are integers;

@FOR(AC_PT_YR(I,J,K): @GIN(Z));
! Ensures available aircraft are integers;
```

Formulation to Minimize Cost

```
SETS:
      AC: BPOS, WRE, ENG_RQ;
      PT;
      YR: BUD, T;
      AC_YR( AC, YR): MAA, MCG, OES, PAI, TAI, WF,Z;
      AC_PT_YR( AC, PT, YR): CST, P_RQ, P_RQ_MD, DTC, UFPC, X, Y;
ENDSETS

DATA:
      AC, PT, YR, BPOS, WRE, ENG_RQ, BUD, MAA, MCG, OES, PAI, TAI, WF,
       CST, DTC, P_RQ, P_RQ_MD, UFPC, PWF =
        @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model Data.XLSX',
         'AC', 'PT', 'YR', 'BPOS', 'WRE', 'ENG_RQ', 'BUD', 'MAA',
          'MCG', 'OES', 'PAI', 'TAI', 'WF', 'CST', 'DTC', 'P_RQ',
           'P_RQ_MD', 'UFPC', 'PWF');
       @OLE('\Users\Rhoads\Documents\Jimmy\Thesis\Model
        Data.XLSX','X_MIN','Y_MIN','Z_MIN','T_MIN') = X, Y, Z, T;
ENDDATA

MIN = @SUM(YR(K): T) - @SUM(AC_YR(I,K): Z);

@FOR(AC_PT_YR(I,J,K): DTC > 0);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD > 0);
@FOR(AC_PT_YR(I,J,K): UFPC > 0);
@FOR(AC_YR(I,K):      MAA > 0);
@FOR(AC_YR(I,K):      MCG > 0);
@FOR(AC_PT_YR(I,J,K): DTC < 1);
@FOR(AC_PT_YR(I,J,K): P_RQ_MD < 1);
@FOR(AC_PT_YR(I,J,K): UFPC < 1);
@FOR(AC_YR(I,K):      MAA < 1);
@FOR(AC_YR(I,K):      MCG < 1);
! Ensures fractional parameters are between 0 and 1;

@FOR(YR(K): T = @SUM(AC_PT_YR(I,J,K): CST * (X + DTC * Y)));
! Calculates the total cost in year k;

@FOR(YR(K): BUD > T);
! Ensures the amount spent in year k is less than the available budget
   that year;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X < P_RQ / UFPC);
! Ensures production does not exceed capacity;

@FOR(AC_PT_YR(I,J,K): X > 0);
! Ensures aircraft production is non negative;

@FOR(AC_PT_YR(I,J,K): Y > 0);
! Ensures aircraft deferrals are non negative;

@FOR(AC_PT_YR(I,J,K): Y(I,J,K) = @SUM(AC_PT_YR(I,J,L)| L #LE# K :
P_RQ(I,J,K) - X(I,J,K)));
! Ensures deferrals for year k are equal to sum of the differences
between the production requirement, P_RQ,
```

```
and actual production, X, in year k and each year prior. Serves as a
linking constraint;

@FOR(AC_PT_YR(I,J,K)| K #GT# 1: X > Y(I,J,K-1));
! Ensures the production in year k is greater than or equal to
deferrals from year k-1;

@FOR(AC_PT_YR(I,J,K): Y < P_RQ * P_RQ_MD);
! Ensures the amount of deferrals are less than the maximum allowed;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < PAI(I,K) - Y);
! Ensures available aircraft does not exceed primary aircraft inventory
minus deferred aircraft;

@FOR(AC_PT_YR(I,J,K): Z(I,K) < ((OES(I,K) - ENG_RQ(I) * Y) * PAI(I,K))
/ (BPOS(I) + WRE(I)));
! Ensures available aircraft does not exceed available engines;

@FOR(AC_YR(I,K): MCG * Z / TAI > MAA);
! Ensures aircraft availability is greater than the mission-capability
goal;

@FOR(AC_YR(I,K): OES > 0);
! Ensures on-hand engine stock is non-negative;

@FOR(AC_PT_YR(I,J,K): @GIN(X));
! Ensures aircraft production are integers;

@FOR(AC_PT_YR(I,J,K): @GIN(Z));
! Ensures available aircraft are integers;
```

Appendix C – Task Requirement Results by Model

RAND Formulation to Maximize Operational Capability

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
A-10	1	AAEEPH_AFMC	2	2	2	2	2	0	0	0	0	0
A-10	2	AAEEPI_AFMC	3	1	3	4	6	0	1	1	2	3
A-10	3	AAEEPJ_AFMC	3	2	2	2	2	0	0	1	1	1
A-10	4	AAEEPT_AFMC	2	3	3	2	3	1	1	1	1	1
A-10	5	AAEEQL_AFMC	2	2	2	1	2	0	0	0	1	1
A-10	6	AAEEQP_AFMC	4	3	3	2	3	0	0	0	1	1
A-10	7	AAEERV_AFMC	13	26	33	43	38	0	0	0	19	19
A-10	8	AAEESW_AFMC	4	7	6	1	1	0	0	0	0	0
A-10	9	BAEEPL_ANG	2	2	1	2	2	0	0	1	1	1
A-10	10	BAEEPQ_ANG	1	1	1	1	1	0	0	0	0	0
A-10	11	BAEEQB_ANG	1	1	1	1	1	0	0	0	0	0
A-10	12	BAEEQR_ANG	5	1	1	1	1	0	0	0	0	0
A-10	13	BAEEQZ_ANG	9	4	5	6	1	0	0	0	0	0
A-10	14	ZAEERB_AFRC	3	2	2	2	3	0	0	1	1	1
A-10	15	ZAEMDA_AFRC	3	1	1	1	1	0	0	0	0	0
B-1	1	AADZXG_AFMC	12	16	1	1	2	0	0	0	0	0
B-1	2	AFDVYE_AFMC	5	4	4	2	1	0	0	0	0	1
B-2	1	AEDABA_AFMC	10	3	1	18	27	0	0	0	0	0
B-2	2	AEDXYO_AFMC	33	65	1	3	2	0	0	0	0	2
B-2	3	AFDZVT_AFMC	5	4	0	0	1	0	0	0	0	1
B-2	4	AFDZWU_AFMC	0	3	0	4	0	0	0	0	0	0
B-52	1	AADZYH_AFMC	13	11	11	11	11	0	0	0	0	0
B-52	2	AEDZET_AFMC	29	54	55	34	64	0	0	0	32	32
B-52	3	AEDZET_AFRC	7	8	15	15	38	0	0	0	15	22
B-52	4	ZADXXI_AFRC	4	4	4	2	4	0	0	0	2	2
C-130	1	A1JCZK_AFMC	2	1	1	1	1	0	0	0	0	0
C-130	2	A1JRQL_AFMC	12	7	1	3	4	0	0	1	1	2
C-130	3	A1JTAZ_AFMC	3	2	1	1	1	0	0	0	0	1
C-130	4	AAJHBA_AFMC	1	1	2	2	1	0	0	0	0	1
C-130	5	AAJHBJ_AFMC	1	1	1	2	2	0	0	0	0	2
C-130	6	AAJHBU_AFMC	1	2	2	3	1	0	0	0	0	0
C-130	7	AAJHCF_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	8	AAJHCJ_AFMC	1	1	1	1	1	0	0	0	0	1
C-130	9	AAJHCW_AFMC	1	2	1	1	1	0	0	0	0	0
C-130	10	AAJHDW_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	11	AAJHGA_AFMC	1	1	2	4	3	0	0	0	0	2
C-130	12	AAJHGB_AFMC	1	1	1	1	1	0	0	0	0	1
C-130	13	AAJHGT_AFMC	1	1	2	1	1	0	0	0	0	0
C-130	14	AAJHGW_AFMC	1	2	1	2	2	0	0	0	0	1
C-130	15	AAJRPM_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	16	AAJRQJ_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	17	AAJRQK_AFMC	2	2	2	1	2	0	0	0	1	1
C-130	18	AAJRRC_AFMC	3	2	3	3	3	0	1	1	1	1
C-130	19	AAJRRE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	20	AAJRSD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	21	AAJRSE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	22	AAJRTB_AFMC	2	3	3	3	3	1	1	1	1	1
C-130	23	AAJRTC_AFMC	4	2	4	4	4	0	2	2	2	2
C-130	24	AAJSJY_AFMC	2	2	2	1	2	0	0	0	1	1
C-130	25	AAJSXE_AFMC	1	2	4	5	1	0	0	0	0	0
C-130	26	AAJTNE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	27	AAJUZD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	28	ABJRQX_AFMC	1	2	2	1	1	0	0	0	0	1
C-130	29	ABJRSN_AFMC	2	2	3	1	1	0	0	0	0	0
C-130	30	ABJTQG_AFMC	3	1	1	1	1	0	0	0	0	0
C-130	31	ABJTTG_AFMC	2	4	2	1	1	0	0	0	0	0
C-130	32	ABJTTH_AFMC	1	1	1	2	2	0	0	0	0	1
C-130	33	ABJUZN_AFMC	2	3	4	1	1	0	0	0	0	0
C-130	34	AEDCMB_AFMC	13	11	15	23	7	0	0	0	3	3
C-130	35	AEDCME_AFMC	3	3	1	2	1	0	0	0	0	0
C-130	36	AEDCMG_AFMC	2	1	1	1	1	0	0	0	0	0

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
C-130	37	AEDCMG_AFRC	3	1	1	1	1	0	0	0	0	0
C-130	38	AEDCMG_ANG	4	7	5	1	1	0	0	0	0	0
C-130	39	AEDDCP_AFRC	35	52	28	18	22	0	9	9	9	13
C-130	40	AEDDCP_ANG	48	64	11	43	30	0	0	11	11	19
C-130	41	AEDDCR_ANG	1	2	2	3	3	1	1	1	1	1
C-130	42	AEDDCS_ANG	2	1	3	4	7	0	1	1	2	4
C-130	43	AEDNUD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	44	AEDZQO_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	45	B1JPAB_ANG	6	3	2	3	2	0	0	0	1	1
C-130	46	BAJARR_ANG	1	1	1	1	1	0	0	0	0	0
C-130	47	BAJFVW_ANG	1	1	1	1	1	0	0	0	0	0
C-130	48	BAJHHL_ANG	6	2	3	4	7	0	1	1	3	4
C-130	49	BAJHHM_ANG	13	1	1	1	1	0	0	0	0	0
C-130	50	BAJOKI_ANG	1	1	1	1	1	0	0	0	0	0
C-130	51	BAJRNH_ANG	1	2	2	3	6	0	0	1	2	4
C-130	52	BAJSOZ_ANG	1	1	1	1	1	0	0	0	0	0
C-130	53	BAJSXC_ANG	1	1	1	1	1	0	0	0	0	0
C-130	54	BAJTMK_ANG	1	1	1	1	1	0	0	0	0	0
C-130	55	BBJQZM_ANG	3	6	9	7	1	0	0	0	0	0
C-130	56	BBJTTM_ANG	7	4	5	4	7	0	0	0	3	3
C-130	57	Z1JRSR_AFRC	2	1	1	2	2	0	0	0	0	1
C-130	58	ZAJCCW_AFRC	9	12	3	6	5	0	1	1	1	4
C-130	59	ZAJFCY_AFRC	6	4	1	2	1	0	0	0	0	0
C-130	60	ZAJKBI_AFRC	1	2	2	2	2	1	1	1	1	1
C-130	61	ZAJOYP_AFRC	1	2	1	1	1	0	0	0	0	1
C-130	62	ZAJTMJ_AFRC	1	1	1	1	1	0	0	0	0	0
C-130	63	ZAJTOI_AFRC	3	4	2	3	3	0	1	1	1	1
C-130	64	ZBJQZK_AFRC	5	7	12	18	11	0	0	0	5	5
C-5	1	AEDDAH_AFRC	15	22	25	24	34	0	0	0	0	0
C-5	2	AEDDAH_ANG	4	2	4	4	4	0	2	2	2	2
C-5	3	AEDDAI_AFRC	3	2	3	3	3	0	1	1	1	1
C-5	4	Z1JAAE_AFRC	6	7	3	2	2	0	0	0	0	1
C-5	5	ZAJPXX_AFRC	4	4	4	2	4	0	0	0	2	2
C-5	6	ZBJQRK_AFRC	2	2	2	1	1	0	0	0	0	0
C-5	7	ZBJTBE_AFRC	2	1	2	1	1	0	0	0	0	0
E-3	1	AADZZL_AFMC	4	4	4	4	4	0	0	0	0	0
E-3	2	AADZZM_AFMC	2	1	2	2	2	0	1	1	1	1
E-3	3	AEDZEQ_AFMC	16	30	17	35	40	0	0	16	16	23
E-3	4	UEDZWA_AFGSC	3	2	2	4	3	1	1	1	1	1
E-8	1	AEDYSP_ANG	16	6	3	1	1	0	0	0	0	0
E-8	2	BFDAXK_ANG	1	1	2	3	1	0	0	0	0	0
F-15	1	AAJROQ_AFMC	10	3	1	1	2	0	0	0	0	0
F-15	2	AAJROR_AFMC	1	1	1	1	1	0	0	0	0	0
F-15	3	AAJROS_AFMC	36	28	20	1	1	0	0	0	0	1
F-15	4	AAJROT_AFMC	9	13	16	7	15	0	0	0	7	8
F-15	5	AAJROU_AFMC	2	2	1	2	2	0	0	1	1	1
F-15	6	AAJTHR_AFMC	4	3	2	1	1	0	0	0	0	0
F-15	7	AEDAMH_AFMC	3	3	2	4	4	1	1	1	1	2
F-15	8	AEDCBK_AFMC	3	6	8	7	4	0	0	0	2	2
F-15	9	BAJLAS_ANG	2	1	2	2	2	0	1	1	1	1
F-15	10	BAJNOJ_ANG	2	1	2	2	2	0	1	1	1	1
F-15	11	BAJNOL_ANG	3	2	3	3	3	0	1	1	1	1
F-15	12	BAJTHQ_ANG	9	6	6	6	15	0	0	0	6	8
F-15	13	BAJTHT_ANG	1	1	1	1	1	0	0	0	0	0
F-16	1	AAEBAE_AFMC	19	15	5	3	5	0	0	0	0	0
F-16	2	AAEBCL_AFMC	7	10	10	3	3	0	0	1	1	2
F-16	3	AAEBCO_AFMC	2	1	1	1	1	0	0	0	0	0
F-16	4	AAEBCP_AFMC	1	1	1	1	1	0	0	0	0	1
F-16	5	AAEBDA_AFMC	21	10	37	62	30	0	10	10	10	20
F-16	6	AAEBDB_AFMC	14	12	8	5	6	0	0	2	2	4
F-16	7	AAEBDC_AFMC	1	1	2	2	4	0	0	0	1	2
F-16	8	AAEBDD_AFMC	6	3	3	5	1	0	0	0	0	0
F-16	9	AAEBRQ_AFMC	11	21	34	31	13	0	0	0	6	6

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
F-16	10	AAEOFJ_AFMC	10	16	15	1	1	0	0	0	0	0
F-16	11	AAEOFK_AFMC	36	30	31	8	16	0	0	0	7	7
F-16	12	AAEOKD_AFMC	18	5	1	1	1	0	0	0	0	0
F-16	13	AAERDF_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	14	AAERDG_AFMC	35	17	27	29	9	0	0	0	4	4
F-16	15	AAERKN_AFMC	9	13	7	1	1	0	0	0	0	1
F-16	16	AAERNA_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	17	AAERNS_AFMC	2	1	1	1	1	0	0	0	0	1
F-16	18	AAERNZ_AFMC	2	3	3	5	7	0	0	2	2	4
F-16	19	AAERXN_AFMC	3	3	2	1	1	0	0	0	0	1
F-16	20	AAERZG_AFMC	2	2	1	1	1	0	0	0	0	0
F-16	21	AEDDAF_AFMC	5	2	1	1	1	0	0	0	0	0
F-16	22	AEDDAG_AFMC	5	1	2	1	3	0	0	0	1	1
F-16	23	AEDDAG_AFRC	1	2	2	2	2	1	1	1	1	1
F-16	24	AEDDAG_ANG	3	3	4	4	6	0	0	2	2	3
F-16	25	AEDZQR_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	26	AFDZWV_AFMC	3	6	12	10	21	0	0	0	9	12
F-16	27	AGEFZT_AFMC	15	11	4	6	1	0	0	0	0	0
F-16	28	BAEBBI_ANG	6	1	2	3	1	0	0	0	0	0
F-16	29	BAEBBO_ANG	3	3	1	1	1	0	0	0	0	0
F-16	30	BAEBCT_ANG	8	15	3	5	4	0	0	2	2	2
F-16	31	BAEBSX_ANG	60	11	14	13	28	0	0	0	13	15
F-16	32	BAEOGV_ANG	12	20	2	1	1	0	0	0	0	0
F-16	33	BAEOGX_ANG	4	7	6	4	3	0	0	0	0	2
F-16	34	BAEOJA_ANG	10	5	2	3	4	0	0	1	2	2
F-16	35	BAERRV_ANG	8	4	7	5	3	0	0	0	1	1
F-16	36	BAERVE_ANG	7	6	5	4	11	0	0	0	4	7
F-16	37	BAERVF_ANG	6	2	1	1	1	0	0	0	0	0
F-16	38	ZAELLP_AFRC	4	8	9	12	8	0	0	0	4	4
HH-60	1	AAJRTN_AFMC	2	1	2	3	5	0	0	0	0	0
HH-60	2	AAJRTQ_AFMC	7	11	17	9	12	0	0	4	4	8
HH-60	3	AAJRTR_AFMC	2	1	2	2	2	0	1	1	1	1
HH-60	4	BAJNOX_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	5	BAJNRP_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	6	BAJPMF_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	7	ZAJQET_AFRC	3	2	1	1	1	0	0	0	0	0
KC/C-135	1	AADAPX_AFMC	1	1	1	1	1	0	0	0	0	0
KC/C-135	2	AADZXU_AFMC	1	1	1	1	1	0	0	0	0	0
KC/C-135	3	AADZYQ_AFMC	4	4	4	2	4	0	0	0	2	2
KC/C-135	4	AADZYV_AFMC	5	5	5	3	5	0	0	0	2	2
KC/C-135	5	AADZZB_AFMC	17	26	21	12	33	0	0	0	11	22
KC/C-135	6	AEDJAA_AFMC	3	5	3	1	1	0	0	0	0	0
KC/C-135	7	AEDJAA_AFRC	2	3	2	2	2	1	1	1	1	1
KC/C-135	8	AEDJAA_ANG	9	1	1	1	1	0	0	0	0	1
KC/C-135	9	AEDZES_AFMC	36	34	60	50	3	0	0	0	1	1
KC/C-135	10	AEDZES_AFRC	16	23	33	9	1	0	0	0	0	0
KC/C-135	11	AEDZES_ANG	35	18	12	7	4	0	0	0	2	2
KC/C-135	12	BADAGC_ANG	3	3	3	2	3	0	0	0	1	1
KC/C-135	13	BADAGG_ANG	2	2	1	2	2	0	0	1	1	1
KC/C-135	14	BADCVJ_ANG	3	3	3	2	3	0	0	0	1	1
KC/C-135	15	BADXNN_ANG	20	29	14	3	4	0	1	1	1	2
KC/C-135	16	BADZZA_ANG	1	1	1	1	1	0	0	0	0	0
KC/C-135	17	ZADXZS_AFRC	11	8	12	8	11	0	4	4	4	7
KC-10	1	AADZQD_AFMC	10	18	17	8	5	0	0	0	0	0
RC/OC-135	1	AEDZRY_AFMC	2	1	1	2	4	0	0	0	0	0
UH-1	1	AAJRTE_AFMC	8	8	5	7	8	0	0	0	0	0
UH-1	2	AAJRTZ_AFMC	16	8	10	15	1	0	0	0	0	0

Modified Formulation to Maximize Operational Capability

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
A-10	1	AAEEPH_AFMC	2	2	2	2	2	0	0	0	0	0
A-10	2	AAEEPI_AFMC	3	2	3	5	7	0	0	0	0	0
A-10	3	AAEEPJ_AFMC	3	2	3	2	2	0	0	0	0	0
A-10	4	AAEEPT_AFMC	3	3	3	2	3	0	0	0	0	0
A-10	5	AAEEQL_AFMC	2	2	2	2	2	0	0	0	0	0
A-10	6	AAEEQP_AFMC	4	3	3	3	3	0	0	0	0	0
A-10	7	AAEERV_AFMC	13	26	33	62	38	0	0	0	0	0
A-10	8	AAEESW_AFMC	4	7	6	1	1	0	0	0	0	0
A-10	9	BAEEPL_ANG	2	2	2	2	2	0	0	0	0	0
A-10	10	BAEEPQ_ANG	1	1	1	1	1	0	0	0	0	0
A-10	11	BAEEQB_ANG	1	1	1	1	1	0	0	0	0	0
A-10	12	BAEEQR_ANG	5	1	1	1	1	0	0	0	0	0
A-10	13	BAEEQZ_ANG	9	4	5	6	1	0	0	0	0	0
A-10	14	ZAEERB_AFRC	3	2	3	2	3	0	0	0	0	0
A-10	15	ZAEMDA_AFRC	3	1	1	1	1	0	0	0	0	0
B-1	1	AADZXG_AFMC	12	16	1	1	2	0	0	0	0	0
B-1	2	AFDVYE_AFMC	5	4	4	2	2	0	0	0	0	0
B-2	1	AEDABA_AFMC	10	3	1	18	27	0	0	0	0	0
B-2	2	AEDXYO_AFMC	33	65	1	3	4	0	0	0	0	0
B-2	3	AFDZVT_AFMC	5	4	0	0	2	0	0	0	0	0
B-2	4	AFDZWU_AFMC	0	3	0	4	0	0	0	0	0	0
B-52	1	AADZYH_AFMC	13	11	11	11	11	0	0	0	0	0
B-52	2	AEDZET_AFMC	29	54	55	66	64	0	0	0	0	0
B-52	3	AEDZET_AFRC	7	8	15	30	45	0	0	0	0	0
B-52	4	ZADXXI_AFRC	4	4	4	4	4	0	0	0	0	0
C-130	1	A1JCZK_AFMC	2	1	1	1	1	0	0	0	0	0
C-130	2	A1JRQL_AFMC	12	7	2	3	5	0	0	0	0	0
C-130	3	A1JTAZ_AFMC	3	2	1	1	2	0	0	0	0	0
C-130	4	AAJHBA_AFMC	1	1	2	2	2	0	0	0	0	0
C-130	5	AAJHBJ_AFMC	1	1	1	2	4	0	0	0	0	0
C-130	6	AAJHBU_AFMC	1	2	2	3	1	0	0	0	0	0
C-130	7	AAJHCF_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	8	AAJHCJ_AFMC	1	1	1	1	2	0	0	0	0	0
C-130	9	AAJHCW_AFMC	1	2	1	1	1	0	0	0	0	0
C-130	10	AAJHDW_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	11	AAJHGA_AFMC	1	1	2	4	5	0	0	0	0	0
C-130	12	AAJHGB_AFMC	1	1	1	1	2	0	0	0	0	0
C-130	13	AAJHGT_AFMC	1	1	2	1	1	0	0	0	0	0
C-130	14	AAJHGW_AFMC	1	2	1	2	3	0	0	0	0	0
C-130	15	AAJRPM_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	16	AAJRQJ_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	17	AAJRQK_AFMC	2	2	2	2	2	0	0	0	0	0
C-130	18	AAJRRC_AFMC	3	3	3	3	3	0	0	0	0	0
C-130	19	AAJRRE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	20	AAJRSD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	21	AAJRSE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	22	AAJRTB_AFMC	3	3	3	3	3	0	0	0	0	0
C-130	23	AAJRTC_AFMC	4	4	4	4	4	0	0	0	0	0
C-130	24	AAJSJY_AFMC	2	2	2	2	2	0	0	0	0	0
C-130	25	AAJSXE_AFMC	1	2	4	5	1	0	0	0	0	0
C-130	26	AAJTNE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	27	AAJUZD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	28	ABJRQX_AFMC	1	2	2	1	2	0	0	0	0	0
C-130	29	ABJRSN_AFMC	2	2	3	1	1	0	0	0	0	0
C-130	30	ABJTQG_AFMC	3	1	1	1	1	0	0	0	0	0
C-130	31	ABJTTG_AFMC	2	4	2	1	1	0	0	0	0	0
C-130	32	ABJTTH_AFMC	1	1	1	2	3	0	0	0	0	0
C-130	33	ABJUZN_AFMC	2	3	4	1	1	0	0	0	0	0
C-130	34	AEDCMB_AFMC	13	11	15	26	7	0	0	0	0	0
C-130	35	AEDCME_AFMC	3	3	1	2	1	0	0	0	0	0
C-130	36	AEDCMG_AFMC	2	1	1	1	1	0	0	0	0	0

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
C-130	37	AEDCMG_AFRC	3	1	1	1	1	0	0	0	0	0
C-130	38	AEDCMG_ANG	4	7	5	1	1	0	0	0	0	0
C-130	39	AEDDCP_AFRC	35	61	28	18	26	0	0	0	0	0
C-130	40	AEDDCP_ANG	48	64	22	43	38	0	0	0	0	0
C-130	41	AEDDCR_ANG	2	2	2	3	3	0	0	0	0	0
C-130	42	AEDDCS_ANG	2	2	3	5	9	0	0	0	0	0
C-130	43	AEDNUD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	44	AEDZQO_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	45	B1JPAB_ANG	6	3	2	4	2	0	0	0	0	0
C-130	46	BAJARR_ANG	1	1	1	1	1	0	0	0	0	0
C-130	47	BAJFVW_ANG	1	1	1	1	1	0	0	0	0	0
C-130	48	BAJHHL_ANG	6	3	3	6	8	0	0	0	0	0
C-130	49	BAJHHM_ANG	13	1	1	1	1	0	0	0	0	0
C-130	50	BAJOKI_ANG	1	1	1	1	1	0	0	0	0	0
C-130	51	BAJRNH_ANG	1	2	3	4	8	0	0	0	0	0
C-130	52	BAJSOZ_ANG	1	1	1	1	1	0	0	0	0	0
C-130	53	BAJSXC_ANG	1	1	1	1	1	0	0	0	0	0
C-130	54	BAJTMK_ANG	1	1	1	1	1	0	0	0	0	0
C-130	55	BBJQZM_ANG	3	6	9	7	1	0	0	0	0	0
C-130	56	BBJTTM_ANG	7	4	5	7	7	0	0	0	0	0
C-130	57	Z1JRSR_AFRC	2	1	1	2	3	0	0	0	0	0
C-130	58	ZAJCCW_AFRC	9	13	3	6	8	0	0	0	0	0
C-130	59	ZAJFCY_AFRC	6	4	1	2	1	0	0	0	0	0
C-130	60	ZAJKBI_AFRC	2	2	2	2	2	0	0	0	0	0
C-130	61	ZAJOYP_AFRC	1	2	1	1	2	0	0	0	0	0
C-130	62	ZAJTMJ_AFRC	1	1	1	1	1	0	0	0	0	0
C-130	63	ZAJTOI_AFRC	3	5	2	3	3	0	0	0	0	0
C-130	64	ZBJQZK_AFRC	5	7	12	23	11	0	0	0	0	0
C-5	1	AEDDAH_AFRC	15	22	25	24	34	0	0	0	0	0
C-5	2	AEDDAH_ANG	4	4	4	4	4	0	0	0	0	0
C-5	3	AEDDAI_AFRC	3	3	3	3	3	0	0	0	0	0
C-5	4	Z1JAAE_AFRC	6	7	3	2	3	0	0	0	0	0
C-5	5	ZAJPXX_AFRC	4	4	4	4	4	0	0	0	0	0
C-5	6	ZBJQRK_AFRC	2	2	2	1	1	0	0	0	0	0
C-5	7	ZBJTBE_AFRC	2	1	2	1	1	0	0	0	0	0
E-3	1	AADZZL_AFMC	4	4	4	4	4	0	0	0	0	0
E-3	2	AADZZM_AFMC	2	2	2	2	2	0	0	0	0	0
E-3	3	AEDZEQ_AFMC	16	30	33	35	47	0	0	0	0	0
E-3	4	UEDZWA_AFGSC	4	2	2	4	3	0	0	0	0	0
E-8	1	AEDYSP_ANG	16	6	3	1	1	0	0	0	0	0
E-8	2	BFDAXK_ANG	1	1	2	3	1	0	0	0	0	0
F-15	1	AAJROQ_AFMC	10	3	1	1	2	0	0	0	0	0
F-15	2	AAJROR_AFMC	1	1	1	1	1	0	0	0	0	0
F-15	3	AAJROS_AFMC	36	28	20	1	2	0	0	0	0	0
F-15	4	AAJROT_AFMC	9	13	16	14	16	0	0	0	0	0
F-15	5	AAJROU_AFMC	1	2	2	2	2	1	0	0	0	0
F-15	6	AAJTHR_AFMC	4	3	2	1	1	0	0	0	0	0
F-15	7	AEDAMH_AFMC	4	3	2	4	5	0	0	0	0	0
F-15	8	AEDCBK_AFMC	2	6	8	9	4	1	0	0	0	0
F-15	9	BAJLAS_ANG	1	2	2	2	2	1	0	0	0	0
F-15	10	BAJNOJ_ANG	2	2	2	2	2	0	0	0	0	0
F-15	11	BAJNOL_ANG	3	3	3	3	3	0	0	0	0	0
F-15	12	BAJTHQ_ANG	9	6	6	12	17	0	0	0	0	0
F-15	13	BAJTHT_ANG	1	1	1	1	1	0	0	0	0	0
F-16	1	AAEBAE_AFMC	19	15	5	3	5	0	0	0	0	0
F-16	2	AAEBCL_AFMC	7	10	11	3	4	0	0	0	0	0
F-16	3	AAEBCO_AFMC	2	1	1	1	1	0	0	0	0	0
F-16	4	AAEBCP_AFMC	1	1	1	1	2	0	0	0	0	0
F-16	5	AAEBDA_AFMC	21	20	37	62	40	0	0	0	0	0
F-16	6	AAEBDB_AFMC	14	12	10	5	8	0	0	0	0	0
F-16	7	AAEBDC_AFMC	1	1	2	3	5	0	0	0	0	0
F-16	8	AAEBDD_AFMC	6	3	3	5	1	0	0	0	0	0
F-16	9	AAEBRQ_AFMC	11	21	34	37	13	0	0	0	0	0

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
F-16	10	AAEOFJ_AFMC	10	16	15	1	1	0	0	0	0	0
F-16	11	AAEOFK_AFMC	36	30	31	15	16	0	0	0	0	0
F-16	12	AAEOKD_AFMC	18	5	1	1	1	0	0	0	0	0
F-16	13	AAERDF_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	14	AAERDG_AFMC	35	17	27	33	9	0	0	0	0	0
F-16	15	AAERKN_AFMC	9	13	7	1	2	0	0	0	0	0
F-16	16	AAERNA_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	17	AAERNS_AFMC	2	1	1	1	2	0	0	0	0	0
F-16	18	AAERNZ_AFMC	2	3	5	5	9	0	0	0	0	0
F-16	19	AAERXN_AFMC	3	3	2	1	2	0	0	0	0	0
F-16	20	AAERZG_AFMC	2	2	1	1	1	0	0	0	0	0
F-16	21	AEDDAF_AFMC	5	2	1	1	1	0	0	0	0	0
F-16	22	AEDDAG_AFMC	5	1	2	2	3	0	0	0	0	0
F-16	23	AEDDAG_AFRC	2	2	2	2	2	0	0	0	0	0
F-16	24	AEDDAG_ANG	3	3	6	4	7	0	0	0	0	0
F-16	25	AEDZQR_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	26	AFDZWV_AFMC	3	6	12	19	24	0	0	0	0	0
F-16	27	AGEFZT_AFMC	15	11	4	6	1	0	0	0	0	0
F-16	28	BAEBBI_ANG	6	1	2	3	1	0	0	0	0	0
F-16	29	BAEBBO_ANG	3	3	1	1	1	0	0	0	0	0
F-16	30	BAEBCT_ANG	8	15	5	5	4	0	0	0	0	0
F-16	31	BAEBSX_ANG	60	11	14	26	30	0	0	0	0	0
F-16	32	BAEOGV_ANG	12	20	2	1	1	0	0	0	0	0
F-16	33	BAEOGX_ANG	4	7	6	4	5	0	0	0	0	0
F-16	34	BAEOJA_ANG	10	5	3	4	4	0	0	0	0	0
F-16	35	BAERRV_ANG	8	4	7	6	3	0	0	0	0	0
F-16	36	BAERVE_ANG	7	6	5	8	14	0	0	0	0	0
F-16	37	BAERVF_ANG	6	2	1	1	1	0	0	0	0	0
F-16	38	ZAELLP_AFRC	4	8	9	16	8	0	0	0	0	0
HH-60	1	AAJRTN_AFMC	2	1	2	3	5	0	0	0	0	0
HH-60	2	AAJRTQ_AFMC	7	11	21	9	16	0	0	0	0	0
HH-60	3	AAJRTR_AFMC	2	2	2	2	2	0	0	0	0	0
HH-60	4	BAJNOX_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	5	BAJNRP_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	6	BAJPMF_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	7	ZAJQET_AFRC	3	2	1	1	1	0	0	0	0	0
KC/C-135	1	AADAPX_AFMC	1	1	1	1	1	0	0	0	0	0
KC/C-135	2	AADZXU_AFMC	1	1	1	1	1	0	0	0	0	0
KC/C-135	3	AADZYQ_AFMC	4	3	4	4	4	0	2	0	0	0
KC/C-135	4	AADZYV_AFMC	5	4	5	5	5	0	2	0	0	0
KC/C-135	5	AADZZB_AFMC	17	25	21	23	44	0	2	0	0	0
KC/C-135	6	AEDJAA_AFMC	3	4	3	1	1	0	2	0	0	0
KC/C-135	7	AEDJAA_AFRC	3	3	2	2	2	0	0	0	0	0
KC/C-135	8	AEDJAA_ANG	9	1	1	1	2	0	0	0	0	0
KC/C-135	9	AEDZES_AFMC	36	33	60	51	3	0	2	0	0	0
KC/C-135	10	AEDZES_AFRC	16	22	33	9	1	0	2	0	0	0
KC/C-135	11	AEDZES_ANG	35	17	12	9	4	0	2	0	0	0
KC/C-135	12	BADAGC_ANG	3	3	3	3	3	0	0	0	0	0
KC/C-135	13	BADAGG_ANG	2	2	2	2	2	0	0	0	0	0
KC/C-135	14	BADCVJ_ANG	3	3	3	3	3	0	0	0	0	0
KC/C-135	15	BADXNN_ANG	20	29	14	3	5	0	2	0	0	0
KC/C-135	16	BADZZA_ANG	1	1	1	1	1	0	0	0	0	0
KC/C-135	17	ZADXZS_AFRC	11	11	12	8	14	0	2	0	0	0
KC-10	1	AADZQD_AFMC	10	18	17	8	5	0	0	0	0	0
RC/OC-135	1	AEDZRY_AFMC	2	1	1	2	4	0	0	0	0	0
UH-1	1	AAJRTE_AFMC	8	8	5	7	8	0	0	0	0	0
UH-1	2	AAJRTZ_AFMC	16	8	10	15	1	0	0	0	0	0

Modified Formulation to Minimize Cost

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
A-10	1	AAEEPH_AFMC	1	2	2	2	2	1	0	0	0	0
A-10	2	AAEEPI_AFMC	2	2	3	5	7	1	0	0	0	0
A-10	3	AAEEPJ_AFMC	2	2	3	2	2	1	0	0	0	0
A-10	4	AAEEPT_AFMC	2	3	3	2	3	1	0	0	0	0
A-10	5	AAEEQL_AFMC	1	2	2	2	2	1	0	0	0	0
A-10	6	AAEEQP_AFMC	2	3	3	3	3	2	0	0	0	0
A-10	7	AAEERV_AFMC	7	20	28	55	35	6	12	15	28	15
A-10	8	AAEESW_AFMC	2	6	6	1	1	2	2	0	0	0
A-10	9	BAEEPL_ANG	1	2	2	2	2	1	0	0	0	0
A-10	10	BAEEPQ_ANG	1	1	1	1	1	0	0	0	0	0
A-10	11	BAEEQB_ANG	1	1	1	1	1	0	0	0	0	0
A-10	12	BAEEQR_ANG	4	1	1	1	1	1	0	0	0	0
A-10	13	BAEEQZ_ANG	5	4	5	6	1	4	0	0	0	0
A-10	14	ZAEERB_AFRC	2	2	3	2	3	1	0	0	0	0
A-10	15	ZAEMDA_AFRC	2	1	1	1	1	1	0	0	0	0
B-1	1	AADZXG_AFMC	6	16	1	1	2	6	0	0	0	0
B-1	2	AFDVYE_AFMC	3	3	4	2	2	2	2	0	0	0
B-2	1	AEDABA_AFMC	7	3	1	17	27	3	0	0	4	0
B-2	2	AEDXYO_AFMC	29	65	1	3	4	4	0	0	0	0
B-2	3	AFDZVT_AFMC	3	4	0	0	2	2	0	0	0	0
B-2	4	AFDZWU_AFMC	0	3	0	4	0	0	0	0	0	0
B-52	1	AADZYH_AFMC	7	9	10	10	10	6	4	3	4	5
B-52	2	AEDZET_AFMC	15	44	49	61	60	14	20	18	20	20
B-52	3	AEDZET_AFRC	4	6	13	27	41	3	4	6	12	20
B-52	4	ZADXXI_AFRC	2	3	4	4	4	2	2	0	0	0
C-130	1	A1JCZK_AFMC	1	1	1	1	1	1	0	0	0	0
C-130	2	A1JRQL_AFMC	6	6	2	3	5	6	2	0	0	0
C-130	3	A1JTAZ_AFMC	2	2	1	1	2	1	0	0	0	0
C-130	4	AAJHBA_AFMC	1	1	2	2	2	0	0	0	0	0
C-130	5	AAJHBJ_AFMC	1	1	1	2	4	0	0	0	0	0
C-130	6	AAJHBU_AFMC	1	2	2	3	1	0	0	0	0	0
C-130	7	AAJHCF_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	8	AAJHCJ_AFMC	1	1	1	1	2	0	0	0	0	0
C-130	9	AAJHCW_AFMC	1	2	1	1	1	0	0	0	0	0
C-130	10	AAJHDW_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	11	AAJHGA_AFMC	1	1	2	4	5	0	0	0	0	0
C-130	12	AAJHGB_AFMC	1	1	1	1	2	0	0	0	0	0
C-130	13	AAJHGT_AFMC	1	1	2	1	1	0	0	0	0	0
C-130	14	AAJHGW_AFMC	1	2	1	2	3	0	0	0	0	0
C-130	15	AAJRPM_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	16	AAJRQJ_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	17	AAJRQK_AFMC	1	2	2	2	2	1	0	0	0	0
C-130	18	AAJRRC_AFMC	2	3	3	3	3	1	0	0	0	0
C-130	19	AAJRRE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	20	AAJRSD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	21	AAJRSE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	22	AAJRTB_AFMC	2	3	3	3	3	1	0	0	0	0
C-130	23	AAJRTC_AFMC	2	3	4	4	4	2	2	0	0	0
C-130	24	AAJSJY_AFMC	1	2	2	2	2	1	0	0	0	0
C-130	25	AAJSXE_AFMC	1	2	4	5	1	0	0	0	0	0
C-130	26	AAJTNE_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	27	AAJUZD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	28	ABJRQX_AFMC	1	2	2	1	2	0	0	0	0	0
C-130	29	ABJRSN_AFMC	1	2	3	1	1	1	0	0	0	0
C-130	30	ABJTQG_AFMC	2	1	1	1	1	1	0	0	0	0
C-130	31	ABJTTG_AFMC	1	3	2	1	1	1	2	0	0	0
C-130	32	ABJTTH_AFMC	1	1	1	2	3	0	0	0	0	0
C-130	33	ABJUZN_AFMC	1	3	4	1	1	1	0	0	0	0
C-130	34	AEDCMB_AFMC	7	9	13	25	7	6	4	6	4	0
C-130	35	AEDCME_AFMC	2	3	1	2	1	1	0	0	0	0
C-130	36	AEDCMG_AFMC	1	1	1	1	1	1	0	0	0	0

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
C-130	37	AEDCMG_AFRC	2	1	1	1	1	1	0	0	0	0
C-130	38	AEDCMG_ANG	2	6	5	1	1	2	2	0	0	0
C-130	39	AEDDCP_AFRC	18	49	24	16	24	17	24	12	8	10
C-130	40	AEDDCP_ANG	24	54	20	38	35	24	20	6	20	15
C-130	41	AEDDCR_ANG	1	2	2	3	3	1	0	0	0	0
C-130	42	AEDDCS_ANG	1	2	3	5	9	1	0	0	0	0
C-130	43	AEDNUD_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	44	AEDZQO_AFMC	1	1	1	1	1	0	0	0	0	0
C-130	45	B1JPAB_ANG	3	3	2	4	2	3	0	0	0	0
C-130	46	BAJARR_ANG	1	1	1	1	1	0	0	0	0	0
C-130	47	BAJFVW_ANG	1	1	1	1	1	0	0	0	0	0
C-130	48	BAJHHL_ANG	3	3	3	6	8	3	0	0	0	0
C-130	49	BAJHHM_ANG	12	1	1	1	1	1	0	0	0	0
C-130	50	BAJOKI_ANG	1	1	1	1	1	0	0	0	0	0
C-130	51	BAJRNH_ANG	1	2	3	4	8	0	0	0	0	0
C-130	52	BAJSOZ_ANG	1	1	1	1	1	0	0	0	0	0
C-130	53	BAJSXC_ANG	1	1	1	1	1	0	0	0	0	0
C-130	54	BAJTMK_ANG	1	1	1	1	1	0	0	0	0	0
C-130	55	BBJQZM_ANG	2	5	8	7	1	1	2	3	0	0
C-130	56	BBJTTM_ANG	4	3	5	7	7	3	2	0	0	0
C-130	57	Z1JRSR_AFRC	1	1	1	2	3	1	0	0	0	0
C-130	58	ZAJCCW_AFRC	5	12	3	6	8	4	2	0	0	0
C-130	59	ZAJFCY_AFRC	3	4	1	2	1	3	0	0	0	0
C-130	60	ZAJKBI_AFRC	1	2	2	2	2	1	0	0	0	0
C-130	61	ZAJOYP_AFRC	1	2	1	1	2	0	0	0	0	0
C-130	62	ZAJTMJ_AFRC	1	1	1	1	1	0	0	0	0	0
C-130	63	ZAJTOI_AFRC	2	4	2	3	3	1	2	0	0	0
C-130	64	ZBJQZK_AFRC	3	6	10	21	10	2	2	6	8	5
C-5	1	AEDDAH_AFRC	8	17	21	21	31	7	10	12	12	15
C-5	2	AEDDAH_ANG	2	3	4	4	4	2	2	0	0	0
C-5	3	AEDDAI_AFRC	2	3	3	3	3	1	0	0	0	0
C-5	4	Z1JAAE_AFRC	3	6	3	2	3	3	2	0	0	0
C-5	5	ZAJPXX_AFRC	2	3	4	4	4	2	2	0	0	0
C-5	6	ZBJQRK_AFRC	1	2	2	1	1	1	0	0	0	0
C-5	7	ZBJTBE_AFRC	1	1	2	1	1	1	0	0	0	0
E-3	1	AADZZL_AFMC	2	3	4	4	4	2	2	0	0	0
E-3	2	AADZZM_AFMC	1	2	2	2	2	1	0	0	0	0
E-3	3	AEDZEQ_AFMC	8	26	30	33	46	8	8	9	8	5
E-3	4	UEDZWA_AFGSC	2	2	2	4	3	2	0	0	0	0
E-8	1	AEDYSP_ANG	12	5	3	1	1	4	2	0	0	0
E-8	2	BFDAXK_ANG	1	1	2	3	1	0	0	0	0	0
F-15	1	AAJROQ_AFMC	7	3	1	1	2	3	0	0	0	0
F-15	2	AAJROR_AFMC	1	1	1	1	1	0	0	0	0	0
F-15	3	AAJROS_AFMC	18	21	20	1	2	18	14	0	0	0
F-15	4	AAJROT_AFMC	5	10	14	13	15	4	6	6	4	5
F-15	5	AAJROU_AFMC	1	2	2	2	2	1	0	0	0	0
F-15	6	AAJTHR_AFMC	2	3	2	1	1	2	0	0	0	0
F-15	7	AEDAMH_AFMC	2	3	2	4	5	2	0	0	0	0
F-15	8	AEDCBK_AFMC	2	5	7	8	4	1	2	3	4	0
F-15	9	BAJLAS_ANG	1	2	2	2	2	1	0	0	0	0
F-15	10	BAJNOJ_ANG	1	2	2	2	2	1	0	0	0	0
F-15	11	BAJNOL_ANG	2	3	3	3	3	1	0	0	0	0
F-15	12	BAJTHQ_ANG	5	5	5	11	16	4	2	3	4	5
F-15	13	BAJTHT_ANG	1	1	1	1	1	0	0	0	0	0
F-16	1	AAEBAE_AFMC	10	13	5	3	5	9	4	0	0	0
F-16	2	AAEBCL_AFMC	4	8	10	3	4	3	4	3	0	0
F-16	3	AAEBCO_AFMC	1	1	1	1	1	1	0	0	0	0
F-16	4	AAEBCP_AFMC	1	1	1	1	2	0	0	0	0	0
F-16	5	AAEBDA_AFMC	11	15	31	55	36	10	10	18	28	20
F-16	6	AAEBDB_AFMC	7	9	9	5	8	7	6	3	0	0
F-16	7	AAEBDC_AFMC	1	1	2	3	5	0	0	0	0	0
F-16	8	AAEBDD_AFMC	3	3	3	5	1	3	0	0	0	0
F-16	9	AAEBRQ_AFMC	6	16	29	34	12	5	10	15	12	5

Aircraft	Task Rqmt ID	Task Requirement	Tasks Completed					Tasks Deferred				
			2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
F-16	10	AAEOFJ_AFMC	5	12	15	1	1	5	8	0	0	0
F-16	11	AAEOFK_AFMC	18	23	26	15	15	18	14	15	0	5
F-16	12	AAEOKD_AFMC	13	5	1	1	1	5	0	0	0	0
F-16	13	AAERDF_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	14	AAERDG_AFMC	18	17	23	31	9	17	0	12	8	0
F-16	15	AAERKN_AFMC	5	10	7	1	2	4	6	0	0	0
F-16	16	AAERNA_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	17	AAERNS_AFMC	1	1	1	1	2	1	0	0	0	0
F-16	18	AAERNZ_AFMC	1	3	5	5	9	1	0	0	0	0
F-16	19	AAERXN_AFMC	2	3	2	1	2	1	0	0	0	0
F-16	20	AAERZG_AFMC	1	2	1	1	1	1	0	0	0	0
F-16	21	AEDDAF_AFMC	3	2	1	1	1	2	0	0	0	0
F-16	22	AEDDAG_AFMC	4	1	2	2	3	1	0	0	0	0
F-16	23	AEDDAG_AFRC	1	2	2	2	2	1	0	0	0	0
F-16	24	AEDDAG_ANG	2	3	5	4	7	1	0	3	0	0
F-16	25	AEDZQR_AFMC	1	1	1	1	1	0	0	0	0	0
F-16	26	AFDZWV_AFMC	2	5	10	17	22	1	2	6	8	10
F-16	27	AGEFZT_AFMC	8	9	4	6	1	7	4	0	0	0
F-16	28	BAEBBI_ANG	5	1	2	3	1	1	0	0	0	0
F-16	29	BAEBBO_ANG	2	3	1	1	1	1	0	0	0	0
F-16	30	BAEBCT_ANG	4	13	5	5	4	4	4	0	0	0
F-16	31	BAEBSX_ANG	49	11	12	23	27	11	0	6	12	15
F-16	32	BAEOGV_ANG	6	19	2	1	1	6	2	0	0	0
F-16	33	BAEOGX_ANG	2	6	5	4	5	2	2	3	0	0
F-16	34	BAEOJA_ANG	5	5	3	4	4	5	0	0	0	0
F-16	35	BAERRV_ANG	4	4	6	6	3	4	0	3	0	0
F-16	36	BAERVE_ANG	4	5	5	7	13	3	2	0	4	5
F-16	37	BAERVF_ANG	4	2	1	1	1	2	0	0	0	0
F-16	38	ZAELLP_AFRC	2	6	8	14	8	2	4	3	8	0
HH-60	1	AAJRTN_AFMC	1	1	2	3	5	1	0	0	0	0
HH-60	2	AAJRTQ_AFMC	4	9	18	9	15	3	4	9	0	5
HH-60	3	AAJRTR_AFMC	1	2	2	2	2	1	0	0	0	0
HH-60	4	BAJNOX_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	5	BAJNRP_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	6	BAJPMF_ANG	1	1	1	1	1	0	0	0	0	0
HH-60	7	ZAJQET_AFRC	2	2	1	1	1	1	0	0	0	0
KC/C-135	1	AADAPX_AFMC	1	1	1	1	1	0	0	0	0	0
KC/C-135	2	AADZXU_AFMC	1	1	1	1	1	0	0	0	0	0
KC/C-135	3	AADZYQ_AFMC	2	3	4	4	4	2	2	0	0	0
KC/C-135	4	AADZYV_AFMC	3	4	5	5	5	2	2	0	0	0
KC/C-135	5	AADZZB_AFMC	9	20	18	21	40	8	12	9	8	20
KC/C-135	6	AEDJAA_AFMC	2	4	3	1	1	1	2	0	0	0
KC/C-135	7	AEDJAA_AFRC	2	3	2	2	2	1	0	0	0	0
KC/C-135	8	AEDJAA_ANG	8	1	1	1	2	1	0	0	0	0
KC/C-135	9	AEDZES_AFMC	18	26	50	51	3	18	16	30	0	0
KC/C-135	10	AEDZES_AFRC	8	18	30	9	1	8	10	9	0	0
KC/C-135	11	AEDZES_ANG	18	17	10	8	4	17	2	6	4	0
KC/C-135	12	BADAGC_ANG	2	3	3	3	3	1	0	0	0	0
KC/C-135	13	BADAGG_ANG	1	2	2	2	2	1	0	0	0	0
KC/C-135	14	BADCVJ_ANG	2	3	3	3	3	1	0	0	0	0
KC/C-135	15	BADXNN_ANG	10	23	14	3	5	10	14	0	0	0
KC/C-135	16	BADZZA_ANG	1	1	1	1	1	0	0	0	0	0
KC/C-135	17	ZADXZS_AFRC	6	9	10	7	13	5	6	6	4	5
KC-10	1	AADZQD_AFMC	5	14	16	7	5	5	8	3	4	0
RC/OC-135	1	AEDZRY_AFMC	1	1	1	2	4	1	0	0	0	0
UH-1	1	AAJRTE_AFMC	4	6	5	7	8	4	4	0	0	0
UH-1	2	AAJRTZ_AFMC	8	8	9	15	1	8	0	3	0	0

Bibliography

Donley, M. B. & Welsh III, M. A., 2013. *Fiscal Year 2014 Air Force Posture Statement.* [Online] Available at: http://www.posturestatement.af.mil/shared/media/document/AFD- 130619-104.pdf [Accessed 13 September 2013].

Jones, J. & Herslow, R., 2005. The United States Air Force Approach to Capabilities-Based Planning & Programming (CBP&P), Part 1: Planning. *In Analytical Support to Defence Transformation,* pp. 10.1-10.10.

LINDO Systems Inc., 2010. *LINGO User's Guide.* Chicago: LINDO Systems Inc..

Radar, D. J., 2010. *Deterministic Operations Research: Models and Methods in Linear Optimization.* Hoboken, NJ: Wiley.

Ragsdale, C. T., 2004. *Spreadsheet Modeling and Decision Making.* 4th ed. Mason, OH: South-Western.

Rumsfeld, D. H., 2004. *Prepared Testimony of U.S. Secretary of Defense.* s.l.:s.n.

Secretary of the Air Force, 2005. Maintenance: Equipment Inventory, Status and Utilization Reporting. *Air Force Instruction 21-103.*

Snyder, D., Kim, J., Carrillo, M. & Hildebrandt, G. G., 2012. *Improving Air Force Depot Programming by Linking Resources to Capabilities,* Santa Monica, CA: RAND Corporation.

Snyder, D., Mills, P., Resnick, A. C. & Fulton, B. D., 2009. *Assessing Capabilities and Risks in Air Force Programming: Framework, Metrics, and Methods,* Santa Monica, CA: RAND Corporation.

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14. ABSTRACT

The Air Force wants to improve the link between resources and weapons system readiness by reducing costs, improving risk-based decision making, and balancing costs with performance. With that in mind, RAND Project Air Force developed a linear programming model linking Depot Purchased Equipment Maintenance to operational capability. This thesis examined that model, provided an alternate model, and then developed a new model that determined the minimum cost necessary to maintain the force structure. The utility of using the models using Weapon System Sustainment (WSS) and additional sources of data for aircraft and engine inventories was evaluated and critiqued. While every WSS requirement has a cost, the vast majority do not have quantities associated with them. Using the sources outlined for aircraft and engine inventories does not match up with WSS data. Aircraft inventory data is more specific than the WSS data requirements. Engine inventories are managed by engine type, not by aircraft. Many engines serve multiple aircraft, and many aircraft require multiple engines. The combined result is that using WSS data to process these models and obtain meaningful results is not possible at this time.

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