

Project AIR FORCE

SUPPORTING EXPEDITIONARY AEROSPACE FORCES

An Integrated Strategic Agile
Combat Support Planning
Framework

*Robert S. Tripp
Lionel Galway
Paul S. Killingsworth
Eric Peltz
Timothy L. Ramey
John G. Drew*

BAND

The research reported here was sponsored by the United States Air Force under Contract F49642-96-C-0001. Further information may be obtained from the Strategic Planning Division, Directorate of Plans, Hq USAF.

Library of Congress Cataloging-in-Publication Data

Supporting expeditionary aerospace forces : an integrated strategic agile combat support planning framework / Robert S. Tripp ... [et al.].

p. cm.

"MR-1056-AE"

Includes bibliographical references (p.).

ISBN 0-8330-2763-8

1. United States. Air Force—Organization. 2. United States. Air Force—Operational readiness. 3. Logistics. I. Tripp, Robert S., 1944-
UG773.T75 1999
358.4 '152 21—dc21

99-040229

CIP

RAND is a nonprofit institution that helps improve policy and decisionmaking through research and analysis. RAND® is a registered trademark. RAND's publications do not necessarily reflect the opinions or policies of its research sponsors.

© Copyright 1999 RAND

All rights reserved. No part of this book may be reproduced in any form by any electronic or mechanical means (including photocopying, recording, or information storage and retrieval) without permission in writing from RAND.

Published 1999 by RAND

1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

1333 H St., N.W., Washington, D.C. 20005-4707

RAND URL: <http://www.rand.org/>

To order RAND documents or to obtain additional information,
contact Distribution Services: Telephone: (310) 451-7002;

Fax: (310) 451-6915; Internet: order@rand.org

Project AIR FORCE

SUPPORTING EXPEDITIONARY AEROSPACE FORCES

**An Integrated Strategic Agile
Combat Support Planning
Framework**

*Robert S. Tripp
Lionel Galway
Paul S. Killingsworth
Eric Peltz
Timothy L. Ramey
John G. Drew*

20000121 012

Prepared for the
UNITED STATES AIR FORCE

MR-1056-AF

RAND

Approved for public release; distribution unlimited

PREFACE

This report addresses support of emerging Air Force employment strategies associated with Expeditionary Aerospace Forces (EAFs). Although much work remains to define these new responsibilities and prepare Air Force units to meet them, it is clear that the EAF concepts will play a central role in the future Air Force. EAF concepts turn on the premise that rapidly tailorable, quickly deployable, immediately employable, and highly effective air and space force packages can serve as a viable substitute for permanent forward presence in both the strategic and the tactical arenas. Success of the EAF will, to a great extent, depend on the effectiveness and efficiency of the Agile Combat Support (ACS) system.

The efficiency and effectiveness of the ACS are affected by decisions made across Planning, Programming, and Budgeting Systems (PPBS) time horizons. Far-term ACS decisions affect future support structures required to meet operational requirements with future force mixes. Mid-term¹ ACS decisions affect the design, development, and evolution of the support infrastructure for meeting operational requirements within the programming and budgeting time horizons. Near-term, or execution, decisions affect where, when, and how existing resources are employed. Across this time spectrum, logistics requirements can be satisfied in a variety of ways, each with different

¹We use the term *strategic decisionmaking* in referring to mid-term decisions to differentiate decisions that can affect ACS postures and major changes affecting the allocation of support resources versus those that are limited to using the existing posture and allocation of resources. We refer to decisions that affect the use of current resources and posture as execution decisions.

deployment requirements, timelines to employ combat capability, costs, flexibility, and risks. An integrated planning framework—one that integrates logistics, mobility, and operational planning across echelons, commands, and phases of warfare—can facilitate EAF ACS decisionmaking across the PPBS time horizons. This report presents some of our ideas on how integrated ACS planning that is aimed at mid-term, or strategic, decisions can be used to enhance the effectiveness and efficiency of EAF operations.

We argue that a detailed, continuous, careful end-to-end planning process that focuses on mid-term time horizons is required to develop the infrastructure necessary to meet the goal of becoming an Expeditionary Air Force in an effective and efficient manner. Design and development of the ACS infrastructure over these time horizons offer the potential for significantly enhancing operational flexibility, improving support responsiveness, and lowering support costs. We argue that much if not most support effectiveness comes from planning and decisions made for these longer time horizons, where options include redesigning support equipment, developing support processes and infrastructure, setting up prepositioned resources, and negotiating base access and relationships with coalition partners.

This is one of a series of RAND publications that address ACS issues in implementing the EAF. Others address alternative ACS structures, practices, policies, and technologies that can enhance the effectiveness and efficiency of the EAF. The research addressed in this report was conducted in the Force Modernization and Employment Program of Project AIR FORCE (PAF) as one element of a project entitled “Implementing an Effective Air Expeditionary Force.” This project was sponsored jointly by the Air Force Deputy Chief of Staff for Installations and Logistics (AF/IL) and the Air Force Deputy Chief of Staff for Air and Space Operations (AF/XO). The project combines research reported here with other research to identify ways of enhancing the effectiveness of Air Expeditionary Forces. This report should be of interest to logisticians, operators, and mobility planners throughout the Department of Defense, especially those in the Air Force.

Chief Master Sergeant John Drew is the Superintendent of Maintenance Analysis at the Air Force Logistics Management Agency.

PROJECT AIR FORCE

Project AIR FORCE, a division of RAND, is the Air Force federally funded research and development center (FFRDC) for studies and analyses. It provides the Air Force with independent analyses of policy alternatives affecting the development, employment, combat readiness, and support of current and future aerospace forces. Research is performed in four programs: Aerospace Force Development; Manpower, Personnel, and Training; Resource Management; and Strategy and Doctrine.

CONTENTS

Preface	iii
Figures	ix
Tables	xi
Summary	xiii
Acknowledgments	xxv
Abbreviations and Acronyms	xxix
Chapter One	
THE EXPEDITIONARY AEROSPACE FORCE AND THE NEED FOR ENHANCED COMBAT SUPPORT SYSTEM PLANNING	1
USAF Challenges in the New Security Environment: Maintaining Readiness for Major Conflicts While Supporting Frequent Deployments	1
The Expeditionary Aerospace Force	3
Agile Combat Support for the Expeditionary Aerospace Force	5
ACS Planning for Expeditionary Operations	9
Report Outline	17
Chapter Two	
AN ENHANCED STRATEGIC ACS PLANNING FRAMEWORK FOR THE EXPEDITIONARY AEROSPACE FORCE	19

Introduction	19
Elements of a Strategic Planning System	19
Summary of Enhanced ACS Planning System	32
Chapter Three	
APPLYING THE ENHANCED ACS STRATEGIC PLANNING FRAMEWORK: INFRASTRUCTURE FOR GLOBAL ADAPTIVENESS	35
Minimum Deployed Maintenance and Support Equipment Analysis	35
Intermediate Avionics Maintenance and Supply Options Analysis	38
Munitions Analysis	50
Integrating Across Commodities	56
Chapter Four	
PROCESS DEVELOPMENT TO SUPPORT CONTINUOUS EXPEDITIONARY ACS SYSTEM PLANNING: AN ORGANIZATIONAL APPROACH	59
Chapter Five	
CONCLUSIONS AND RECOMMENDATIONS	63
The Need for a New Strategic Planning Framework	63
Elements of an ACS Planning Framework for the EAF	64
Results from Illustrative Analyses	65
Organizational Changes	66
Conclusion	67
Appendix	
A. SUPPORT REQUIREMENTS DETERMINATION MODEL: MUNITIONS	69
B. SUPPORT OPTIONS ANALYSIS: MUNITIONS	81
C. SUPPORT REQUIREMENTS DETERMINATION MODEL: MINIMUM MAINTENANCE PERSONNEL AND SUPPORT EQUIPMENT	89
D. SUPPORT REQUIREMENTS DETERMINATION MODEL: AVIONICS MAINTENANCE	99
E. AEF DEPLOYMENT AND PLANNING TOOL (ADAPT)	107
Bibliography	111

FIGURES

S.1. Elements of the Strategic ACS Planning Framework . .	xvi
S.2. Scorecard for Evaluating Alternative Support Options	xviii
S.3. The Integration Model Assists in Choosing Among EAF Support Options	xix
1.1. Recent USAF Deployments	2
1.2. Combat Support System Must Meet Spectrum of Operational Requirements	7
2.1. Employment-Driven Combat Support Requirements Generation	22
2.2. Criteria for Evaluating Support Options	25
2.3. Scorecard for Evaluating Alternative Individual Resource Support Options	26
2.4. The Integration Model Assists in Choosing Among EAF Support Options	28
3.1. Modeling Unit-Level Aviation Support Package Requirements as Functions of Operational Scenario and Logistics Policies and Technologies	36
3.2. Results of Unit-Level Aviation Package Requirements Analysis	37
3.3. Employment-Driven F-15 Avionics Maintenance Model Inputs and Outputs	39
3.4. F-15 Avionics Test Station Costs for Each Option	43
3.5. FSLs Reduce Personnel Requirements	44
3.6. Additive Inventory Buy and Repair Requirements . . .	45
3.7. Cost Summary of Options	47
3.8. Personnel Deployment Requirements for Each Avionics Support Option	48

3.9. Employment-Driven Munitions Model Inputs and Outputs	51
3.10. Integrated Munitions Support Analysis	54
A.1. Structure of the Munitions Requirements Model	70
A.2. Scenario Input (Row 1)	71
A.3. Expenditure Rates by Role	72
A.4. Aircraft Loads	73
A.5. Munitions Summary	74
A.6. Aggregated Munitions Summary	74
A.7. Daily Sortie Schedule for AEF Operation	75
A.8. Bomb Requirements by Time of Day	75
A.9. Build Start Time Panel	76
A.10. Build Time and Equipment Summary Panel	77
A.11. Teams Panel	78
A.12. Inventory Panel	79
A.13. Summary Panel	79
B.1. Timelines Panel (Partial)	83
B.2. Cost Panel (Partial)	85
B.3. Summary of Options	86
C.1. Structure of the Minimum Maintenance Requirements Model	90
C.2. Scenario Input in Model Program Panel	91
C.3. Minimum Fighter Squadron Maintenance Requirements Model	93
C.4. Minimum EMS and CRS Maintenance Requirements Model	94
C.5. Support Equipment Data and Rules	96
C.6. Support Equipment Portion of the Model	97
C.7. Total Requirements Charts	98
D.1. Basic Structure of the Tester Requirements Model	100
D.2. Test Station Demand Calculations	101
D.3. Spreadsheet Model Input and Output Screen	104
E.1. CONUS Airlifter Home Base Processes	108

TABLES

3.1. Application of Integrating Model	58
E.1. CONUS Base ADAPT Processes	107
E.2. En Route System ADAPT Processes	109
E.3. Forward Base ADAPT Processes	109

SUMMARY

THE EXPEDITIONARY AEROSPACE FORCE AND THE NEED FOR ENHANCED STRATEGIC AGILE COMBAT SUPPORT (ACS) SYSTEM PLANNING

This report addresses a key challenge facing the future Air Force: how to support the nearly continuous deployments of relatively small-scale forces for peacekeeping and humanitarian relief missions while maintaining the capability to win major theater wars should that become necessary. Continuing political and economic pressures are likely to result in the basing of a larger percentage of a smaller force structure in the Continental United States (CONUS). To meet these challenges, the Air Force has formulated the new concept of the Expeditionary Aerospace Force (EAF). In this concept, the force is divided into roughly equal Air Expeditionary Forces (AEFs) which are mixtures of fighters, bombers, and tankers. Two AEFs are on-call for 90 days to provide forces for contingencies and overseas rotation, and then spend 12 months for training and exercises before facing another on-call period.

Because of the demand to respond quickly to contingencies by deploying from CONUS, the new concept presents significant support challenges. The requirement to deploy quickly places pressures on the deploying units to minimize the amount of support they deploy; the demanding employment scenarios place counterbalancing pressures on the support system to ensure that there are sufficient resources to sustain combat operations.

A complete reexamination of the support system design is required to determine how these new support challenges can best be met. Strategic Agile Combat Support (ACS) design tradeoff and investment decisions need to be made in the near term to create the ACS capabilities needed to achieve future operational requirements. These capabilities include

- Supporting the spectrum of operations from permanent rotational requirements (e.g., Operation Southern Watch) to deterrence, halt-phase operations to Major Theater Wars (MTWs), and the transitions between them.
- Dealing with uncertainty as to location and timing of deployments.
- Evolving in response to changing political situations, new technologies, and new weapon systems.

To support expeditionary operations, the Air Force will require a global infrastructure system consisting of Forward Operating Locations (FOLs) from which missions are flown, and Forward Support Locations/CONUS Support Locations (FSLs/CSLs)—regional facilities providing a selected set of support resources—and both location types must be assured resupply and a logistics command and control (C2) system to coordinate and tie together the FOLs and FSLs. This is a quite different system from either the system used during the Cold War or the austere “bring-it-all-from-CONUS” system implicitly envisioned during early discussions of the EAF. This new ACS system will require new planning methods as well.

ACS PLANNING FOR EXPEDITIONARY OPERATIONS

The ACS system and planning must operate on three different time horizons: execution (supporting ongoing operations), strategic (acquiring support resources for the current force), and long term (modifying support for new force structures). Whereas the Air Force has focused on the first, in this report we provide an integrated planning framework that addresses strategic decisions.

Given the support challenges, the following enhancements are needed to plan for an expeditionary-oriented ACS system:

- Support the range of operations. The resources needed for boiling peacetime operations may be different from those needed for MTWs. A unit may now deploy less than a squadron, although its structure and manning was based on squadron-only deployments.
- Deal with uncertainty. The planning for expeditionary operations must take into account uncertainties such as base access and location. The current planning system largely assumes a fixed configuration of equipped bases in theater.
- Evaluate alternative timelines and costs. Each of the options for achieving fast deployment (e.g., prepositioning of unit equipment) has peacetime costs that require tradeoff analyses.
- Integrate ACS planning across support functions, across theaters, and with operations. The current combat support planning system is largely stove-piped in several ways, such as by commodity and process: For example, it is unlikely that designs for engine repair would affect designs for avionics system repairs. Feedback also needs to be provided to operations planners on the support effects of alternative campaign plans.
- Integrate the development processes for technology and policy. Different actors are pursuing initiatives that are part of the overall ACS system but are formally uncoordinated below the level of the Air Staff. For example, there has been little attention given to developing a global ACS capability that can serve multiple theaters.
- Evaluate new designs. The expeditionary environment will require redesign of the support system, which will require evaluating the comparative benefits and costs of radical new systems.
- Control variability and improve performance. Ensuring that a redesigned support process is working and identifying areas for improvement will require monitoring the support system as it evolves. Feedback for system design improvements is not routinely captured by the current planning system.

AN ENHANCED STRATEGIC ACS PLANNING FRAMEWORK FOR THE EXPEDITIONARY AEROSPACE FORCE

We describe the major features of an enhanced strategic ACS planning process that is detailed, continuous, and end-to-end and focuses on mid-term time horizons. We argue that much, if not most, support effectiveness comes from planning and decisions made for these longer time horizons, where options include redesigning support equipment, developing support processes and infrastructure, setting up prepositioned resources, and negotiating base access and relationships with coalition partners.

Key elements of the ACS strategic planning system are shown in Figure S.1.

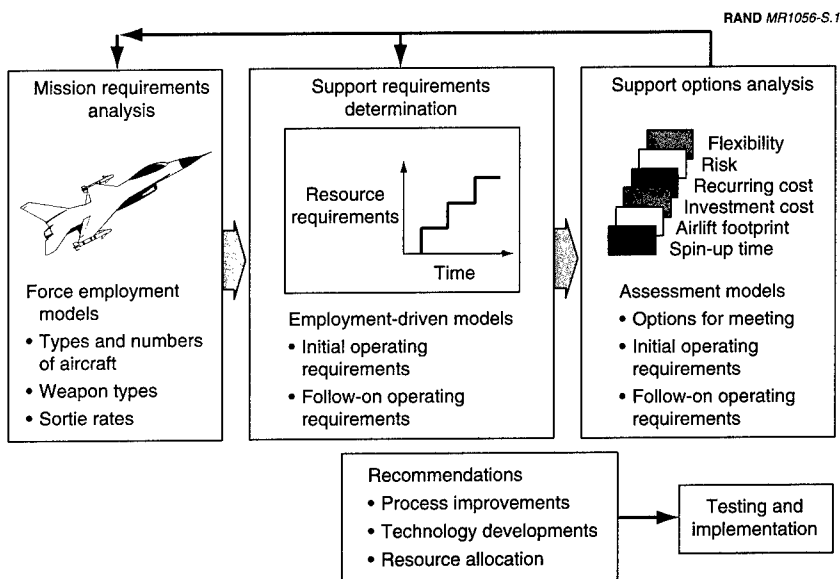


Figure S.1—Elements of the Strategic ACS Planning Framework

Operational Analysis

Operational analysis is the primary input to combat support planning; it provides inputs (e.g., force modules, sortie rates, mission types, etc.), for ACS employment-driven resource requirements determination models.

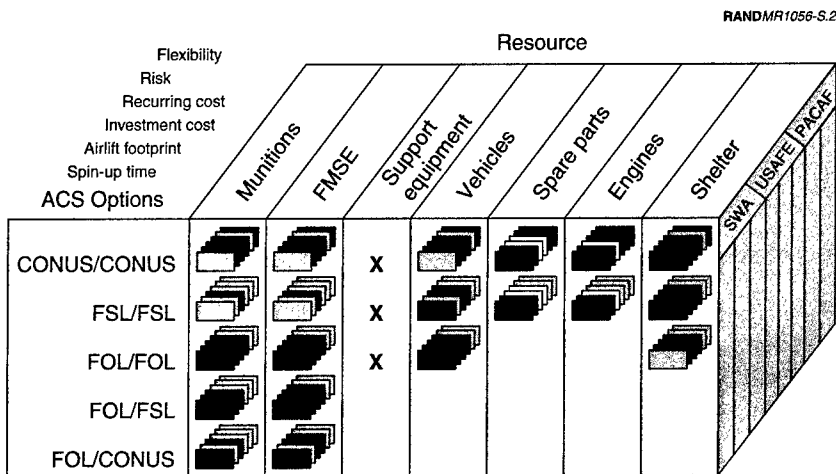
Employment-Driven ACS Requirements Generation

For ACS planning, we use a set of fairly simple, aggregated employment-driven support models to generate time-phased support requirements for each commodity as functions of the operational scenario and alternative support policies, practices, and technologies. As a part of this research, we have constructed simple spreadsheet models to compute requirements for fuel, munitions, vehicles, shelters, aviation support packages, and support equipment. We also used existing models in the spare parts analysis. We demonstrate and describe the nature of some of these models in this report.

Evaluation of ACS Options

The support options need to be evaluated in a number of ways: across the phases of operations and across a number of key metrics. These metrics include spin-up time, airlift footprint, investment cost, recurring cost, risk, and flexibility. Assessment models are used to generate metrics for use in evaluation of various options for satisfying the time-phased support requirements. The evaluations are combined into a set of multidimensional scorecards, as shown in Figure S.2 for a notional evaluation of a given commodity. The figure shows options associated with some key resources, including munitions, Fuel Mobility Support Equipment (FMSE), vehicles, and shelter. We illustrate five options:

- CONUS/CONUS: Supply the Initial Operating Requirement (IOR) and Follow-on Operating Requirements (FOR) for each resource from CONUS.
- FSL/FSL: Both IOR and FOR are prepositioned at a regional forward support location and airlifted into the reception base.



Initial Operating Requirement (IOR): less than 7 days
Follow-on Operating Requirements (FOR)

FMSE = Fuel Mobility Support Equipment

SWA = Southwest Asia

USAFE = U.S. Air Force, Europe

PACAF = Pacific Air Forces

Figure S.2—Scorecard for Evaluating Alternative Support Options

- FOL/FOL: Both IOR and FOR are prepositioned at the FOL.
- FOL/FSL: The IOR for each resource is prepositioned at the FOL and the FOR is supplied from an FSL.
- FOL/CONUS: The IOR is prepositioned at the FOL with FOR supplied from the CONUS.

Note that various other mixed strategies are possible (e.g., prepositioning all heavy munitions at bases, keeping equipment at regional centers).

Integration of Options into an ACS System

The next step was to select among these options in each commodity area to create candidate AEF support concepts. As shown in Figure S.3, we used an “integrating model” to choose among the options we

RAND MR1056-S.3

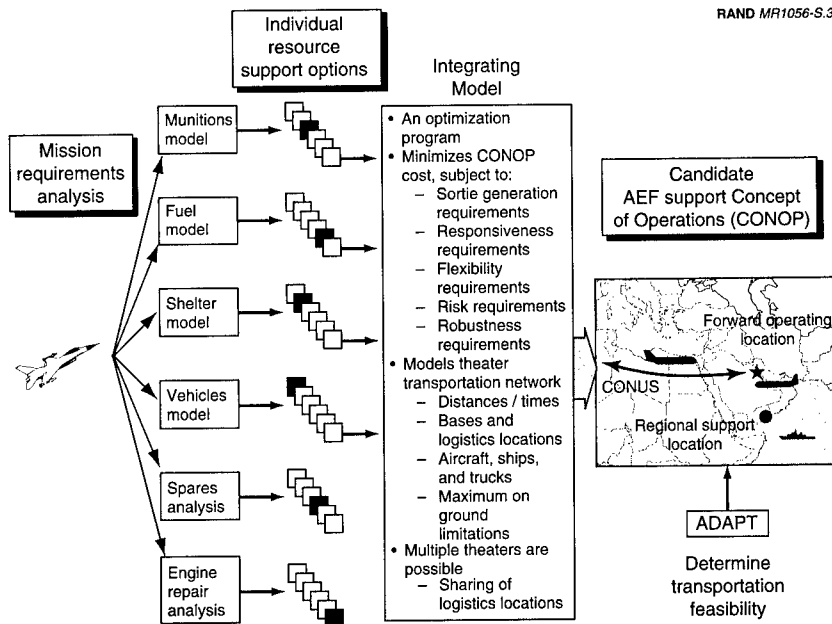


Figure S.3—The Integration Model Assists in Choosing Among EAF Support Options

analyzed. This is a mixed-integer optimization model that selects combinations of the options that meet the objective function subject to several constraints. These options represent a possible support concept for AEFs that could then be looked at more closely to consider additional issues such as the flexibility and risk of the concept and its transportation feasibility.

Integration of ACS and Mobility System

The enabling of AEF deployments requires that a multitude of mobility-related actions be set in motion, including setting up crew rest, positioning airlift at onload sites, and positioning tankers. Since mobility processes constitute a substantial portion of the overall AEF deployment timeline, an understanding of them is important to the facilitation of quick-response AEF operations. Toward this end, we

developed a high-level simulation model of the air mobility system, called the AEF Deployment and Planning Tool (ADAPT), which provides insight into the chain of mobility-related events that makes AEF deployments possible and can test the transportation feasibility of possible AEF support structures.

Feedback Loops for Control

The final element of the proposed planning framework (see Figure S.1) is feedback, which provides indications that there are discrepancies between plans and reality, along with correctional actions to solve the problem. The first feedback loop is between logistics planning and operations planning; alternative force packages can have very different support requirements and the operations planners need to know how alternative employment concepts affect support requirements and vice versa. The second feedback loop is between logistics planners for monitoring and controlling logistics processes and resource levels needed to achieve operational objectives. This feedback loop compares actual performance with planned values to ensure that the logistics system evolves as needed to support current and future operational plans and that the system achieves and maintains required support capability. The result is a continuous cycle of planning, diagnostics, improvement, and replanning.

EXAMPLES OF ENHANCED STRATEGIC ACS PLANNING CAPABILITIES: ESTABLISHING INFRASTRUCTURE FOR GLOBAL ADAPTIVENESS

We present an example of using the ACS planning framework to evaluate support alternatives for a strike AEF deployment to SWA. We investigate support requirements and options for deploying and employing an AEF composed of 12 F-15Cs, 12 F-15Es, and 12 F-16CJs. This AEF fighter package is to deploy to SWA within 48 hours after receiving deployment execution orders and sustain high sortie rates for seven or more days. The example planning analyses address aviation support, repairable avionics components, and munitions.

Aviation Support Analysis

We developed a simple rule-based EXCEL spreadsheet model to determine unit-level aviation support package requirements for the F-15E as functions of alternative operational scenarios and logistics policies, practices, and technologies. The employment-driven unit-level aviation support model incorporates rules for determining fighter squadron maintenance requirements and associated equipment maintenance and component repair functions for tasks that would need to be performed during the first seven days of operations for alternative numbers of F-15Es deployed in an AEF package. The rules can be adjusted to consider a different initial deployment period.

This model and others like it can serve as a basis for establishing aviation Unit Type Codes (UTCs) for various force packages and modules in a structured and repeatable fashion. We used the model to project the effects of not deploying the F-15E Avionics Intermediate Test Station (AIS). The model projected that relying on remove and replace (RR) actions (for the first seven days) reduces the unit deployment requirements by 44 people and 29 pallet positions. We used this information in the evaluation of alternative Readiness Spares Package (RSP) designs, discussed below.

Intermediate Avionics Maintenance and Supply Options

Regional repair of avionics components at FSLs offers advantages over the existing decentralized structure for supporting rapid deployment MTW and AEF scenarios. In this analysis, we looked at the performance of several configurations of F-15 test equipment in facilities ranging from the current decentralized shops to centralization of all repair in CONUS. As part of the centralized options, we re-designed the Peacetime Operating Stock (POS) and the RSPs, and created a new centralized inventory buffer, the Consolidated Support Package (CSP) to help ensure avionics components would be available when requisitioned from deployed units. Our analysis found that the consolidated structures have less total system cost, reduce deployment footprints, and may help reduce personnel turbulence. These benefits come with increased transportation risk and some

political risk, which depends on the locations of the regional facilities.

Munitions Analysis

Because of its bulk and special characteristics, munitions support deserves special attention for EAF operations. Our analysis uses an employment-driven model to determine munitions, munitions equipment, and personnel requirements. We then use assessment models to compute metrics to compare the performance of various options for satisfying those requirements. The options include prepositioning IORs of munitions and missiles at an operating FOL, prepositioning these commodities at an FSL, deploying these commodities from CONUS, and mixed options where missiles were deployed to the FOL from either an FSL or CONUS while the IORs of heavy munitions were prepositioned at the FOL. No one alternative dominates the rest in all dimensions, but the mixed options provided the best compromise in cost, speed, and risk.

Integrating Across Commodities

The three examples demonstrate how an employment-driven analytic framework can be used to help evaluate single commodity support options. Although graphical displays such as the “scorecard” we have used here can help evaluate options across commodities, a more rigorous tool is needed. We have developed a mixed-integer optimization model to select the least-cost combinations of the options that satisfy various delivery criteria for meeting deployment and employment timelines. For a single operational theater, Southwest Asia, this automated tool selected a set of support options in each of the commodity areas that represented a possible support concept for AEFs that could then be looked at more closely to consider additional issues such as the flexibility of the concept and its transportation feasibility.

ORGANIZATIONAL DESIGN AND PLANNING PROCESS MODIFICATIONS TO SUPPORT STRATEGIC COMBAT SUPPORT SYSTEM PLANNING

To effectively use the framework we have described, the Air Force must embed this framework in a continuous strategic planning and development process and assign organizational responsibilities for exercising that process. Integration and coordination are required across operational units, across functions, between logistics and operations, across phases of operations, and across the various planning time horizons. However, current support system design and development decisions are highly fragmented across Air Force organizations; no one agency has responsibility and authority to integrate and rationalize ACS strategic planning from an Air Force perspective.

Although requirements would probably come from the Major Commands (MAJCOMs), there are several possibilities to accomplish the integration. One way would be to create a Director for ACS Design and Development in AF/IL with each of the functional areas represented. A second way would be to form an ACS Technology Planning and Policy Integrated Process Team with representation from the MAJCOMs. A third way would be to retain AF/XOP, and particularly AF/XOPE, which is working on many of these issues. In all cases, modeling support could be through AF/SAA.

The Air Staff could delegate most of the implementation responsibilities to the MAJCOMs in a system of centralized control but decentralized execution. Alternatively, the responsibility for acquisition and maintenance of the global support infrastructure could be the responsibility of an SPO (System Program Office) infrastructure at Air Force Materiel Command (AFMC), who would be responsible for building the infrastructure and ensuring that its performance meets the operators' needs.

CONCLUSION

The EAF concept is a radical departure from past Air Force employment concepts and requires a major rethinking and reorganization of the ACS planning process to meet its ambitious goals. An integrated,

continuous planning process, with feedback to control support system performance against goals will allow the Air Force to realize the full potential of expeditionary operations.

ACKNOWLEDGMENTS

Numerous persons inside and outside the Air Force have provided valuable assistance and support to our work.¹ We thank General John Jumper for initiating this study when he was Deputy Chief of Staff, Operations (AF/XO), and Lieutenant General William Hallin, Deputy Chief of Staff, Installations and Logistics (AF/IL), for his sponsorship and support. General Patrick Gamble has been a staunch proponent of this effort as well. Lieutenant Generals Esmond (AF/XO) and Handy (AF/IL) have enthusiastically supported this effort. Dr. Robert Wolff, when he was AF/ILX, provided valuable guidance and assistance throughout the research. Ms. Sue O'Neal (AF/ILX) has continued to support and sponsor this research.

At the Air Staff, we thank Major General Zettler and Mr. Dunne (AF/ILM), Brigadier General Stuart and Colonel Totsch (AF/ILS), Brigadier General Petersen (AF/ILT), and their staff for their support and critique of this work. In particular, we thank Colonels Leonard, Toole, Sandiford, Brewer, Gunnselman, and Boatright; Lieutenant Colonels Virostko, Melendrez, and Seawell; and Major Romero for their time in reviewing and providing valuable feedback on earlier versions of the briefing.

We have enjoyed support for our research from the Air Force's Major Commands responsible for implementing the EAF. Major General Dennis Haines (ACC/LG) and Brigadier General Terry Gabreski

¹This report is the result of a research program that has been continuing for several years. Some of the individuals mentioned here have left the positions where we had contact with them, have been promoted, or have retired.

(USAFE/LG) provided access to personnel and data at their operating locations. Colonel Lowman (USAFE/LGX) and MSgt Scott Carter (USAFE/LGXX) helped arrange visits to USAFE bases and facilitate data collection efforts on logistics operation, and provided keen insights into their area of responsibility (AOR). Colonel Daup (ACC/LGS) and Colonel Austin (USAFE/LGS) sponsored briefings to the ACC and USAFE staff to fully vet the ideas in this study. Lieutenant General Cranston (AFMC/CV) and Colonel Dehnert (AFMC/LG) encouraged us to show how our research could provide insights for AFMC on how to most effectively support the implementation of the EAF.

Colonel Michael Weitzel (CENTAF/LG), Major Philip Moore (CENTAF/LGXX), Captain Jennifer Murphy (CENTAF/LGT), SMSgt Anthony Locker and MSgt Michael Barton (CENTAF/LGSF), and MSgt James Tucker and MSgt Matthew Madison (CENTAF/LGMM) helped in arranging visits to Southwest Asia, answered numerous questions, and provided keen insights into the AOR and data on logistics operations.

Several AEF deploying units provided complete access to deployment and employment processes and data. We thank Major General Lance Smith (4th FW/CC), Colonel Gail Duke (4th FW/LG), and Colonel Modlin (4th FW/LG) for supporting our visits to Seymour-Johnson AFB and at the deployed site in Southwest Asia (SWA) in collecting information on AEF IV. We also thank the 20th Fighter Wing (FW) for supporting visits to Shaw AFB and the 169th FW for supporting visits to McEntire Field. We thank Colonel William Clark (366th FW/LG) and Colonel Gail Duke (366th FW/LG) for their help in supporting our data collection efforts on the 366th AEF VI deployment to SWA.

Our research has been a team effort with the AF Logistics Management Agency (AFLMA); the support of the AFLMA has been critical to the conduct of this research. We wish especially to thank Colonel Richard Bereit (AFLMA/CC), and Lieutenant Colonel Mark McConnell (AFLMA/LGM), MSgt Eric Mazlik, and Major Theodore Lewis for their support. Randy King of the Logistics Management Institute (LMI) has contributed to our analysis involving spare parts. Colonel Donald Okrup, Lieutenant Colonel Jeff Nueber, and Captain

Jeff Meserve of the AEF Battle Lab have been helpful in collecting data and validating our models.

Finally, we wish to thank our action officers, Lieutenant Colonel Tony Dronkers (AF/ILXX) and Major Ernie Eannarino (AF/XOCD) for their encouragement and support. We also thank Bob Johnson and Captain Joe Martin, Armstrong Lab, for their assistance in collecting data on deployment planning technology initiatives. And at RAND, Hy Shulman, Ray Pyles, Bob Roll, Charlie Kelley, and Lieutenant Colonel Richard Modell (Air Force Research Fellow) have made key contributions to the research reported here. We thank Tom Hamilton and John Folkeson for their thoughtful and thorough review and critique of this work. We thank Gina Sandberg for working many hours on preparing numerous project memoranda, briefings, and iterations of an early draft of this document that led to the publication of this report.

ABBREVIATIONS AND ACRONYMS

ABAM	Aircraft Beddown Allocation Module
ACC	Air Combat Command
ACS	Agile Combat Support
ADAPT	AEF Deployment and Planning Tool
ADVON	Advance Party
AEF	Aerospace Expeditionary Force
AEG	Aerospace Expeditionary Group
AES	Aerospace Expeditionary Squadron
AEW	Air Expeditionary Wing
AFB	Air Force Base
AFFOR	Air Force Component
AF/IL	Air Force Deputy Chief of Staff for Installations and Logistics
AFLMA	Air Force Logistics Management Agency
AFMC	Air Force Materiel Command
AFSAA	Air Force Studies and Analysis Agency
AFSC	Air Force Specialty Code
AF/XO	Air Force Deputy Chief of Staff for Air and Space Operations
AGE	Aerospace Ground Equipment
AGSE	Aerospace Ground Support Equipment
AIS	Avionics Intermediate Test Station
AMC	Air Mobility Command

AMX	Air Mobility Express
AOR	Area of Responsibility
ASM	Aircraft Sustainability Model
ATO	Air Tasking Order
BCAT	Beddown Capability Assessment Tool
BDS	Battlefield Distribution System
BOT	Bombs on Target
C2	Command and control
CAP	Combat Air Patrol
CENTAF	Central Command Air Force
CINC	Commander in Chief
COMAFFOR	Commander Air Force Component
CONOP	Concept of Operation
CONUS	Continental United States
CRS	Component Repair Squadron
CSAF	Chief of Staff of the Air Force
CSI	Consolidated Serviceable Inventory
CSL	CONUS Support Location
CSP	Consolidated Support Package
DARPA	Defense Advanced Research Projects Agency
DMAS	Dyna-Metric Assessment model
DSO	Designated Support Objective
DSS	Decision Support System
DT	Design Tool
EAF	Expeditionary Aerospace Force
EARTS	Enhanced Aircraft Radar Test Station
ECM	Electronic Countermeasure
EMS	Equipment Maintenance Squadron
EOR	End of Runway
ESTS	Electronic System Test Set
EW	Electronic Warfare
F/S	Flightline Support

FFRDC	Federally Funded Research and Development Center
FLL	Forward Logistics Location
FMC	Fully Mission Capable
FMS	Foreign Military Sales
FMSE	Fuel Mobility Support Equipment
FOC	Final Operations Capability
FOL	Forward Operating Location
FOR	Follow-on Operating Requirements
FSL	Forward Support Location
GA	Ground Attack
GBU	Guided Bomb Unit
HARM	High-Speed Anti-Radiation Missile
HNS	Host Nation Support
ILM	Intermediate Level Maintenance
IMP	Inventory Management Plan
IOC	Initial Operating Capability
IOR	Initial Operating Requirement
JCS	Joint Chiefs of Staff
JEIM	Jet Engine Intermediate Maintenance
JFACC	Joint Forces Air Component Commander
JPT	JFACC Planning Tool
JTF	Joint Task Force
LOGCAT	Logistics Contingency Assessment Tool
LRU	Line Replaceable Unit
MAJCOM	Major Command
MAP	Mission Area Plan
MDS	Mission Design Series
METS	Mobile Electronic Test Set
MICAP	Mission Impaired Capability, Awaiting Parts
MIP	Mission Investment Plan
MOG	Maximum on Ground

MOOTW	Military Operations Other Than War
MSC	Military Sealift Command
MTMC	Military Traffic Management Command
MTW	Major Theater War
NAF	Numbered Air Force
NBC	Nuclear, Biological, Chemical
NMC	Not Mission Capable
NOP	Non-optimized
NOTAM	Notice to Airmen
NSN	National Stock Number
OODA	Observe, Orient, Decide, Act
OSD	Office of the Secretary of Defense
OST	Order and Ship Time
PAA	Primary Assigned Aircraft
PACAF	Pacific Air Forces
PAF	Project AIR FORCE
PDM	Programmed Depot Maintenance
PGM	Precision Guided Munitions
POL	Petroleum, Oil, Lubricants
POM	Program Objective Memorandum
POS	Peacetime Operating Stock
PPB	Planning, Programming, Budgeting
PPBS	Planning, Programming, and Budgeting System
PSAB	Prince Sultan Air Base (Saudi Arabia)
QDR	Quadrennial Defense Review
RAEF	Rapid Air Expeditionary Force
RAM	Rapid Ammunition Mobility System
RR	Remove and Replace
RRR	Remove, Repair, and Replace
RSP	Readiness Spares Package
SBS	Small Bomb System
SEAD	Suppression of Enemy Air Defenses

SORTS	Status of Resources and Training System
SPO	System Program Office
SRU	Ship Replaceable Unit
SWA	Southwest Asia
TALCE	Tanker-Airlift Control Element
TDS	Theater Distribution System
TISS	Tactical Electronic Warfare Intermediate Support System
TPFDD	Time-Phased Force and Deployment Data
TPIPT	Technology Planning Integrated Product Team
TPPIPT	Technology Planning and Policy Integrated Process Team
TRAP	Tanks, Racks, and Pylons
USAFE	United States Air Force, Europe
USTRANSCOM	U.S. Transportation Command
UTC	Unit Type Code
VAL	Vehicle Authorization Listing
WCDO	War Consumable Distribution Objective
WCMD	Wind-Corrected Munitions Dispenser
WMP	War Mobilization Plan
WPARR	War Plans Additive Requirements Report
WRM	War Reserve Materiel
WSMIS	Weapon System Management Information System

Chapter One

THE EXPEDITIONARY AEROSPACE FORCE AND THE NEED FOR ENHANCED COMBAT SUPPORT SYSTEM PLANNING

This report addresses a key challenge facing the future Air Force: how to support the nearly continuous deployments of relatively small-scale forces for peacekeeping and humanitarian relief missions while maintaining the capability to win major theater wars should that become necessary. We describe the new Expeditionary Aerospace Force (EAF) organizational and employment concepts that the Air Force has developed to deal with its range of missions, and we argue that these new concepts require a complete reexamination of the combat support system. As a corollary, the *planning* framework for combat support must also be reexamined and, because the current planning system does not address some key needs, enhanced. To a large degree future global combat capability will be dependent upon planners' choices for strategic combat support system design that will be made in the near future.

USAF CHALLENGES IN THE NEW SECURITY ENVIRONMENT: MAINTAINING READINESS FOR MAJOR CONFLICTS WHILE SUPPORTING FREQUENT DEPLOYMENTS

With the end of the Cold War, symbolized by the destruction of the Berlin Wall in 1989, the United States has entered an entirely new security environment. In the course of a decade, that environment has changed from a bipolar world where two superpowers confronted each other around the globe to a multipolar world where the United

long deployments, and increased workload, both for the deployed personnel and for the people left behind who must perform the duties of those deployed. This turbulence is blamed for further force reductions arising from decreases in retention—skilled personnel from all specialties have begun to leave the service.¹ The decreased retention, coupled with recent declining defense expenditures, has contributed to recent troubling decreases in overall readiness, which in turn raises the question of whether the Air Force can carry out its role in a Major Theater War (MTW).

The future is always uncertain, but we can expect that the Air Force will continue to be called upon to support a similar wide range of crucial missions.² Because the security environment has changed, the Air Force leadership has formulated a major change in Air Force organization and employment: the Expeditionary Aerospace Force (EAF). The new concept was formally announced in August 1998, when the Chief of Staff of the Air Force (CSAF) held a press conference to announce that the Air Force was adopting the EAF concept as its basis for responding to small-scale contingencies and outlined the basic framework for moving the force to an expeditionary posture.³ Although the CSAF emphasized that there were many details still to be decided, the EAF concept would be the key part of the Air Force's response to the new environment.

THE EXPEDITIONARY AEROSPACE FORCE

The aim of the EAF is to reduce the operating tempo (optempo) strain on the Air Force by substantially reducing the need for forward deployment of forces for deterrence and by rotating the responsibility for deployments across the Air Force's operational units in a planned schedule. In the press conference, the CSAF announced that the force would be divided into 10 Air Expeditionary

¹This has been the subject of numerous news stories. See, for example, Paul Richter, "Buildup in Gulf Costly: Expenses, Stress Surge for Military," *Los Angeles Times*, November 17, 1998. However, there is evidence that some deployments help retention (Hosek and Totten, 1998).

²Khalilzad and Ochmanek, 1997.

³Press conference August 4, 1998, at the Pentagon, held by Acting Secretary of the Air Force F. Whitten Peters and CSAF General Michael Ryan. This is the most comprehensive of several talks on the subject by General Ryan. See, for example, Ryan (1998).

Forces (AEFs), each composed of a mixture of fighters, bombers, and tankers.⁴ This organizes forces from the current predominantly single mission design series (MDS) wing structure to the 10 AEFs. For a 90-day period, two of the AEFs would supply forces for permanent rotations and be on-call, during which time forces from those AEFs could be deployed for any crisis needing air power. These forces would be tailored in size and/or capability to match the requirements of the situation.⁵ The on-call period for a unit would be followed by a 12-month period during which it would not be available for short-notice deployments or rotations.⁶ This schedule would create more predictability in planning unit activities such as training and phase maintenance. The reduction in uncertainty about sudden deployments should also improve the quality of life for personnel.

The core of the new concept is that the on-call AEF would provide highly capable force packages that could be deployed from the continental United States (CONUS) quickly, travel to deployed sites with a minimum of in-place infrastructure, be employed as soon as they arrived in theater, and sustain the required level of operations. Such a capability would deter an aggressor from an attack in the absence of permanent in-theater U.S. forces, as long as the threat was credible. To make the threat credible, therefore, the Air Force has to be

⁴Although the concept is not necessarily limited to combat forces, the focus on problems in Southwest Asia (SWA) has led to attention being given to packages of air superiority, ground attack, and Suppression of Enemy Air Defenses (SEAD) aircraft that could attack targets in that Area of Responsibility (AOR).

⁵There is a terminology problem with discussing the structure and employment of the EAF: while the basic concept has remained the same, the name has gone through several iterations. The original expeditionary force package, tailored to SWA, was a 30- or 36-ship fighter package that was termed an Air Expeditionary Force. The concept was broadened to include other types of missions, including space support (hence the replacement of Air by Aerospace). Finally, as it became clear that this would be a significant shift in Air Force culture to an expeditionary mind-set, the new organization was called the EAF, which was divided into AEFs as noted in the text. There is no general term for the force package actually deployed, although AES (for squadrons), AEG (for groups), and AEW (for wings) have been used. Here, we will use EAF and AEF as defined above, and call the actual deployed force an AEW.

⁶Recent months have seen proposals for new additions to the basic structure described here: two additional mixed-MDS wings for certain types of crises, plus a set of special-purpose humanitarian forces that would rotate the responsibility for these operations. More alterations seem likely.

able to move aircraft and support activities to any location, with a wide range of infrastructure, in a very compressed timeline.⁷

Recognizing the magnitude of the changes that are involved in implementing the expeditionary concept, the CSAF directed the establishment of a new Air Staff organization, Director of Expeditionary Aerospace Force Implementation (AF/XOP), to oversee the implementation of the EAF. The rationale for the new organization is that the shift to the EAF is a fundamental Air Force move: terms such as “cultural shift” have been used by the CSAF and other senior leaders. AF/XOP is responsible for determining how combat units will be assigned to AEFs, the timing of AEF on-call cycles, if additional personnel and equipment are needed to support the AEF operations, if command and control systems need to be modified, and how quickly deployment timelines and war mobilization plan (WMP) sustainment rates can be achieved under the new organizational framework, among other issues.⁸ Because many of the issues that need to be addressed are analytical in nature, AF/XOP tasked the Air Force Studies and Analysis Agency (AFSAA) to be responsible for conducting and/or coordinating the analysis activities associated with critical EAF implementation. After the Air Force has made the transition to expeditionary operations, AF/XOP is planned to disband, and transfer operational and planning responsibilities to (possibly reorganized) Air Staff organizations.

AGILE COMBAT SUPPORT FOR THE EXPEDITIONARY AEROSPACE FORCE

A Reexamination of the ACS System Is Needed

To meet the demanding EAF deployment and employment timelines, units must be able to rapidly deploy to the reception site and set up logistics production processes quickly. The requirement to

⁷Current drafts have a goal of 48 hours from execute order to full deployment and full operation, after a 24-hour strategic warning.

⁸Many deployments involve splitting a squadron into smaller units and deploying the smaller force package as part of a tailored AEW—for example, 12 aircraft and 6 aircraft out of an 18 primary assigned aircraft (PAA) squadron. These split operations have staffing implications, since it takes more resources to support split operations than it does to support the full squadron. We demonstrate this in Chapter Three.

deploy quickly pressures the deploying units to minimize the amount of support they deploy; base access, uncertain demands, and force protection issues place counterbalancing pressures on minimizing the amount of prepositioning at reception bases. The demanding employment scenarios require that the support system provide sufficient resources to sustain combat operations, which calls for a balanced mixture of easily deployable support processes, judicious prepositioning, and responsive resupply for the remainder of the support required.

Maintaining readiness to meet potential MTW requirements while a significant portion of the force is temporarily deployed to meet boiling peacetime commitments⁹ presents additional support challenges. The support system must be able to accommodate EAF operations at a number of possible locations, with potentially different infrastructure capabilities, in a number of theaters. The support system must be flexible enough to deal with rapidly changing events and must be able to shift rapidly from supporting one kind of operation (e.g., peacetime training operations) to another type of operation (e.g., contingency deployment and employment).

These challenges, which are quite different from those posed by Cold War employment concepts, call for a complete reexamination of the combat support system to determine how these new support requirements can be met. We begin by listing some of the most important ACS capabilities needed for expeditionary operations.

EAF ACS Capabilities

Supporting the spectrum of operations. The support system must be prepared to meet the full spectrum of likely future operational requirements. Figure 1.2 shows some of the missions on a spectrum that includes peacetime training, boiling peacetime, halt phase, and MTW operations. Many of these operational requirements place more stress on the design of the future combat support system than has been the case to date. The challenge is to develop a combat sup-

⁹“Boiling peacetime” commitments is a term coined by General John Jumper to describe the requirements to deploy a number of aerospace forces to ensure global stability.

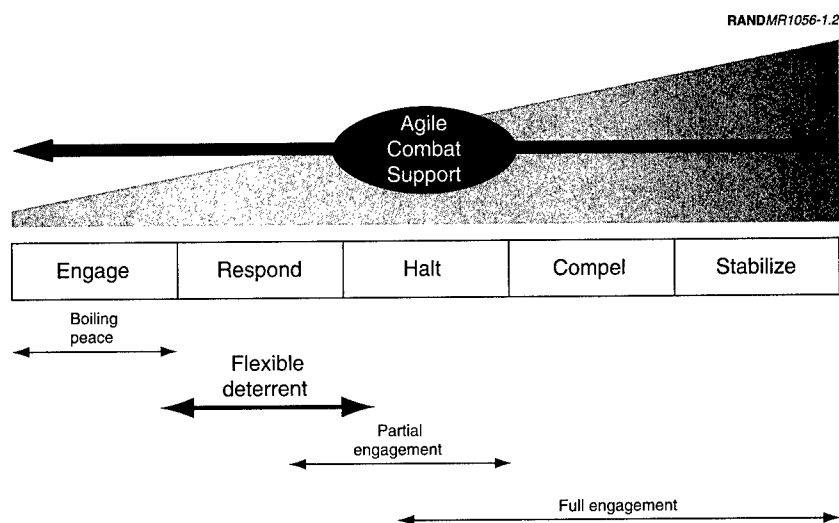


Figure 1.2—Combat Support System Must Meet Spectrum of Operational Requirements

port system design that is capable of meeting all of these requirements at reasonable risks and peacetime costs.

Examples of the different mission types include:

- Permanent rotational requirements—counterdrug operations, Operations Joint Endeavor/Joint Guard in Bosnia-Herzegovina, and Operations Southern Watch/Provide Comfort/Northern Watch around Iraq.
- AEF operational requirements. Deployment of an AEW to a theater is intended to deter aggressor action by demonstrating the commitment of the United States and its allies to engage in combat activities should aggressive acts continue. The specific AEF force is intended to have sufficient firepower to levy punitive strikes and initiate sustained combat operations should the need arise.
- Halt phase operational requirements. As a result of the Quadrennial Defense Review (QDR), analysts at RAND and the

Air Staff pointed out that the effect of air power was being systematically undervalued in some combat assessments of potential MTW force mixes. The rapid deployment of air power, they asserted, could blunt major armored attacks (such as occurred during the seizure of Kuwait by Iraq in 1990) without the necessity of engaging the enemy with large formations of friendly ground forces.¹⁰ As with expeditionary operations, halt phase operations required very fast deployment and immediate employment, as well as a demanding optempo for the first few days of the battle.

- MTW operational requirements. Even if the massive application of aerospace power does halt a potential adversary, the adversary needs to be defeated and/or driven back to his own territory. Meeting these MTW requirements mandates the development of the combat support infrastructure and resources to accomplish these objectives well before conflict is imminent.

Supporting these different types of operations also requires that the ACS system be able to gracefully deal with transitions as units are called into action, redeployed from one type of operation to another, and reconstituted.

Dealing with uncertainty. The ACS system for expeditionary operations must be ready to support operations at a much wider number of locations, rather than focusing primarily on Europe and Korea, as was the case during the Cold War. The timing of these operations may be unpredictable, as will be the precipitating crises and the forces required. Various strategies for dealing with these uncertainties will need to be formulated and included in the design of the support system (e.g., focusing resources in high-risk areas or covering multiple theaters with support from a single location).

Evolving over time. The ACS system must change over time as factors change. For example, changing political circumstances may mean that some regions that were critical to U.S. interests become stable, while others require U.S. attention. New technologies will change support requirements by providing new and lighter munitions or new shelters that are lightweight and easy to set up. New

¹⁰We are indebted to David Ochmanek and others for this point.

weapon systems may reduce maintenance requirements or may require new types of support.

The expeditionary ACS support system. Part of our research has been to develop concepts for an expeditionary system. The basic outcome of that research¹¹ is that to support expeditionary operations for today's forces and support processes the Air Force will need to forward base carefully selected capabilities. This global support infrastructure will consist of the following components:

- Forward Operating Locations (FOLs)—bases from which missions can be flown. Depending on the time-criticality of the likely missions, the FOLs will need judicious prepositioning of materiel.
- Forward Support Locations/CONUS Support Locations (FSLs/CSLs)—regional and/or CONUS facilities that provide a selected set of support resources such as materiel storage, repair of certain equipment, and transportation hubs. For today's forces, our analysis indicates that some FSLs must be located overseas.
- Assured resupply to tie together the operational FOLs and the FSLs/CSLs and a logistics command and control (C2) system to coordinate the system.

This is a quite different system from either the system used during the Cold War, which depended on deploying to fully equipped bases in known locations, or the austere "bring-it-all-from-CONUS" system implicitly envisioned during early discussions of the EAF. We will argue that this new ACS system will require new planning methods as well.

ACS PLANNING FOR EXPEDITIONARY OPERATIONS

Because expeditionary operations are so different from the Air Force's previous concept of operations, we should expect that the current ACS planning framework must also be changed. In this section we describe the various time horizons for ACS planning, explain

¹¹Galway et al. (forthcoming).

our focus on *strategic* ACS planning, and list the major characteristics of strategic planning for expeditionary support along with arguments as to why a change is needed from current planning processes.¹²

Timescales for ACS Planning

To set our research in context, it is useful to note that the ACS system (and hence planning for the ACS system) must operate on three time horizons:

- At the level of *execution* (days to weeks), the ACS system must support ongoing operations. Planning decisions are concerned with how to use existing resources to meet current EAF taskings (e.g., allocating existing transportation to meet specific deployments).
- At the mid-term or *strategic* level¹³ (months to years), the system must acquire or construct resources to support the current force structure across the full spectrum of operations and in any location critical to U.S. interests, subject to peacetime cost constraints. (This is roughly the time horizon of the Planning, Programming, and Budgeting System—PPBS). Some planning issues for this time horizon include decisions on prepositioning of resources at FOLs and establishing FSLs, and determining how resources designed to support MTWs can be leveraged to support boiling peace and other non-MTW operations such as AEW deployments without jeopardizing the MTW responsibilities.
- At the *long-term* level (decades), the ACS/mobility system and its strategic infrastructure must be modified to support new force

¹²The Air Force has a corporate strategic planning process whose primary focus is 20–25 years out, and the Air Force Long-Range Plan has, as one of its main thrust areas, “Shape Infrastructure for the Future Force.” Both of these efforts are currently in process. We hope that the planning process described in this report will help stimulate thinking in these efforts, although, as will be seen shortly, our focus is on a somewhat shorter time horizon.

¹³We use the term *strategic* because these decisions are affected not only by time horizon but also by the geopolitical strategic situation, by technology, and by fiscal constraints. As we will argue, these decisions have to be made by complex tradeoffs of risks and benefits using criteria that are strategic in the broadest sense.

structures as they come on line and to incorporate new technologies.

The time horizon for planning determines a number of key characteristics of the planning process: the response time required to construct a plan, the level of input detail, and the flexibility of the available resources. An integrated planning framework that examines operations, logistics, and mobility tradeoffs can facilitate decision-making in each time horizon.

Scope: Focus on Strategic Planning

Much of the Air Force's attention has been focused on the execution time horizon to support the EAF, where the key factors are real-time situation awareness and visibility of assets. Although the execution focus is important, our focus is on an integrated planning framework that addresses strategic decisions. Planning decisions on ACS system design and policy issues, made in peacetime, affect the logistics footprint, closure time, peacetime costs, and other metrics (such as the logistics workload that must be accomplished at the home station and within the theater) for evaluating support of expeditionary operations.

The goal of our research is to begin formulating a strategic planning process that addresses how to make decisions about infrastructure development, resource positioning at forward locations, and other policies and practices affecting logistics support. Specific questions include:

- How many FOLs should be built up in specific AORs?
- What resource levels should they have?
- Should there be FSLs or en route support bases to serve various AORs? What functions should they perform?
- How many FSLs should there be?
- What policies should govern opening and closing FOLs and FSLs?
- Should scheduled maintenance activities be accomplished early to reduce workload and logistics footprint in the deployed AOR?

If so, what scheduled maintenance policies should be adopted to keep a set of aircraft ready to deploy? How do alternative maintenance policies compare with today's policies of dealing with scheduled maintenance on a subsystem basis?

- How large should home station units be to manage preparation and reconstitution workload and minimize effects on overall readiness?
- What are appropriate staffing standards for the EAF of tomorrow?

Answers to such questions must be developed by examining how functional processes (logistics, operations, and mobility) interact across command lines, echelons, and phases of operations. An integrated strategic planning framework that addresses how these processes interact to produce time-phased sortie generation capability and resource requirements would provide a powerful means to evaluate combat support system design options.

Characteristics of ACS Planning in the EAF Environment

In general, a strategic ACS planning system for the new environment needs to reflect how alternative logistics designs affect the time to achieve the desired operational capabilities, peacetime costs, risks, flexibility, and to provide feedback on how the existing ACS system is meeting the spectrum of operational requirements. In comparing the current planning system's remaining Cold War structure and orientation with the ACS planning requirements of the EAF concept, we argue that enhancements must be made in the following areas to plan for an expeditionary-oriented ACS system.

Supporting the entire spectrum of operations. The current planning system assumes that combat support capabilities designed for MTW scenarios (especially the mass of materiel) can handle any other situation. However, it may well be that the resources required to support boiling peacetime operations are more than or even different from those required for MTWs. For example, current planning assumed that squadrons would deploy and fight as a single unit and their personnel and support equipment were accordingly designed for squadron-level deployments. This is no longer the case: current peacetime deployments involve deploying only portions of

squadrons (e.g., 12 or even six aircraft) and EAF operational concepts explicitly call for force packages of subsquadron size that are tailored for specific missions. As another example, the current planning system assumes that the key transition for the ACS system is from peacetime to MTW operations. Other transitions include moving from supporting boiling peacetime operations and one or more AEWs to MTW operations.

Dealing with uncertainty. Expeditionary operations are fraught with uncertainty. For example, access to a specific set of bases may be a problem, as it has been in SWA on several occasions.¹⁴ A number of reception sites may have to be prepared to support combat operations, and minimum prepositioning of resources located at a number of potential sites (possibly outside the theater of operations) to increase the probability of access. This in turn places a burden on responsive resupply operations to maintain operations at high tempos. Expeditionary ACS planning must decide on the locations and prepositioned materiel for the FOLs as well as estimate and provide for resupply of sufficient capacity. In contrast, the current planning system, with its focus on MTWs, has largely assumed that a fixed configuration of well-equipped bases will be available in theater.

Evaluating alternative deployment/employment timelines and associated costs. The current canonical MTW scenarios assume that there is sufficient strategic warning to spend days or weeks closing a force to meet the planning threat. The EAF emphasis on rapid deployment timelines must be explicitly taken into account when designing the future ACS system. However, each of the options for achieving fast deployment (e.g., prepositioning of unit equipment, developing FOLs with adequate facilities and resources to support rapid deployments and immediate employment, or developing host nation support agreements) has peacetime costs that require tradeoff analyses. For instance, the timeline associated with prepositioning materials at FOLs may meet the requirement, but it might be very expensive to preposition materials at all of the FOLs required to support EAF operations worldwide. On the other hand, the time-

¹⁴During Operation Desert Thunder, Saudi Arabia would not allow combat operations to take place from its soil, and other Gulf States such as Bahrain have shown similar reluctance about allowing operations from their territory. See *Los Angeles Times*, "U.S. May Need New Battle Plan, Experts Say," February 25, 1998, p. A10.

lines might be slightly longer if materials were held at regional storage sites, but the cost might be significantly lower. The ability to make these kinds of tradeoffs is integral to future strategic ACS system planning, but the current Air Force support planning system has not had to address these issues.¹⁵

Integrating ACS planning between support functions, between theaters, and with operations. The current combat support planning system is largely stove-piped in several ways. First, each commodity and process is viewed independently in terms of generating resource requirements. For instance, if regional repair designs for engines are developed, it is unlikely that how this strategic design may affect designs for avionics system repairs would be systematically considered. Second, both the theater Air Component Commands (e.g., for CENTAF) and the Air Staff have roles in determining logistics requirements. Some of these requirements, such as munitions, are centrally computed and allocated to the theater Commanders in Chief (CINCs). Others may be computed by the Air Component Commands and sent forward to the Air Staff for approval. In this fragmented process, opportunities to develop consolidated support operations or other policies that may support more than one theater may be missed. Examples include consolidated engine repair facilities and en route support bases that could serve as central distribution hubs for both the European and SWA theaters, coalition support facilities that may be closer and more responsive than CONUS options for serving deployed units,¹⁶ and the allocation of War Reserve Materiel (WRM) resources.¹⁷ Finally, feedback needs to be

¹⁵Logistics planners in several Major Commands (MAJCOMs) (especially Central Command Air Force, CENTAF) have had to develop their own methods.

¹⁶An example might be to develop engine support facilities with the F-16 European Participating Governments (EPG) or other consortiums. The EPG was a consortium of governments that engaged in coproduction of the F-16 in cooperation with the United States. Under this arrangement, several components of the F-16 were produced in EPG countries with assembly in Europe.

¹⁷The effective use and management of WRM assets is integral to ACS and the EAF concept. There are several issues with current WRM management practices that impede their effective support of EAF operations: inconsistent requirements determination, incomplete asset visibility, and malpositioning of worldwide assets. The War Plans Additive Requirements Report (WPARR), War Consumable Distribution Objective (WCDO), Vehicle Authorization Listing (VAL), and Inventory Management Plan (IMP) are all derived from the USAF War and Mobilization Plan and other planning factors. These serve as the primary authorization documents for WRM that filter

provided to operations planners on the support effects of alternative campaign plans. Different employment concepts yielding the same operational effects can have very different impacts on deployment timelines, sustainment capabilities, and costs. The effects of different employment concepts need to be considered as an integral part of strategic operational planning.

Integrate the assessment and development process for technology and policy. Many different actors in technology and policy are pursuing initiatives that are part of the overall ACS system but are formally uncoordinated below the level of the Air Staff. For example, in lean logistics, the Air Mobility Command (AMC) is actively engaged in evaluations of Air Mobility Express (AMX) and Theater Distribution System (TDS)¹⁸ to determine how to improve time-definite delivery. The Air Force Materiel Command (AFMC) is examining ways to improve supply responsiveness, but these efforts have been primarily directed toward organic depot-level activities and have not addressed the role of forward-based infrastructure. Air Component Commands such as CENTAF have developed theater-

down to the base level. Most of these documents continue to be based upon Cold War MTW scenarios. There is no direct automated link between changes in operational plans and supporting WRM assets. In a similar vein, there is no direct correlation between deploying unit size (or mission profile) and the apportioned WRM for that unit.

There is also significant variation in how MAJCOMs view the two main classifications of WRM assets. There are differing views among MAJCOMs as to which are starter assets—those intended to support operations until resupply can be established—and which are swing assets—assets set aside to support the theater CINC but that can be redirected as needed. With the inconsistency among MAJCOMs as to which assets are starter and which are swing, MAJCOMs are unable to ensure that assets are prepositioned correctly. The lack of a worldwide distribution strategy further complicates the use of existing WRM assets. Since MAJCOMs are the highest level of integration for WRM management, each individual MAJCOM/Air Component acts on its own when allocating starter/swing stocks in support of the Defense Planning Guidance. The result is the failure to identify areas where duplication of effort and asset misallocation are taking place. Furthermore, current policy (AFI 25-101), links WRM positioning to theater-level war scenarios. This positioning policy is suboptimal for supporting the spectrum of global operations, such as AEF and Military Operations Other than War (MOOTW), which may or may not promulgate according to MTW scenarios. SOURCES: Headquarters, USAF (1997); a briefing by Capt. Boley of the Air Force Logistics Management Agency, "WRM Tiger Team Report"; and Crowley and Smith (1998).

¹⁸AMX is a plan for wartime fast delivery from CONUS to theater using a combination of military and commercial airlift. TDS is a plan for distribution within theater using various forms of military transport.

specific infrastructure (such as bases and regional support facilities) to meet specific war plan requirements. And the Air Staff has supported development of systems that track order and ship time (OST) and retrograde transportation. In all of this activity, little attention has been given to developing a global ACS capability that can serve multiple theaters. Similarly, in developing technology for maintenance, air base support, and mobility, actors such as AFMC, Air Combat Command (ACC), and AMC pursue individual uncoordinated initiatives. These processes all include portions of the combat support systems requirements, but they are not integrated before they reach the Air Staff panels. Even here they are stove-piped, and the opportunity to view combat support as a system is not addressed as a matter of routine.

Evaluating new designs. The expeditionary environment will require major rethinking and significant redesign of the support system to cover the spectrum of operations and integrate previously fragmented support processes. Based on our experience, the current strategic planning process was not developed to consider radical departures from the current system, being geared instead toward evaluating marginal changes to existing capabilities baselines. For instance, when considering the manning issues associated with sub-squadron split operations for AEFs, current maintenance practices require more resources than squadron-size operations. Current planning focuses on estimating how much more. Although it may be true that more personnel and support equipment are needed for “on-equipment maintenance,” consolidating backshop maintenance activities in a regional facility may reduce overall personnel requirements and help pay the bill for additional flightline maintenance personnel.

Controlling variability and improving performance. Finally, ensuring that a redesigned support process is working and identifying areas for improvement will require monitoring the support system as it evolves. A few critical parameters drive wartime and peacetime requirements for resources. Although many parameters used in computing wartime resource requirements are not observable during boiling peacetime operations, observations of a few key parameters may provide insights as to expected wartime values. Some of the more important parameters include OSTs, retrograde transportation times to sources of repair, consolidated serviceable WRM stock lev-

els, transit times to reception bases, and so forth. Some of these parameters are not measured. In other cases where a parameter may be measured, there is little attempt to control variability. OST is a good example of the latter. No single person or organization is in charge of performance because responsibilities are fragmented over the various segments of the supply and maintenance systems. Thus, feedback for system design improvements is not routinely captured. Furthermore, the impact of current logistics process performances on wartime operational capability is not routinely estimated. This attention could result in highlighting consistent underperformance and lead to system redesign if warranted.¹⁹

We note that a planning process that has these characteristics helps long-term planning as well, in that the goal of continuous performance improvement and focus on evolution of the support system for changing circumstances provide a stream of improvement actions for a long-term planning system to evaluate and plan to implement.

REPORT OUTLINE

Chapter Two outlines the ACS planning framework that we have developed to examine strategic support issues associated with the EAF of tomorrow. Chapter Three illustrates how the planning framework can be used to provide strategic direction for the development of the logistics infrastructure for three key resources—munitions, engines, and reparable components—and the processes associated with them. Chapter Four presents ideas for implementing the new combat support planning process, including a tentative organizational design. Chapter Five presents our conclusions and summarizes recommendations for implementing the planning process. Appendices A through E outline the features and characteristics of the munitions, support options assessment, minimum maintenance personnel/equipment, avionics support models, and the mobility model ADAPT.

¹⁹For more details, see Pyles and Tripp (1982).

**AN ENHANCED STRATEGIC ACS PLANNING
FRAMEWORK FOR THE EXPEDITIONARY
AEROSPACE FORCE**

INTRODUCTION

This chapter describes the major features of an enhanced ACS planning process. We argue that a detailed, continuous, careful end-to-end planning process that focuses on strategic time horizons is required to develop the infrastructure necessary to meet the goal of becoming an Expeditionary Aerospace Force in an effective and efficient manner. Design and development of the combat support infrastructure over these time horizons offer the potential for significantly enhancing operational flexibility, improving support responsiveness, and lowering support costs. We argue that much, if not most, support effectiveness comes from planning and decisions made for these longer time horizons, where options include redesigning support equipment, developing support processes and infrastructure, setting up prepositioned resources, and negotiating base access and relationships with coalition partners.

ELEMENTS OF A STRATEGIC PLANNING SYSTEM

The system begins with operational analysis to determine likely force modules that will be needed to meet the spectrum of EAF operational requirements in various AORs. Employment-driven logistics requirements determination models use the operational information to compute requirements for logistics resources and

processes as functions of alternative policies, practices, technologies, and uncertainties. Options for satisfying these requirements are then evaluated in terms of how they affect key metrics such as operational effectiveness, timeline, mobility resources, peacetime costs, risks, and flexibility. Finally, the system measures actual parameters of logistics process performance and resource levels for critical resources against the planned values and alerts designers of significant deviations for use in system control, system redesign, or plan modifications.

Operational Analysis

Operational analysis is the primary input to combat support planning; combat support planners need to know the characteristics of the force that they will be required to support such as its size, equipment, weapons, required arrival times, optempo, and so forth. The operational planning process is generally a modeling exercise in which forces are determined to meet various scenarios. We discuss operational modeling in some detail in this chapter for two reasons. First, a new approach to such modeling has been proposed for strategic planning purposes, and second, this approach to operational analysis is the basis for our approach to ACS strategic planning.

Currently, many operational analyses for mid-term time horizons use detailed computer models of engagements between various forces. The models focus on the detailed interactions of individual and aggregations of weapon systems, trying to capture with great fidelity platform movements, target acquisition, and weapon effectiveness; the models typically do not include logistics. The problem with using such detailed models for strategic planning is that there is considerable uncertainty about virtually all parameters that characterize the forces, and, since such complex models are time-consuming to specify and run, analysis of different scenarios is necessarily limited.

A new approach to operational analysis, exploratory modeling, has been proposed by Davis and co-workers.¹ This approach argues that

¹See Banks (1992); Banks (1993); Brooks et al. (1996); and Davis and Carrillo (1997).

simpler, aggregated models are more appropriate for the broader analyses required by operational strategic planning. Such models are easier to specify² and run than the usual detailed models by orders of magnitude and therefore can be used to swiftly screen many different courses of action. Further, they also allow for a more thorough analysis of uncertainty by making it possible to explore many different scenarios as well. The result is a better picture of both the effects of different parameter values on the outcomes *and* of the range of scenarios in which a given planning solution gives good results.

Exploratory modeling performs hundreds of model runs with a carefully chosen set of parameters and scenarios and then uses multidimensional graphical displays to show the dependence of outcomes on both parameters and scenarios. The aim is twofold:

- To determine which parameters are important in determining the success of an operation and what their critical values are.
- To determine in which set of scenarios a particular choice of parameters gives a successful outcome. This allows the analyst to determine if a particular planning solution is robust across different scenarios and, in particular, whether it is successful in scenarios that are either highly likely or crucial.

The output of such an analysis can be shown as a multidimensional “stoplight” chart, in which the colored panels indicate whether the outcome is good, bad, or ambiguous (green, red, yellow) according to the values of key parameters. The critical values of those parameters can then be compared with the parameters of actual forces to assess whether the forces are adequate. The result of this form of operational analysis is an operational plan that is robust over various scenarios.

²Davis and his colleagues argue that for strategic planning, where there are often substantial uncertainties in parameter values, precise specification of details is not appropriate. See the articles in Paul K. Davis (ed.), *New Challenges for Defense Planning*, RAND, MR-400-RC, 1994.

Employment-Driven ACS Requirements Generation

We call our approach to requirements generation “employment-driven” because it starts with the results of the operational analysis: the forces, weapons, optempo, and required timelines. These key parameters in turn determine most of the support requirements. This step is the leftmost panel in Figure 2.1, which depicts our overall approach to analyzing support requirements. The middle panel represents the requirements determination model, which generates time-phased combat support requirements for each support resource as a function of the operational requirements and alternative logistics policies, practices, and technologies.

Like operational planning, ACS planning is beset by uncertainties and options. The framework proposed here, therefore, uses a similar approach to the one described above: We have constructed simple

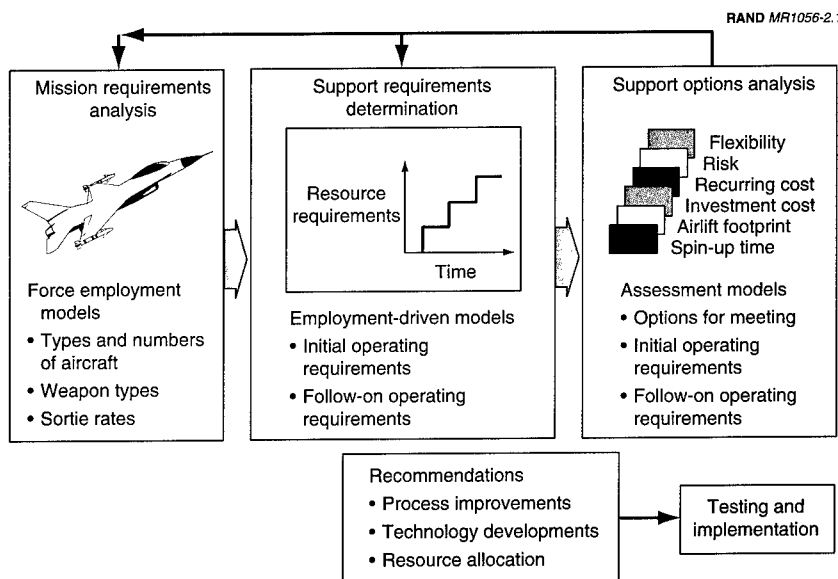


Figure 2.1—Employment-Driven Combat Support Requirements Generation

spreadsheet models to compute requirements for fuel, munitions, vehicles, support equipment, and shelters. These relatively simple models provide enough detail to estimate the personnel, equipment, and commodity requirements to support alternative operational requirements, and the time frames required to assemble the production function for those commodities and sustain operations for the scenario provided. For instance, in the fuel model, the refueling system requirements (e.g., number of R-9 refuelers) are determined by the aircraft launch sequence, aircraft fuel acceptance rates and capacities, and refueling system flow rates. For refueling by truck, the system flow rate would be determined by the truck acceptance rate, the distribution system pumping rate (e.g., fill stand), and the driving time to and from the fill stands. Although not a detailed simulation of the fuel support operation, the model can be used to compute requirements for a number of fuel reception, storage, and distribution methods. The munitions model has similar detail to determine requirements for personnel, equipment, and munitions for a wide variety of weapon systems and munitions types.

To determine engine repair and inspection requirements and associated personnel and equipment workload, we had to develop new algorithms and modeling technology. In other cases, suitable models exist or can be modified to generate requirements for resources. Such is the case for spare parts. The Aircraft Sustainability Model³ provides requirements for spares as a function of optempo, force module size, maintenance concept, resupply times, and so forth.

As noted in the second panel of Figure 2.1, two of the key outputs from the requirements determination models are the Initial Operating Requirement (IOR) and Follow-on Operating Requirement (FOR) for each resource (if applicable). The IOR is the amount of resource that is necessary to initiate and sustain operations while resupply pipelines are initiated for that resource. In the case of munitions, three days may be required to reestablish munitions resupply. Thus, three days of munitions would be the IOR. The FOR is the projected amount of the resource that is required during the remainder of the planned operation. The FOR can be delivered

³See Slay (1996).

periodically to keep the flow of resources into the FOL easy to handle by a relatively lean forward support force. The parameters are the key to determining deployment resources and timelines, and sizing the resupply capability, respectively.

Evaluation of ACS Options

The simplicity and speed of the employment-driven models allow requirements to be computed for a number of different cases that include both alternative support options and employment alternatives. We now proceed to the process pictured in the third panel of Figure 2.1: the analysis of support options. This process involves the use of support options assessment models. Appendix B describes their features and characteristics.

The support options for various commodities need to be evaluated across the phases of operation (peacetime operations and readiness preparation, deployment, employment/sustainment, redeployment, and reconstitution). As with operational analysis, the aim is to identify support options that provide good performance (in terms of the set of metrics) across all phases of operation and across a range of potential scenarios (the number and range depending on the time horizon under consideration). Again, tradeoffs may have to be made across the scenarios and the metrics (e.g., a low-cost option may have a large risk). This approach allows these tradeoffs to be made with a clear picture of the effects across options and scenarios.

Figure 2.2 shows illustrative criteria⁴ for evaluating alternative ACS options with regard to six central metrics. Our assessment models compute values for the first four metrics: spin-up time, airlift footprint, investment costs, and recurring costs; analysts assign values to the other two qualitative criteria: risk and flexibility. Risk and flexibility are used to evaluate such factors as probability of access to specific bases, availability of airlift when needed, ability to control movement of resources and people, and so forth.

⁴The criteria are illustrative because they may change for different commodities (especially the costs) or for different scenarios (in some regions, the spin-up time categories may be longer because of a lower threat or limited importance to U.S. interests).

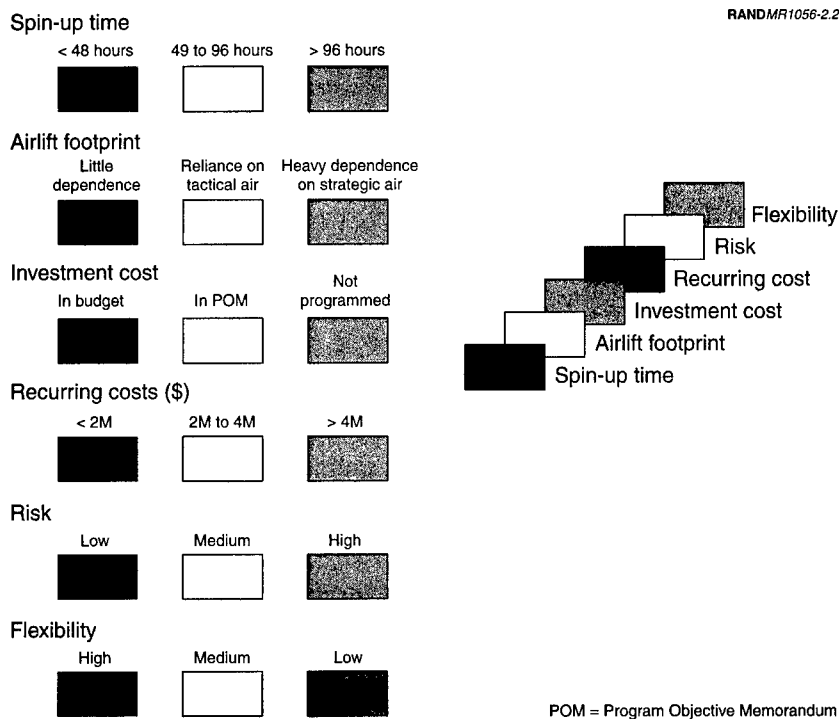
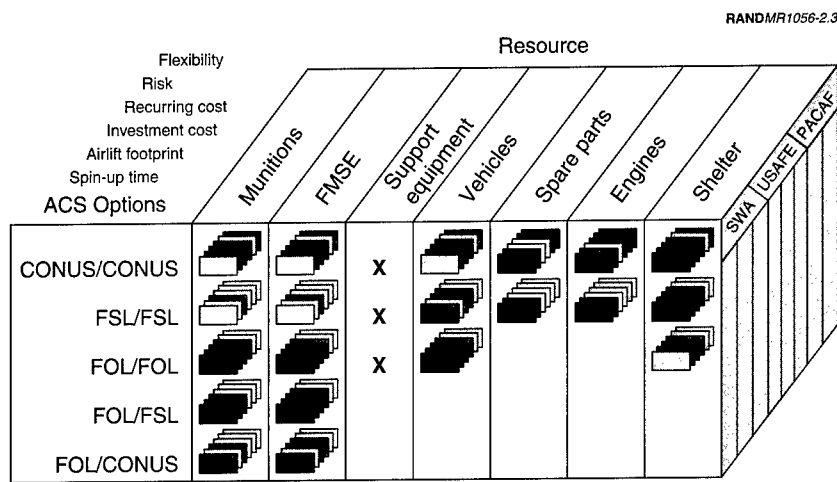


Figure 2.2—Criteria for Evaluating Support Options

Figure 2.3 shows some of the option tradeoffs associated with some key resources, including munitions, Fuel Mobility Support Equipment (FMSE), vehicles, and shelter, based on computations by our models.⁵ For illustration, we show five options:

- CONUS/CONUS: Supply the IOR and FOR for each resource from CONUS. In other words, all resources are airlifted from CONUS to satisfy requirements at the AEF reception base.

⁵The scenario was a 36-ship AEW consisting of 12 F-15Cs, 12 F-15Es, and 12 F-16CJs. The primary mission was ground attack with Guided Bomb Units (GBU-10s, 2000-lb precision munitions).



Initial Operating Requirement (IOR): less than 7 days

Follow-on Operating Requirements (FOR)

FMSE = Fuel Mobility Support Equipment

SWA = Southwest Asia

USAFE = U.S. Air Force, Europe

PACAF = Pacific Air Forces

Figure 2.3—Scorecard for Evaluating Alternative Individual Resource Support Options

- FSL/FSL: All resource requirements (IOR and FOR) are prepositioned at a regional FSL and airlifted⁶ into the reception base.
- FOL/FOL: All resource requirements (IOR and FOR) are prepositioned (and in good operating condition) at the FOL.
- FOL/FSL: The IOR for each resource is prepositioned at the FOL and the FOR is supplied from an FSL.
- FOL/CONUS: The IOR is prepositioned at the FOL, but sustainment resources are supplied from the CONUS.

Note that various other mixed strategies are possible (e.g., prepositioning all heavy munitions at bases, keeping equipment at

⁶The model can also treat the cases of using ship or truck to deliver munitions.

regional centers). All of these can be studied using the same methods described here.

These results can be viewed in multidimensional displays such as the scorecard used in Figure 2.3. The scorecard illustrates a notional evaluation of several different options for positioning munitions, FMSE, support equipment, vehicles, spare parts, engines, and shelter. The order of the “cards” is shown in the legend at the top left of the figure.

In this illustration some of the options are not considered for some resources. For instance, the only options considered for engines and spares was to deploy the resource with the unit or deploy the resource from an FSL. This analysis considered these resources to be too expensive to locate at each potential FOL. In the case of vehicles, the IOR is the full complement of vehicles; there is no FOR.

Mobility options are integrated in the analyses and affect the evaluation of each ACS option. For instance, mobility concepts of operations (CONOPs) affect airlift allocations and timelines, and these constraints influence decisions on deployment and prepositioning tradeoffs. They also affect resupply time in sustainment operations. More will be said about integrating mobility and ACS analyses later in this chapter.

Integration of Individual Commodities Options into an ACS System

The next step is to select among these options in each commodity area to create candidate AEF support concepts. As shown in Figure 2.4, we developed an “integrating model” to choose among the options we analyzed. This is a mixed-integer optimization model that selects combinations of the options that meet the objective function subject to several constraints and thereby quickly identifies feasible support concepts. Taken together, these options represent a possible support concept for AEFs that could then be looked at more closely to consider additional issues such as the flexibility of the concept and its transportation feasibility.

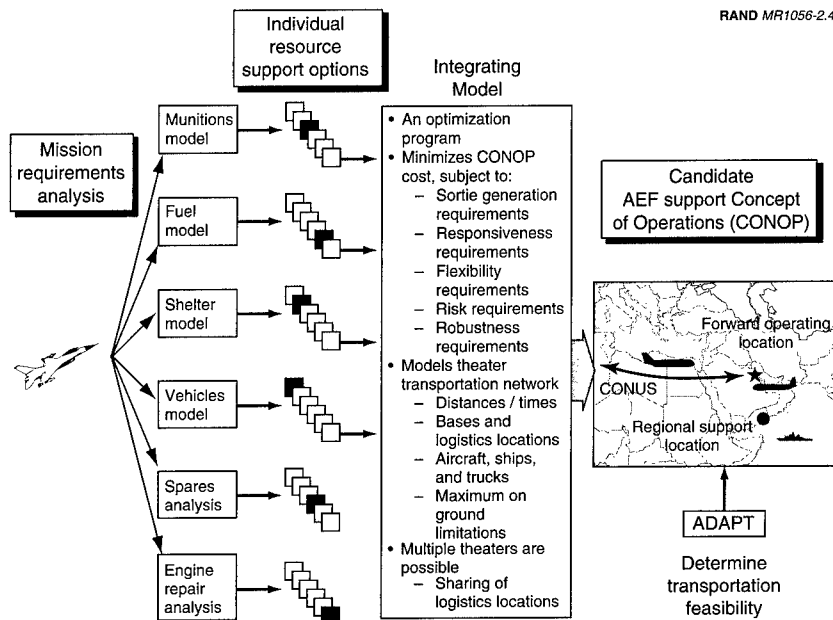


Figure 2.4—The Integration Model Assists in Choosing Among EAF Support Options

A possible formulation that we explored is to minimize the investment and annual costs subject to meeting the following constraints:

- Generating minimum sortie requirements over time
- Meeting minimum robustness requirements for options over time
- Limits by transportation mode capacities
- Limits imposed by airlift allocation
- Limit aircraft/truck/ship departure unless one is available
- Limit aerial port cargo throughput to that allowable by available MOG

- Limit support sortie generation until minimum resources are available to initiate sortie production.

For each commodity considered, the model can select among as many as six alternative ways to provide the resources needed to support operations. Each option has different fixed (investment) and variable (recurring) costs. Each option will also vary according to its robustness and suitability for long-term use. For example, an austere shelter option may be permissible during the first few days of a deployment, but must be replaced by a more robust option as time goes on and the airlift capacity is available. The model accounts for such issues by allowing each option to be given a subjective rating with respect to its robustness. It then requires options with low robustness (but high initial deployability) to be replaced by more robust options within a specified time period.

The daily operational requirement for sorties is the chief driver of the model—and meeting this constraint causes the selection of support options to provide the required sortie generation capability. The model uses descriptive data on the resource options, bases, transportation modes, and theater distances involved. The “footprint” of each option, in terms of the number of short tons that must be in-place or delivered to the FOL, is used as a measure of its deployability.

In addition to allowing the identification of interesting EAF support concepts, the model is useful in answering a range of questions that give insight into the robustness of the concepts. For example, by varying the costs of certain aspects of a CONOP, the “breakpoints” could be identified that would motivate a switch to another CONOP. This allows a number of questions to be explored, such as the maximum desirable cost associated with the opening of a new FSL, or how sensitive a CONOP might be to annual transportation costs. Another important issue that was made analytically tractable by the model is the effect of various levels of airlift availability, which is a key make-or-break assumption associated with each AEF support CONOP. Finally, the payoff of improved technology to lower the deployment footprint of a resource option could be explored. In this way, the effect of an improvement in the deployability of a particular resource on the overall AEF deployment could be gauged.

As the Air Force extends its analysis of support structures beyond single theaters of operation, the complexity of issues involved will make the application of automated techniques such as the integrating model essential. The complex interactions among the region-specific security challenges, mutually supporting theaters, geography, and required levels of responsiveness will create an almost overwhelming number of possible support structures. Automated models are needed to manage this complexity to identify low-cost global support structures for the EAF.

Integration of ACS and Mobility System

Executing AEF deployments requires that a multitude of mobility-related actions be set in motion:

- Airlift and tanker crews must be placed in crew rest.
- Aircraft must be generated and positioned at CONUS onload sites.
- Aerial port personnel and equipment must be deployed to en route locations and offload bases.
- Tankers must be positioned forward to support aerial refueling operations.
- Theater airlifters must be deployed to haul equipment and supplies from storage sites in the region to the forward operating base.

These are just a few of the preparatory processes that must take place before AEFs can be rapidly deployed to commence operations. Because mobility processes constitute a substantial portion of the overall AEF deployment timeline, an understanding of them is necessary to facilitate quick-response AEF operations. In addition, a key aspect of future AEF agile combat support structures will be the interweaving of mobility processes with logistics support processes. It is therefore important to have a way to test the mobility/logistics interfaces for any candidate AEF support structures we might devise. Toward this end, we developed the AEF Deployment and Planning

Tool, or ADAPT,⁷ a high-level simulation model of the air mobility system. This model provides insight into the chain of mobility-related events that makes AEF deployments possible, and can test the transportation feasibility of possible AEF support structures.

Feedback Loops for Control

The final element of the proposed planning framework is feedback, which can indicate that there are discrepancies between plans and reality. Information on deviations from plans can be used to initiate correctional actions to solve the problem. We envision two primary feedback loops in the planning framework.

The first feedback loop is between logistics planning and operations planning, as shown at the top of Figure 2.1. Operational analysis can provide alternative force packages that can accomplish “equivalent” goals with possibly very different support requirements. For instance, an AEF operational analysis might indicate that, under some scenario variations, an AEF composed of 12 F-15Es, 12 F-16CGs, and six F-16CJs could produce the same results as an AEF composed of 18 B-1 bombers and six F-16CJs. Again, the support requirements and corresponding support alternatives are very different for these force packages. They may also have different deterrent implications. The fighter package may involve bedding down the force closer to the adversary. Using the reception sites of a neighbor may have a greater deterrent impact than indicating to an adversary that we may inflict punitive strikes from bomber bases located farther away. These alternatives have different costs and risks.

In some circumstances, logistics constraints may not be removable if resources are strongly tied to expensive and relatively fixed infrastructure, which has limited flexibility. For example, fuel resources available within a given country and distribution capabilities to forward operating bases may not be available to support sustained high EAF optempo. Operational plans may have to be modified to deal with this constraint. Therefore, there must be close

⁷The model is programmed using *ithink Analyst* software. See *ithink Analyst Technical Documentation* (1997).

interaction between logistics and operations in designing the future ACS system. In these strategic time horizons, the interaction needs to be continuous but not real-time. Time is available to plan and acquire logistics infrastructure that can support more ambitious operational plans if the costs and risks are judged to be acceptable.

The second feedback loop is between logistics planning and the control of the logistics infrastructure. First, there is a diagnostic loop in which logistics constraints identify areas of the ACS system where enhancement is needed: a process that is too slow, a transportation link that has insufficient capacity, or a lack of repair capability. The diagnostic results are used to focus modifications to the logistics infrastructure to enhance its capabilities at the points where such improvement is needed to support operational plans.

A tracking and control feedback loop is needed that monitors the performance of logistics processes that are not (currently) constraints and ensures that their performance stays adequate—at or above the level needed for logistics plans to be carried out.

These feedback loops and control systems ensure that the logistics system evolves as needed to support current and future operational plans and that the system achieves and maintains required support capability.⁸ The result is a continuous cycle of planning, diagnostics, improvement, and replanning.

SUMMARY OF ENHANCED ACS PLANNING SYSTEM

The essence of the proposed planning system for ACS is captured in the following points:

- It uses employment-driven models, at an appropriate level of detail, to evaluate individual resource alternative support options across a large number of scenarios and parameter combinations.
- It uses an integrating model to facilitate an integrated planning process—with operations and across traditional functional and resource stovepipes.

⁸For a more detailed description, see Pyles and Tripp (1982).

- It assesses combat support processes, providing diagnostic feedback to fix problems, and it monitors their performance over time to ensure that previously feasible plans remain feasible.
- It is a continuous process of planning; monitoring events and requirements; modifying scenarios based on new developments, new opportunities, and new technologies; and then replanning to ensure that the ACS system and available resources can indeed support the entire spectrum of Air Force operational requirements from peacetime training to MTW engagements.

Chapter Three

APPLYING THE ENHANCED ACS STRATEGIC PLANNING FRAMEWORK: INFRASTRUCTURE FOR GLOBAL ADAPTIVENESS

This chapter will illustrate the implementation of key parts of the proposed strategic support planning system. Planning analyses address deploying unit aviation support, reparable avionics components, and munitions—three processes with very different characteristics. We use these analyses to illustrate how the enhanced planning system can be used to establish the strategic direction for developing ACS capabilities to effectively meet future dynamic EAF operational requirements.

MINIMUM DEPLOYED MAINTENANCE AND SUPPORT EQUIPMENT ANALYSIS

Our first task is to determine deploying unit aviation support requirements. We developed a simple rule-based EXCEL spreadsheet model to determine unit-level aviation support package requirements for the F-15E as functions of alternative operational scenarios and logistics policies, practices, and technologies. Features of the model are shown in Figure 3.1. Appendix C describes some of the major features and characteristics of the rule-based aviation support model.

The employment-driven unit-level aviation support model incorporates rules for determining maintenance personnel and equipment requirements to support the first seven days of operations for alternative numbers of F-15Es deployed in an AEF package and for vari-

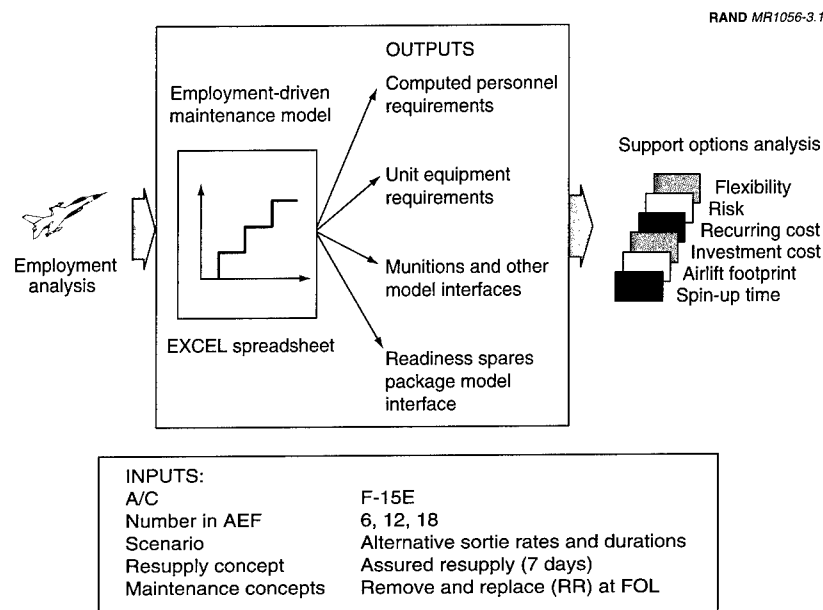


Figure 3.1—Modeling Unit-Level Aviation Support Package Requirements as Functions of Operational Scenario and Logistics Policies and Technologies

ous sortie requirements. Seven days was picked as a starting point to define a leading-edge deployment package, but the rules can be adjusted to consider a different initial deployment period. This model can interface with the munitions and other employment-driven models to incorporate their outputs. The rules in the model were developed to include only support tasks that pertain directly to combat sortie production in austere operating environments (e.g., the model excludes requirements for pilots, intelligence, and life support). In other words, the model was developed to produce “lean and mean” requirements. As such, the rules do not include estimates for any other demands on personnel (e.g., extra duty, days off, or environmental extremes). Rules could be added to incorporate these conditions, but were not developed for our initial AEF work.

The results of our unit-level aviation package requirements analysis are shown in Figure 3.2. The figure shows the minimum aviation

RAND MR1056-3.2

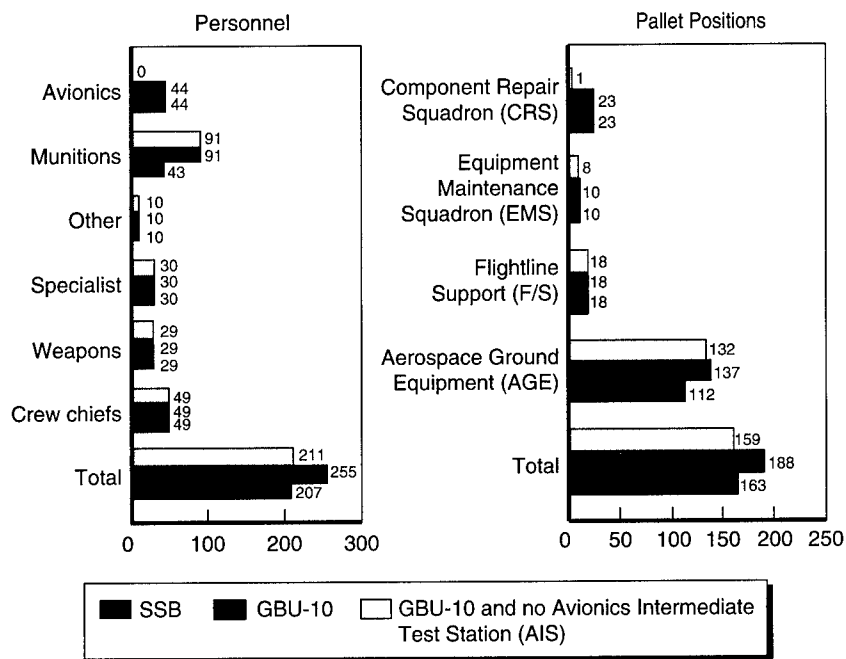


Figure 3.2—Results of Unit-Level Aviation Package Requirements Analysis

support personnel and pallet positions of support equipment required to support a high optempo scenario (approximately 2.5 sorties per day per aircraft) for 12 F-15Es using precision-guided munitions—e.g., a Small Smart Bomb (SSB) or a Guided Bomb Unit (GBU-10). The model projects that using an SSB could reduce the fighter squadron munitions loaders and munitions maintenance squadron personnel by 48 and reduce unit-level equipment needs by 25 pallet positions.¹ The effects on munitions maintenance squadron people and equipment were obtained through the interface with the employment-driven munitions model. That model will be described below.

¹This of course assumes that the SSB can, in fact, replace the GBU-10 munitions for the strikes to be made.

We also used the F-15 aviation support model to project the effects of not deploying the F-15E AIS. As shown in Figure 3.2, relying on remove-and-replace actions only for the first seven days reduces the unit deployment requirements by 44 people and 29 pallet positions, if the primary air-to-ground munitions is the GBU-10.

The F-15E aviation support model and others that we are developing, such as the F-15C, F-16, Joint Strike Fighter (JSF), F-22, KC-135, and B-52 and B-1 models, can also be used to answer questions concerning AEF split-operations effects. Split-operations considerations arise in the AEF organizational scheme when units on-call or deployed may have to split a squadron into multiple force packages (e.g., 12 aircraft and six aircraft from an 18-PAA squadron for operations at two deployed sites). The models show that the sum of the operating requirements is larger than the single support package that was designed to support squadron operations. Analyses based on these models could help the Air Force determine the additive personnel and equipment requirements needed to support flightline operations associated with split operations.

INTERMEDIATE AVIONICS MAINTENANCE AND SUPPLY OPTIONS ANALYSIS

Our AEF split-operations analysis² indicates that additional personnel and equipment are needed to support the future EAF when F-15 squadrons deploy intermediate avionics maintenance with each set of aircraft. These analyses raise questions on how centralizing intermediate avionics maintenance at regional locations would affect overall EAF employment concepts:

- Would personnel and equipment savings result if intermediate avionics maintenance for the F-15 were regionalized?
- Would regionalization increase spares requirements?
- What would be the peacetime transportation requirements?

²This section (and Appendix D) is based on work by Eric H. Peltz, H. L. Shulman, Robert S. Tripp, and John G. Drew. It will be published as a RAND document.

- How do the number of regional sites affect costs and effectiveness of operations?

Requirements Analysis

We use the same strategic planning approach described in Chapter Two and illustrated in the previous example. In this more complex analysis, we used the Aircraft Sustainability Model (ASM), the employment-driven requirements model for spare parts, and developed spreadsheet models to compute requirements for F-15 test equipment and personnel as functions of the maintenance concept. We also developed models to estimate the additional peacetime transportation requirements and infrastructure costs that would be necessary to develop regional repair operations at FSLs and CONUS sites. See Figure 3.3.

For the operational scenario we used a notional 2004 peacetime F-15 beddown, with a transition to a notional two-MTW scenario similar to the one used in the current Defense Planning Guidance (DPG). With this beddown and planned peacetime and wartime operating rates, we computed test equipment, personnel, spares, and transportation requirements for each support option considered.

RAND MR1056-3.3

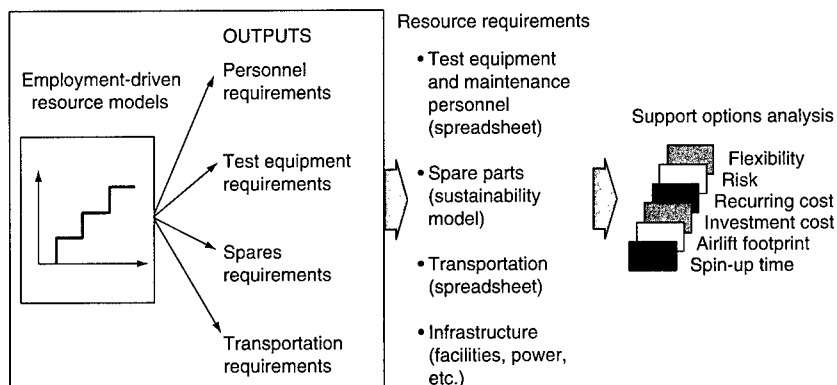


Figure 3.3—Employment-Driven F-15 Avionics Maintenance Model Inputs and Outputs

The Support Alternatives

The central question of this analysis—how would centralizing avionics intermediate maintenance affect EAF employment concepts—drives the selection of support alternatives to consider. To establish a baseline for comparison, we start with the current Air Force F-15 avionics intermediate maintenance structure, which employs a completely decentralized approach that relies on local repair: each combat-coded squadron is essentially assigned one set of intermediate maintenance assets intended to follow it to any FOL. To gain insight into how the level of consolidation affects EAF employment and cost, we compare the decentralized structure with a range of consolidated options. These options include consolidating all intermediate maintenance for peace and war at one location within CONUS and several networks of regional centers, some of which would be located outside CONUS to support conflicts. Under the consolidated options, crew-level maintenance personnel would conduct remove-and-replace maintenance operations and send all Line Replaceable Units (LRUs) to their assigned regional repair site.

We considered three intermediate concepts between the fully consolidated and decentralized extremes. The first had three FSLs: one each for CONUS, Southwest Asia (SWA)/Europe/Africa, and East Asia. The second concept added an SWA FSL, and the third concept added a second Asian FSL. Notional locations were selected at current bases. Other configurations based upon projected political situations could be analyzed using the methods that follow.

When analyzing configurations of repair facilities, we must also specify supply policies. For the current decentralized maintenance option, the associated supply policy is to deploy a Readiness Spares Package with the unit. This RSP is composed of LRUs to satisfy demands until the repair facility is operational at the FOL, LRUs to satisfy demands while awaiting the repair of unserviceable LRUs once the facility is operational, and shop replaceable units (SRUs) for LRU repair. There is no resupply planned for the current RSP until after day 30 of wartime operations. At each home operating base, the supply system maintains a peacetime operating stock (POS) of SRUs to repair LRUs and sufficient LRUs to cover demand over the average repair time of the avionics intermediate shop.

For the consolidated options, we computed a new RSP to provide LRUs to the flying units until resupply can satisfy demand. In cases where the FSL and the FOL are in the same region, this period was set at seven days, and it was set at 10 days when a CONUS facility must resupply an out of CONUS (OCONUS) FOL. After that period, resupply from the consolidated repair facilities will continue to provide all additional LRUs that are needed.³ Because LRU repair is not being done at FOLs, the new kits would not have any SRUs.

The new kits are designed to support 12 aircraft, with supplemental kits for the aircraft left behind. If a squadron is split for an AEF, both portions retain warfighting capability. The new supply policy also contains a new buffer level that we have called a Consolidated Support Package (CSP). The CSP is a pool of stock designed to have serviceable LRUs on-hand to immediately satisfy requisitions from deployed units, thus avoiding delays resulting from repair of assets. The CSP also has SRUs that the FSLs and CONUS site can use to fix repairable LRUs. The intent of the CSP is to give deployed units confidence that stock will be available to satisfy their needs. Unserviceable LRUs sent back to regional repair sites would refill the CSPs after being repaired.

The POS for the consolidated options would be similar in concept to the decentralized option, but the change in structure would force changes in execution. Such changes include the elimination of SRUs from home base stocks, an increase in LRU inventory depth at home bases to cover the increased resupply time, and the addition of stock at the regional repair facilities. The POS at regional repair facilities would have SRUs for LRU repair and safety stock of LRUs for shipment to bases when repair time becomes excessive.

For the F-15, the choice of test equipment configuration adds complexity to the analysis. There are currently two test string configurations, one for F-15Cs and one for F-15Es. The F-15C configuration is the original test string configuration for all F-15s. The F-15E configu-

³Data collected from operations in SWA indicate that MICAP requisitions (requisitions for parts that are preventing an aircraft from flying) are being filled from CONUS sources with a mean of around eight days and from regional sites (e.g., Prince Sultan Air Base in Saudi Arabia) in about five days, on average. Based upon these data and discussion with senior Air Force logisticians, we use seven days as a feasible OST from FSLs.

ration replaced five of the original test stations with two newer ones [Mobile Electronic Test Set (METS) and Enhanced Aircraft Radar Test Station (EARTS)], which reduced the deployment footprint and increased test automation. Both the F-15C and F-15E configurations are scheduled for further modification over the next three years by replacing all but three test sets with the ESTS (Electronic System Test Set).

There are two reasons to analyze the support structures with regard to different tester configurations. First, it will serve as a form of sensitivity analysis by enabling comparison of the options under each of the tester configurations. If the same option looks best regardless of configuration, then it should increase our confidence in the solution. Second, the analysis may be able to serve as a decision tool for modernization decisions, and illustrate how to expand the trade space for future decisions by comparing technology solutions with policy solutions.

Later figures in the report refer to two configurations of testers: The first uses the current configurations (either the F-15C or the F-15E configuration as appropriate), and the second uses the ESTS configuration for all F-15s.

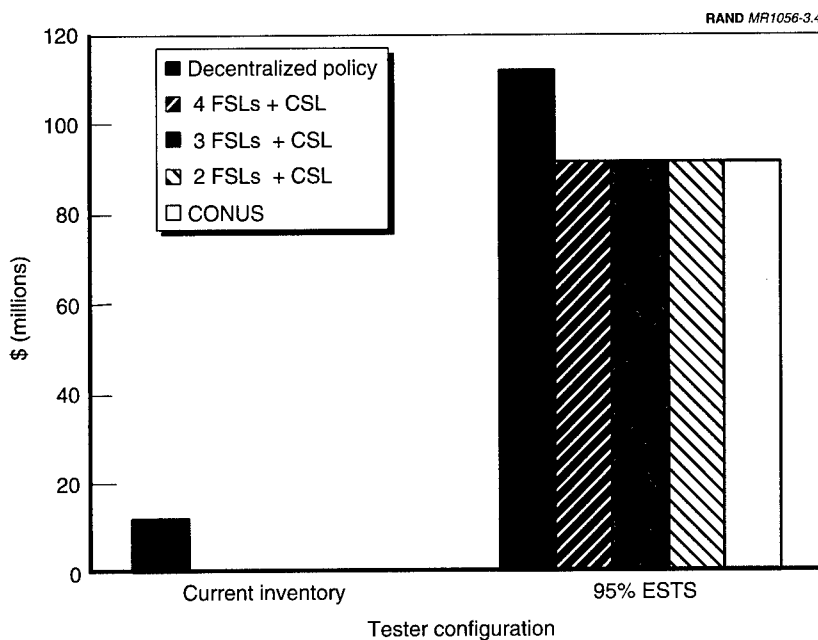
The Results

Avionics test stations. The results of our analysis are easy to state: Because the current decentralized policy places a test string with each squadron, the Air Force has enough test stands to completely equip any of the consolidated options with the existing or ESTS configurations. Interestingly, we found that the current configuration is actually short of one of the testers, the Tactical Electronic Warfare Intermediate Support System (TISS) stand, so continuing to use it would require some investment.⁴ Likewise, we found the present ESTS plan to be short of ESTS as well as the TISS, which would increase the required investment to field ESTS.

⁴Note that collocating test strings has the additional advantage of increasing the probability that there will be test capability available because extra strings can provide parts from cannibalization. This cannot be done when single strings are deployed with each squadron.

Figure 3.4 summarizes the costs for the two tester configurations by option. For existing testers, there is a cost shown only if the requirement is larger than the current inventory, although there is a cost risk because of obsolescence. The “95% ESTS” case means that we assume the ESTS achieves its design goal of 95% uptime.⁵

Personnel requirements. The number of testers required determines the number of personnel required to support operational objectives. Figure 3.5 displays the personnel requirements for the tester configurations for each support structure option. The personnel re-



NOTES: With \$30 million for ESTS program stretch and \$63 million in future planned expenditures. CSL = CONUS support location.

Figure 3.4—F-15 Avionics Test Station Costs for Each Option

⁵As of this writing, the ESTS has not met this milestone.

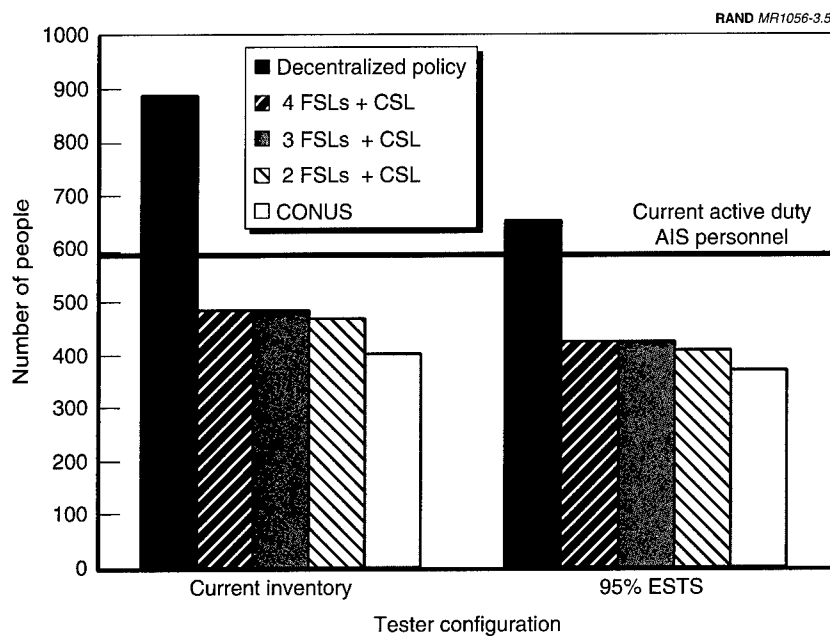


Figure 3.5—FSLs Reduce Personnel Requirements

requirements for the current decentralized structure are greater under all tester configurations, even with the personnel reductions possible through ESTS, than for any tester configuration under any of the consolidated options.

As with tester requirements, we found current personnel levels insufficient to meet two-MTW requirements. For ESTS, the number of people required for the decentralized structure is only slightly higher than the current personnel level. In any of the consolidated cases, the Air Force could draw down the required number of avionics maintainers. Judicious planning focused on a temporary reduction in accessions and an emphasis on retention could enrich the skill mix of personnel.

Supply and transportation. As pointed out earlier, supply policy must correspond with the maintenance structure design. If the planned resupply time is met, then the resupply time assumption it-

self does not affect operating performance. However, the longer the resupply time, the more parts are required in the pipeline and the higher the system investment cost.

To determine the investment in spares required for each consolidated option, we must find the total inventory requirement for the POS at each location, the CSP, and the RSPs. These requirements are summed and compared against the current serviceable Air Force inventory program (which includes planned procurement and repair of unserviceables). To satisfy the shortfall, if any, we start with the repair of on-hand excess unserviceable parts. If these are not sufficient to meet the inventory requirement, then we compute additional procurement requirements. The additive repair program costs and procurement costs for each LRU and SRU are combined to produce the required spare parts investments indicated in Figure 3.6.

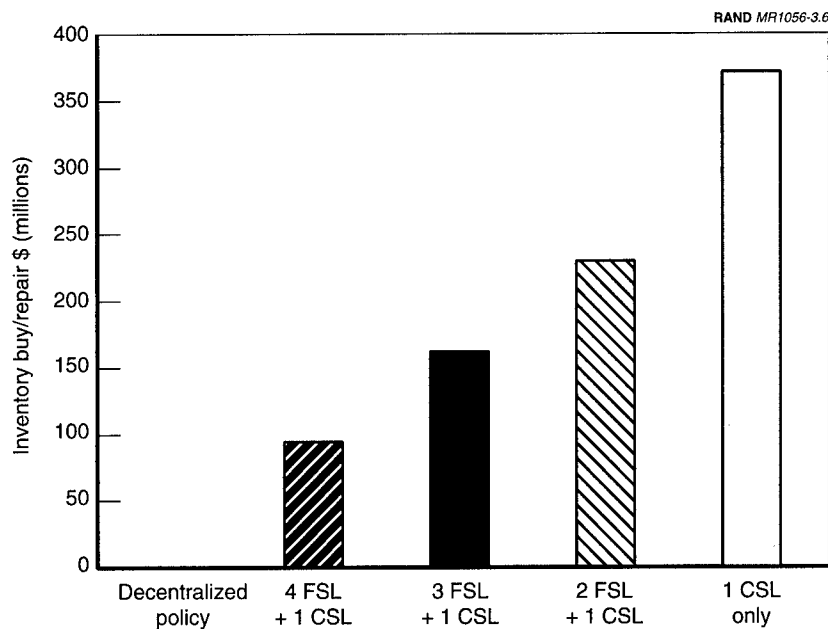


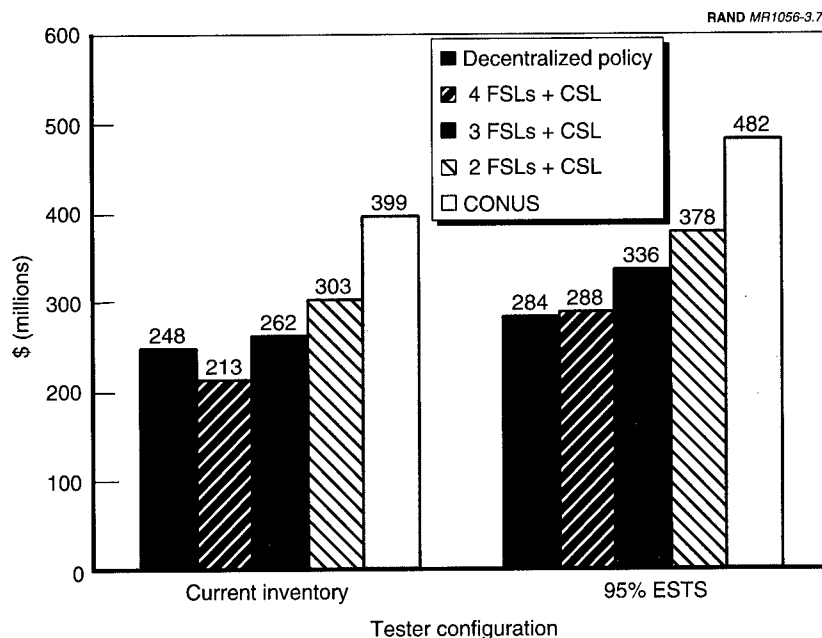
Figure 3.6—Additive Inventory Buy and Repair Requirements

As consolidation increases, the average peacetime resupply time increases, because fewer and fewer bases are collocated with regional repair facilities. The general upward trend in required spare parts investment as consolidation decreases from five locations to three is indicative of increasing POS requirements. For the RSP and CSP there are only two jumps. The first occurs at the first stage of consolidation, from decentralization to five locations, as resupply time increases from the local repair cycle time to the resupply time between FSLs and FOLs. At complete consolidation in CONUS, resupply to FOLs shifts from FSLs to the CONUS repair facility, again lengthening the resupply time and thus increasing the additive spares cost.

Maintenance locations and concepts also drive transportation requirements. In a remove-and-replace system, all unserviceable parts have to be shipped from FOLs or bases to the appropriate regional repair FSL or to CONUS and then a serviceable part has to be shipped back. As consolidation increases, transportation cost increases. For the consolidated options considered here, the present value costs of transportation for eight years (the economic life of test sets, for comparison with test set costs) range from \$28 million (4 FSLs + CONUS) to \$44 million (CONUS).

Cost summary of options. Figure 3.7 combines the costs of the four resources. For the current tester configuration, the four-FSL option is the lowest in total cost, and for the ESTS configuration this option is cost neutral against the current decentralized approach. Reducing the number of FSLs increases the cost, because the additional spare parts outweigh further personnel reductions.

The current configuration with the four-FSL option has a \$71 million cost advantage over the ESTS configuration with the decentralized structure. The current numbers assume no investment in the existing testers, so any investment required as the result of obsolescence would reduce the cost difference between the cases. However, there is also risk in the ESTS configuration cost in the event that the program stretch does not lead to achievement of the system objectives. The cost difference is the amount of money that the Air Force could invest in either the current testers or an alternative and achieve a cost-neutral position against the ESTS program if the Air Force were to consolidate F-15 avionics maintenance at five locations.



NOTE: With \$30 million for ESTS program stretch and \$63 million in future planned expenditures.

Figure 3.7—Cost Summary of Options

Impact on deployment requirements. Personnel deployment requirements are slashed in a consolidated system compared with a decentralized one, and the effect is relatively similar for all tester configurations. See Figure 3.8. In addition to the reduction in deployment requirements, the deployments are to regional FSLs instead of to FOLs. In some instances, the FSLs will be outside the conflict theater, and they will provide more comfortable living conditions than temporary FOLs. More important, FSL options do not require any deployments for boiling peacetime operations, and small-scale AEFs are supportable from FSLs staffed at peacetime levels.

Consolidation has an additional deployment advantage: it reduces initial airlift requirements by 18 to 60 C-141 equivalents from the de-

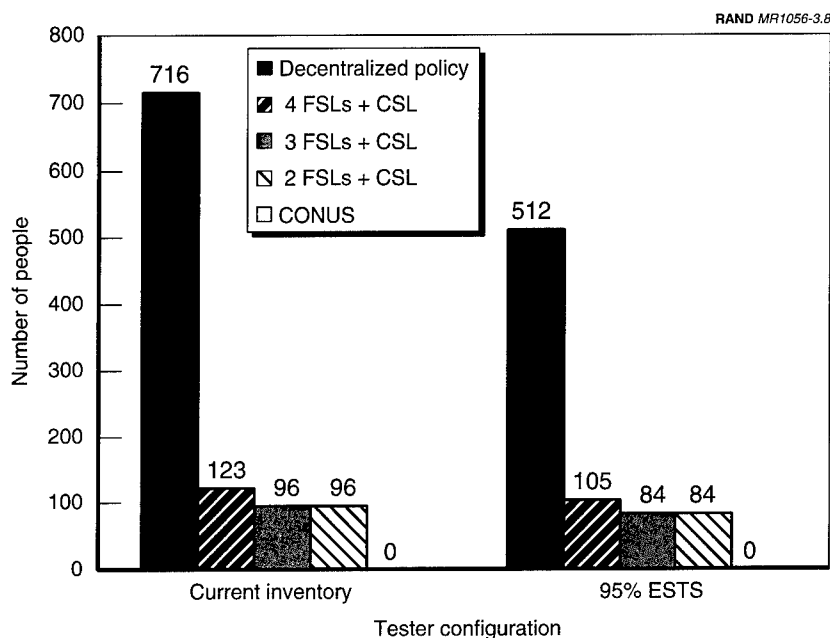


Figure 3.8—Personnel Deployment Requirements for Each Avionics Support Option

centralized option (depending on whether the maintenance shops must bring their tester shelters). Although the ESTS configuration also saves on up-front airlift requirements, the saving is less because the ESTS footprint is potentially one-fifth that of the current testers and they replace up to five testers each. Much of the remaining airlift requirement with ESTS results from the TISS and antenna stations, which remain in use with ESTS.

Summarizing the F-15 Avionics Support Analysis

As noted earlier, our assessment models compute four of the six critical metrics: spin-up time, airlift footprint, investment costs, and recurring costs; analysts assign values to the other two qualitative criteria: risk and flexibility. Risk and flexibility are used to evaluate such factors as probability of access to specific bases, availability of

airlift when needed, ability to control movement of resources and people, and so forth.

Using these criteria, we can provide a macro assessment of the options we presented earlier. The centralized options do not increase spin-up time because the new RSP, like the old version, deploys with the unit and arrives before the aircraft, and so there is no delay in starting repair. In addition, the footprint is much less than deploying the test equipment and personnel, as discussed above.

The FSL/FSL option is better for recurring costs because the costs are lower than in today's support concept but investment costs are higher for this option than for today's concept. The CONUS/CONUS option substantially increases the investment costs beyond the FSL/FSL option's cost while producing only a small additional reduction in recurring cost. The FSL and CONUS options have medium risk from an operational standpoint, because even though the current values for resupply within the AOR and from CONUS to OCONUS meet the design standards, these options are dependent upon having a resupply network established and operating when the AEF is initiated. Having repair in the CONUS provides the most flexibility and reduces the overall risk level for the CONUS option when compared with the FSL option: we will always have access to our own resources and facilities.

This analysis illustrates the necessity of monitoring key performance parameters. In this analysis, the ability to support operational objectives is dependent upon the resupply time (OST and retrograde transportation time), depot or FSL repair times, and serviceable levels for the consolidated portion of the stock needed to support the new kits. Of these parameters, OST and depot-level repair times are reported only for those items repaired exclusively at the depot. The importance of consolidated support package levels and the ability to relate these levels to combat performance are new. These parameters are so important to operational effectiveness that a modification to Status of Resources and Training System (SORTS) that reports their values and translates these values to wartime (boiling peacetime surge) sortie generation capability has to be considered as part of an implementation plan. This would emphasize the criticality of the entire combat support system in meeting wartime operational objectives.

The regional options do pose the risk of potential misalignment of objectives that may occur in a consolidated, functionally organized structure arising from different incentives. Maintenance may work toward maintenance-specific objectives such as cost minimization instead of balancing these with total organizational outcomes. Similarly, operational forces may demand outputs from maintenance without considering the effect on the total system. Depending on the location of the regional facilities, component repair for one theater may even take place in another theater—for example, Europe supporting both Europe and SWA. Overall management can overcome these potential problems, but only with careful creation of the incentive structure and strong effort on the part of functional managers to keep lines of communication open.

In summary, consolidated structures can have lower total system cost in some circumstances, reduce deployment footprints, and help reduce personnel turbulence. These benefits come with increased transportation risk and with some political risk, which depends on the locations of the regional facilities. The ESTS option illustrates that technology options need to be considered along with policy options to make cost-effective decisions. Finally, operational planning can vitally affect logistics planning, so a logistics system must be sensitive to operational requirements and able to adapt to unexpected scenarios, particularly in today's uncertain world.

MUNITIONS ANALYSIS

This analysis shows how alternative posturing options for munitions are evaluated using the methods outlined in Chapter Two. Of all the resources required by an AEF, munitions are second only to petroleum, oil, and lubricants (POL) in weight, both in initial requirements and in the amounts needed to sustain combat operations. Further, munitions require specialized storage and transportation precautions, which further complicate their management. Add to this the demanding timeline for EAF deployment and munitions support becomes a key constraint on future EAF operations.

Requirements Analysis

As in all our analyses, we begin by using an employment-driven model to determine munitions, munitions equipment, and personnel requirements as functions of alternative operational requirements. In this case, as shown in Figure 3.9, the model is an EXCEL spreadsheet developed for this study, which takes as inputs the composition of the EAF, the missions to be flown, the types of munitions to be used, and the schedule of missions. Combining this with tables that contain such data as munitions buildup time, loading time, and standard conventional loads and expenditure rates for various munitions, the spreadsheet computes timelines to establish the production function, and equipment, personnel, and munitions required to meet the operational scenario. This production-function view explicitly integrates portions of the total job across organizations (munitions buildup is done by the munitions squadron, whereas loading is done by aviation squadron personnel) and functions (such as transportation, supply, and maintenance). Appendix A describes

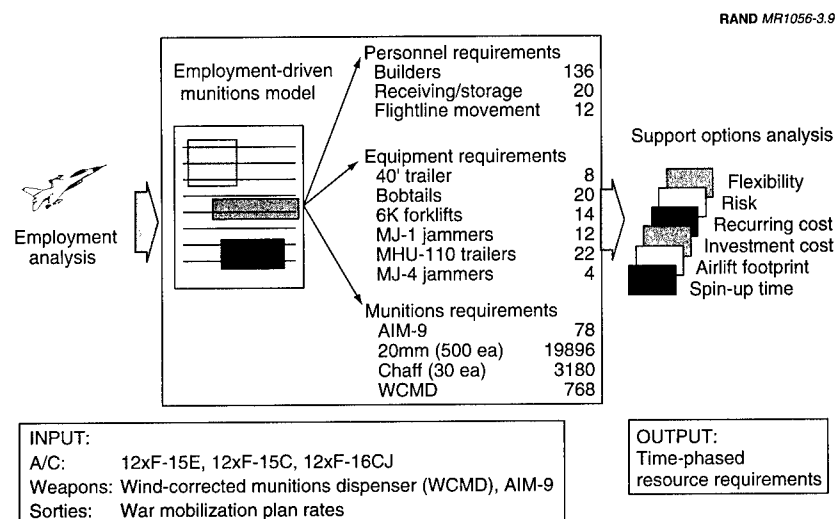


Figure 3.9—Employment-Driven Munitions Model Inputs and Outputs

the basic features of the munitions requirements determination model.

With this basic requirements computation framework in place, the support options analysis spreadsheet can then compute the performance of various options for providing munitions support. These options could include specific personnel constraints with cross training, the replacement of current equipment with equipment with different characteristics, or the imposition of constraints such as airlift, dollars for prepositioning, and so forth. The spreadsheets help in calculating the performance measures introduced above—for example, the timeline to produce sorties, investment and recurring costs of the option, and airlift footprint.

In the scenario treated here, the AEF was an “F-15 heavy” AEF,⁶ using GBU-10s for ground attack, AGM-88 (high-speed anti-radiation missile, HARM) for suppression of enemy air defenses (SEAD), and AIM-9 and AIM-120 for air-to-air combat. (This scenario was the same as that used above when we computed the aviation support personnel and equipment for a 12-PAA F-15E deployment.)

The model computes a quantity of munitions to satisfy an IOR that should be available at the reception base to satisfy the first few days of combat operations (e.g., three days). The remainder of the munitions needed in the scenario can be brought in as the operation proceeds, although this sustainment resupply of munitions components must keep pace with the munitions production capability that is operating at the reception base. These parameters can be changed to determine the effects of alternative IOR quantities on investment and recurring costs, risks, flexibility, and airlift requirements.

Support Options Analysis

In this analysis, we will focus on options for positioning the munitions to be used. The tight timeline of the AEF combined with the weight of munitions [especially bomb bodies used in most precision-guided munitions (PGMs) such as the GBU-10] present the AEF planner with basically two feasible options: preposition at least

⁶The AEF consists of 12 F-15Cs, 12 F-15Es, and 12 F-16CJs.

some of the munitions at or close to the site of operations or devote a great deal of transportation in a very short time frame to moving the munitions into place. Both sets of options have advantages, disadvantages, and risks.

For illustration, we consider modifications of the five options discussed above:

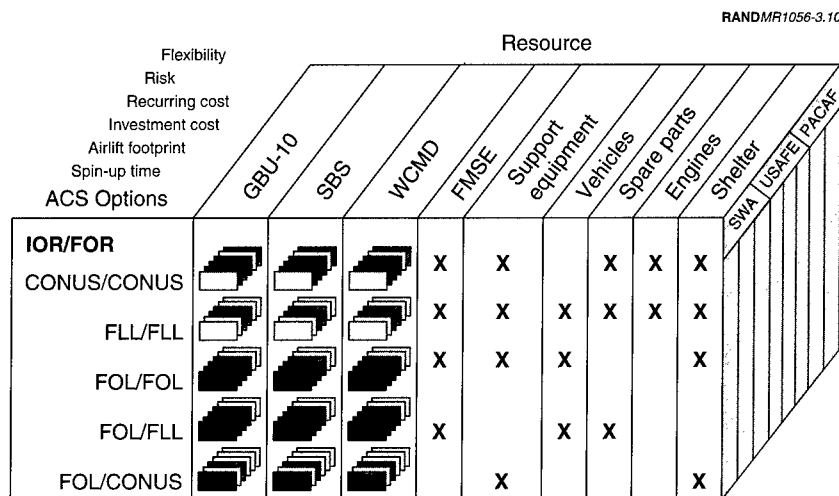
- CONUS/CONUS: Supply IOR and FOR from CONUS. In other words, all munitions and equipment are airlifted from CONUS to satisfy requirements at the AEF reception base.
- FSL/FSL: All munitions and equipment requirements (IOR and FOR) are prepositioned at a regional forward logistics location and airlifted into the reception base.
- FOL/FOL: All munitions and equipment requirements (IOR and FOR) are prepositioned (and in good operating condition) at the reception base.
- FOL/FSL: The IOR for bombs are prepositioned at the reception base and the missiles and bomb FOR are airlifted from an FSL.
- FOL/CONUS: The IOR and FOR for bombs (seven days) are prepositioned at the reception base along with all equipment; other sustainment munitions and all missiles are airlifted from the CONUS.

Note that various other mixed strategies are possible (prepositioning all heavy munitions at bases, keeping equipment at regional centers, etc.). All of these can be studied using the same methods described here.

In computing the costs for each option, we have assumed that three reception bases within the region will be used as alternative reception sites to increase the probability of gaining access to the AOR when hostilities or exercise schedules dictate. The other major assumptions are that the system must be prepared to execute two simultaneous AEFs annually. For munitions, this primarily involves transportation; munitions expenditures are assumed to be minimal in demonstrations. The demonstrations both ensure that the support system is working and prove to potential adversaries that the United States has the capability to execute an AEF.

Figure 3.10 integrates the spin-up time, airlift footprint, and cost analyses with qualitative risk and flexibility assessments of the options. Here we show how alternative munitions analyses can be brought together—for example, AEFs with the GBU-10, wind-corrected munitions dispenser (WCMD), or SBS used as the primary air-to-ground munitions. As might be expected, no one alternative dominates the rest; for example, alternatives that meet the AEF timeline have different costs, risks, and flexibility.

Of the alternatives, only the GBU-10 has feasible solutions, as is illustrated by the absence of a solid black, “show stopper” card in some of the option rows. The black cards in the investment (third) row of the SBS and WCMD options indicate that these munitions have not been programmed to meet the requirements generated in our determination models. In this case, the SBS is not programmed for F-15 or F-16



Initial Operating Requirement (IOR): less than 7 days

Follow-on Operating Requirements (FOR)

Forward Logistics Location (FLL)

SBS = Small bomb system

Figure 3.10—Integrated Munitions Support Analysis

use. In the case of WCMD, assets have not been procured to meet the projected requirements.

By examining the GBU-10 column, one can see that the options that preposition heavy bomb IORs at prospective FOLs are the only options that meet the 48-hour employment timeline requirement. The FOR for bomb requirements can be satisfied from either the FSL or prepositioned assets located at the FOL. Requirements for the lighter and more expensive missiles can be satisfied from either the FSL or the CONUS. However, the FOL alternative has the highest investment cost because of the necessity of providing equipment and munitions for seven days of operations for nine bases (the air-to-air missiles account for much of this expenditure).⁷ In contrast, the CONUS option has the lowest investment cost but the highest recurring cost (because for each of the annual demonstrations the munitions and equipment must be transported from CONUS to the operating base and back). Also, the airlift requirements in C-141 equivalents for CONUS and the regional case are very large (although transportation from the regional base could be easier to provide given the availability of tactical airlift). The FOL/FSL distributed option provides a compromise along all dimensions—it cuts down on purchases of expensive missiles and places initial heavy munitions at the operating base, saving up-front airlift requirements.

As noted above, these alternatives are not exhaustive, but we believe that this use of fairly simple employment-driven requirements models and support options analysis models illustrates how such models can quickly screen a number of support alternatives and provide information for comparison along multiple dimensions. The alternatives also illustrate that with current equipment the AEF may not be lean, but with judicious prepositioning decisions and expenditures, it can still be rapid, agile, and lethal, provided that it uses careful strategic planning to make those decisions and expenditures. This strategic planning focuses on developing the tradeoff space over different scenarios and support alternatives and finding the factors that have the most effect on outcomes. This planning has the additional advantage that support alternatives can be screened across a number

⁷It may not be necessary to buy all of this equipment, particularly that for building and loading.

of possible scenarios and the analyses of constraints can provide insights as to the ACS that can best support a wide variety of scenarios.

INTEGRATING ACROSS COMMODITIES

The three examples in this chapter show how an employment-driven analytic framework can help integrate single commodity processes over the phases of operations, across echelons, among functions, and with operations. It is more difficult to address integration *among* the commodity groups. From the discussions above, an analyst could “see” areas where a common infrastructure design can efficiently support more than one commodity. Although this approach does provide insights, a more objective modeling approach, such as a mixed-integer mathematical programming formulation, could aid decisionmakers in deciding how many regional sites should be opened to minimize support costs while meeting operational needs.

As discussed in Chapter Two, we have developed a mixed-integer optimization model to assist in selection of ACS options. The integration model selects the least-cost combinations of the options that satisfy various delivery criteria for meeting deployment and employment timelines. For a single operational theater, Southwest Asia, this automated tool selected one or more support options in each of the commodity areas, using the criteria of responsiveness and cost. Taken together, these options represented a possible support concept for AEFs that could then be looked at more closely to consider additional issues such as the flexibility of the concept and its transportation feasibility.

As formulated for the analysis of the EAF support structure in Southwest Asia, the integrating model considered the following resource groups, which constitute more than 80 percent of the deployment footprint of a typical AEF:

- Munitions equipment
- Bombs
- Missiles
- Fuel management and storage equipment

- Fuel distribution equipment
- Shelter.

As noted in Chapter Two, the model can select among as many as six alternative ways to provide the resources needed to support operations. For our analysis, we considered a number of options for each commodity, such as prepositioning munitions equipment at FOLs or FSLs or bringing it in from CONUS, or breaking up the munitions requirement by storing heavy but inexpensive bombs at FOLs, with more expensive munitions held at FSLs or in CONUS.⁸

During a model run, the selected options must meet the criteria specified by a series of mathematical constraints. For example, delivery to an FOL is constrained by the capacity of the transportation system, which can include airlifters, ground transportation, and afloat prepositioning ships.

Table 3.1 shows results from the application of the integrating model. The reader can see how the model located various resources to meet three levels of responsiveness. To make the most demanding timeline—48 hours from the deployment order to the generation of the first combat sortie—many resources must be prepositioned at the FOL. As the timeline is extended, more resources can be centralized regionally or in CONUS to provide the needed sortie capability at a lower cost. In this way, the model provided guidance on where resources ought to be located within the SWA theater of operations.

⁸The details of this analysis may be found in Killingsworth et al. (1999).

Table 3.1
Application of Integrating Model

Timeline	Forward Operating Location	Regional Support Location	CONUS
48 hours	Bombs (3-day IOR) Fuel Fuel storage Fuel distribution Shelter	Missiles (IOR) & (FOR) Bombs (FOR) Avionics repair	Munitions equipment
96 hours	Bomb (3-day supply) Fuel Fuel distribution Shelter	Missiles (all) Bombs (> 3 days) Avionics repair	Munitions equipment Fuel storage
144 hours	Fuel	Missiles (all) Bombs (all) Avionics repair Fuel distribution Shelter	Munitions equipment Fuel storage

NOTE: Deployment times and distances are based on Southwest Asia; force protection and vehicles are not included.

**PROCESS DEVELOPMENT TO SUPPORT CONTINUOUS
EXPEDITIONARY ACS SYSTEM PLANNING: AN
ORGANIZATIONAL APPROACH**

A planning and analysis framework is necessary to make informed decisions on designing and developing the future ACS system to meet future operational visions, but it is not sufficient. The Air Force must embed this framework in a continuous planning and development process and assign organizational responsibilities for exercising that process. Integration and coordination are required across operational units, across functions, between logistics and operations, across phases of operations, and across the various planning time horizons. Tradeoffs must be coordinated to balance ACS resources to meet the spectrum of future EAF operational requirements. Tools (such as the simpler, employment-driven models advocated above) and an integration approach can facilitate such tradeoff analyses, but they cannot make coordination happen. ACS design and development need to be viewed from a systems perspective, in much the same manner that weapon systems are viewed. A global ACS systems perspective would facilitate integration of capabilities and allow for better representation in funding decisions.

Current support system design and development decisions are highly fragmented across Air Force organizations. The CINCs' Air Component Commands (Numbered Air Forces or NAFs), the combat and mobility air forces, AFMC, the Air Staff, the U.S. Transportation Command (USTRANSCOM), and other organizations have portions of the responsibility and authority to make strategic decisions concerning ACS resources. For example, the decision to develop FSLs

could be the subject of NAF, MAJCOM, or AFMC strategic planning. There have been periods when AFMC played an important role in combat support delivery in various AORs—for example, Royal Air Force (RAF) Kimble Air Base in England contract Programmed Depot Maintenance (PDM) operations, at Kim Hae in South Korea, and AFMC Detachment 35 at Kadena Air Base on Okinawa. The MAJCOMs have developed various regional operations to support combat requirements, including centralized component repair activities and engine repair facilities. Air Component Commands, such as CENTAF, have agreements and master plans to develop infrastructure within their AORs. AMC has agreements for en route bases to support strategic airlift operations, and USTRANSCOM and its subordinate commands negotiate for transportation to serve the needs of all theaters. However, no one agency has the responsibility and authority to integrate and rationalize global strategic planning from an Air Force (or joint) perspective.

We briefly discuss modifications of the existing support planning process to better address the design and development of the future ACS system infrastructure. We also discuss possible assignment of organizational responsibilities to implement the proposed ACS strategic planning process.

There are several ways the Air Force could organize to develop the future combat support system using the process described above. Strong leadership will be necessary to initiate this process, and Air Staff commitment is essential because significant cultural changes must accompany the integrated planning we are discussing. These changes need to be championed by the Chief of Staff and supported by AF/IL, AF/XP, and AF/XO.

In general, each MAJCOM and appropriate NAF could be held responsible for developing ACS requirements based on their own area of focus, supplemented by other internal and external organizations as appropriate. The real key is analyzing and integrating the requirements at a system level, and ensuring that tradeoffs are made and resources are directed appropriately.

The Air Staff (AF/IL) could initiate the organizational and process changes needed to support the new strategic ACS planning framework by creating a Director for ACS Design and Development under

whom each of the functional areas could be represented. This kind of organization could foster the integration and coordination that is needed to develop and continuously evolve the future ACS. This directorate could enlist the support of AFSAA, and possibly RAND and others, in developing the analytic framework and assessing alternative technologies and policies for inputs into the ACS design and resulting POM process, in the same manner that the XO/XP community uses AFSAA.

Another way to integrate the development of combat support requirements across all command lines is to include them in an ACS Technology Planning and Policy Integrated Process Team (ACS TPPIPT), which would formally review the MAJCOM outputs on a periodic basis.¹ The membership of this TPPIPT might be expanded to include coalition partners, academics, and think tanks.

A third option for accomplishing this integration would be to extend AF/XOP's charter to develop the future ACS system along with new employment concepts. AF/XOP was created to oversee the development of the EAF, as discussed in Chapter One.² AF/XOPE has delegated analysis to AFSAA. AFSAA is strengthening its ACS capabilities and is committed to create the kinds of concepts described here. Its output could be used by the MAJCOMs or by the Air Staff.

The Air Staff could delegate implementation responsibilities to the MAJCOMs in a system of centralized control but decentralized execution. The integrating agent—the Director of ACS Design and Development, the TPPIPT, or AF/XOP—would provide direction and guidance to the MAJCOMs to ensure multiple AOR infrastructure developments are considered. Requirements ready for development could be approved for funding and delegated to the MAJCOMs. Alternatively, acquisition and maintenance of the global support infrastructure could become the responsibility of an SPO for

¹The IPT would consider both policy and technology because, as discussed in Chapter Three, the appropriate tradeoff may be between the two. Policy and technology investments are currently considered separately, with the technology process being better defined and organized.

²As part of this structure, AF/XOPE has created a support cell to come up with alternatives for meeting support requirements associated with the EAF. The AF/XOPE cell has representatives from all support disciplines and is responsible for evaluating options to meet EAF operational objectives.

infrastructure at AFMC, who, under the guidance of the integrating agency, would oversee building the infrastructure and ensure that its performance meets the needs of operators.

CONCLUSIONS AND RECOMMENDATIONS

THE NEED FOR A NEW STRATEGIC PLANNING FRAMEWORK

The future security environment will require the Air Force to be prepared to meet a spectrum of operational requirements, ranging from humanitarian aid to full-scale MTWs under uncertain circumstances that are subject to continuous change. To meet this range of requirements and uncertainties, as well as to reduce extensive overseas presence, the Air Force has decided to pursue its transformation into an Expeditionary Aerospace Force (or EAF) ready to deploy tailored forces quickly from CONUS to immediately begin operations. However, the requirement for quick response to uncertain situations means that the success of the EAF concept depends on the agility and responsiveness of the support system to provide the resources needed to conduct operations in areas of the world that are important to U.S. interests. The effectiveness and efficiency of that support system are in turn, we have argued, critically dependent on strategic support decisions such as infrastructure investment in FOLs, FSLs, and transportation. Our research describes a deliberate strategic planning framework that can be used to make decisions for designing and developing the ACS system to support the future EAF.

An ACS strategic planning framework that supports the EAF must focus on meeting rapid deployment timelines; supporting the spectrum of operations from boiling peace to MTW; evaluating new support designs; dealing with prevalent uncertainty; integrating planning across time horizons, echelons, functions, phases of war and

with operations; and incorporating feedback mechanisms to diagnose and monitor support system performance. In short, it must guide the shaping and continual modification of the support system as it faces a changing world with changing security environments and changing operational plans. We have argued that to meet these challenges, the Air Force support planning process will need enhancement in a number of key areas, primarily because it was designed for the Cold War era of marginal changes to an existing infrastructure where the threats were known and relatively stable.

ELEMENTS OF AN ACS PLANNING FRAMEWORK FOR THE EAF

Based on the requirements listed above, we recommend that the following elements be developed as integral components of an enhanced ACS planning framework:

- Development of a closed-loop strategic ACS planning process between AF/XO and AF/IL that would be used to develop alternative strategic ACS designs for the EAF. This planning framework would be provided to the MAJCOMs (NAF/A4) for development of specific AOR ACS designs in concert with the CINC/A3. The ACS planning framework must start with operational analyses that provide inputs (e.g., force modules, sortie rates, mission types) for ACS employment-driven resource requirements determination models.
- Use of employment-driven end-to-end requirements generation models to specify requirements as a function of operational needs and logistics policies, practices, and technologies for logistics commodities and processes.
- Use of support options assessment models to compute metrics to compare alternative approaches for satisfying the requirements for individual commodities and processes across the phases of operations (e.g., peacetime operations and readiness preparation, deployment, employment/sustainment, redeployment, and reconstitution).
- Use of an integration model to evaluate ACS structures and processes.

- Use of a mobility model, such as ADAPT, to examine feasibility of various ACS options.
- Evaluation of effects of uncertainty and alternative transition paths to MTW operations.
- Use of measurements and assessments of actual process performance and resource levels with those that were planned.
- Designation of ACS planning and assessment responsibilities to direct and advocate the strategic system design and evolution.

RESULTS FROM ILLUSTRATIVE ANALYSES

We demonstrated several elements of the planning framework for three key resources: aviation support packages, avionics components, and munitions. In each case, we showed how employment-driven models, using spreadsheet models or modifications of existing models, could generate requirements for these resources. We then showed how assessment models could compute a number of metrics for use in evaluating several ACS options that satisfy the requirements.

From this work we gained several insights:

- For both munitions and avionics components, a strong case can be made for forward-based support, which could include FSLs as potential avionics repair sites and for storage of high-value munitions. Heavy bombs may have to be prepositioned at FOLs depending on the intensity of the operational requirements.
- Time-definite resupply is necessary if the ambitious EAF timelines are to be met. The rapid deployment timelines and high optempo that we explored call for prepositioning, but the access issue, cost, and uncertainty push for minimizing the amount. Thus, resources must be resupplied quickly to sustain operations beyond the sustainment provided by an affordable prepositioned IOR.
- The support system must have a measurement and control system that provides feedback from planning and ensures that system performance is maintained to the standards assumed during planning, and that problems are fixed.

- The planning must be integrated across commodities. That is, key decisions about support facilities must take into account all major resource categories when computing costs and benefits. Decisions made within resource stovepipes need to be examined from an overall system design viewpoint.

ORGANIZATIONAL CHANGES

A key characteristic of our proposed strategic ACS planning framework is that it requires integration across organizations and functions. In contrast, current support planning is divided among a number of players, including the Air Staff, the various MAJCOMs, and the NAFs. The corresponding decision processes are also fragmented, resulting in decisions that are often made independently, without coordinating strategies that might lower costs or enhance performance. Further, initiatives for new developments are somewhat biased toward technology, not toward new policies.

We recommend that a Director for ACS Design and Development, possibly subsuming the functions of the organizations concerned with Agile Logistics (formerly Lean Logistics) and ACS, reside within the Air Staff. The Director and his staff would work closely with AF/XOC and AF/XPX in developing ACS options to support evolving operational concepts. Technical support to the Director for developing employment-driven models (such as the suite of employment-driven models discussed in this report) could come from AFSAA. Technology and infrastructure development requirements would be provided by ACC and AMC development with input on requirements from the NAFs and MAJCOMs, who would be responsible for implementing this planning approach within their areas of responsibility and would use the planning framework. The acquisition and maintenance function for infrastructure could be the responsibility of an SPO at AFMC or implementation could be under the NAFs or CINCs with the coordination of the responsible Air Staff organization. Such a structure would allow for decentralized requirements generation and implementation, but would facilitate centralized review and coordination.

CONCLUSION

The EAF is a radical departure from past Air Force employment concepts, and it holds promise for enhancing the Air Force's ability to deal with a new and uncertain international environment while alleviating serious readiness problems caused by lengthy overseas deployments. However, this new concept requires new ways of thinking about ACS. We believe that an integrated, continuous strategic ACS planning process will enable the realization of the full potential of EAF capabilities.

SUPPORT REQUIREMENTS DETERMINATION MODEL: MUNITIONS

PURPOSE OF MODEL

As discussed in the main text, the goal in building a support requirements determination model for each resource is to have a relatively simple model (at an appropriate level of detail) that can quickly determine support requirements as assumptions about scenario, technology, and policy are varied. In this appendix, we describe the munitions requirements model that was used for the example in Chapter Three. The aim is not to provide detailed documentation for the munitions model, but to give an overview of its structure, data, methodology, and outputs.

BASIC MODEL STRUCTURE

Munitions activities are usually divided into four categories: receipt and storage, production (buildup of ready-to-load rounds from bodies, guidance packages, etc.), holding of rounds for loading, and actual loading on the aircraft. Because of the complexity and the length of time required to arm aircraft, our model focuses on the production function, although the other functions are represented as well in somewhat simplified form.

The munitions model is an EXCEL spreadsheet. Its basic structure (main inputs, data, and computational processes) is shown in Figure

A.1. The boxes roughly correspond to the key panels¹ in the spreadsheet. The model has two interacting flows: one is the computation of munitions required, and the other is the computation of the equipment and people required to build and load the munitions according to the schedule.

The basic scenario inputs are the aircraft and their roles, the schedule of sorties, and the number and assignments of the munitions build and load teams. The aircraft and their roles determine the munitions that will be expended (based on data inputs such as aircraft loads, expenditure rates, and the like, derived from Air Force publications and interviews with knowledgeable personnel); data on munitions characteristics are then used to determine the lift and cost of the munitions. Based on the expenditures and the required sortie

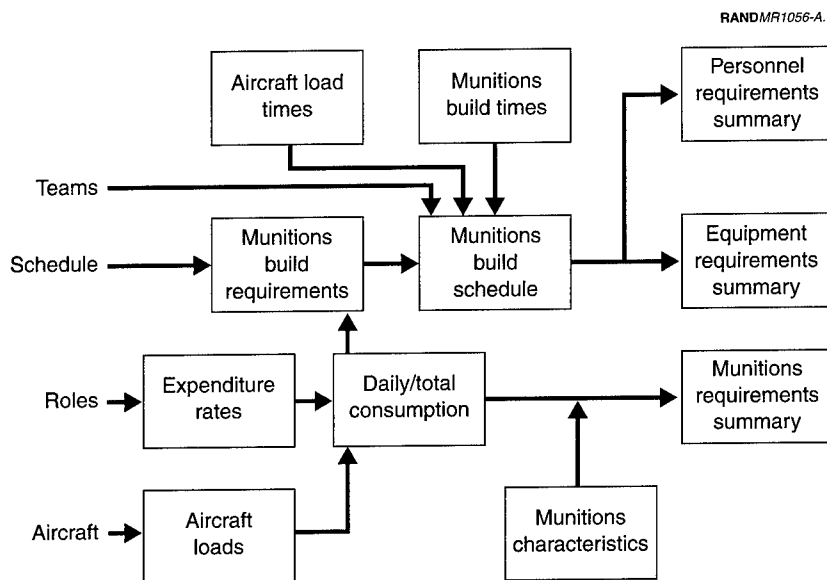


Figure A.1—Structure of the Munitions Requirements Model

¹We use the term *panel* to designate a rectangular area of a spreadsheet that contains related data or a relatively self-contained set of computations.

schedule, the model uses the inputs on the number and assignment of build and load teams and data on load-and-build times to compute a build schedule. The teams and equipment can be adjusted to ensure that the schedule is feasible; the final product of this part of the model is the number of people and munitions equipment required and the lead time before the first sortie for munitions build to start.

DETAILED DESCRIPTION

We now describe selected parts of the model to illustrate how underlying processes are represented and how the model can be used for widely varying scenarios.

Munitions Expenditures

The munitions expenditures for the operation flow directly from the types of aircraft employed and their roles. Figure A.2 shows the Program panel of the spreadsheet where the roles and aircraft are specified, along with a number of other key scenario parameters. In this example, the AEF force consists of 12 F-15Cs, 12 F-15Es, and 6 F-16CJs, flying AE (air cover), GA (ground attack), and SEAD missions, respectively. The daily number of sorties for each aircraft type is 28, 28, and 10, respectively (a stressing scenario). The total length of the operation is planned to be seven days.

In general, the white areas designate cells where the analyst can enter scenario data. This scenario could be varied as to aircraft type

AEFI	
Program	length is 7 days
MDG:	
F/A	F-15C 12 F-15E 12 F-16CJ 6
Role	CAP GA SEAD
Sorties	Day 1-7 20 20 12
S/P/A	Day 1-7 1.67 1.67 2.00 0.00 0.00 0.00
Turns	Day 1-7 2 2 2 2 2 2
launch/turn	Day 1-7 10 10 6 0 0 0
External tanks?	Yes Yes Yes

Figure A.2—Scenario Input (Row 1)

and role (see below for other data needed), number of sorties per day, and total days of the operation. The remaining parameters such as turns, sorties/PAA, etc., are computed from the input parameters.

For each of the roles used in this scenario, there is an expenditure rate for the set of munitions that is used in the roles. These are contained in the Expenditure Rates panel illustrated in Figure A.3; in this table "1" means that on every mission with that role all of the associated munitions are expended. For example, in the ground attack (GA) role, all GBU-10s mounted are dropped. In contrast, not all air-to-air missiles are expended on each sortie. The table can be expanded to include new munitions or new mission types.

For each munition, a given aircraft has a specific number of that type that it can carry. These are contained in the Aircraft Load Assumptions panel, shown in Figure A.4. Note that the model has spaces for the A-10 and C-130 gunship, but we have not included information on loads for these aircraft because they have not yet been used in our AEF analyses.

From the aircraft/roles inputs and the data on expenditure rates and aircraft loads, the model can compute the daily expenditure for each type of munition (expenditure rate multiplied by load multiplied by

Expenditure Rates										
Munition	AR	AT	CAS	CAS	GA	GA	GA	GA	GA	GA
AIM-7	1									
AIM-9	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
AIM-120	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
AIM-45										
AGM-88										
AGM-130										
B-41										
BLU-107										
CBU-28										
CBU-29										
CBU-10										
CBU-15										
CBU-24										
CBU-27										
CBU-28										
HCM-65B										
20mm H&I (500mm)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
MU-10 (class 24mm)	1	1	1	1	1	1	1	1	1	1
MU-7 (class 30mm)	1	1	1	1	1	1	1	1	1	1
Rel10/180 (rel 120mm)	1	1	1	1	1	1	1	1	1	1
TS&E										
AGU-44										
BRU-47/A (F-15) (P-15)										
LAMPFR										
LAU-88 (3xAGM-65)										
LAU-133/A (3xAGM-65)										
LAU-128/A (F-15) (P-15)										
LAU-129/A (F-15) (P-15)										
TSP-9/A (F-15) (P-15)										
600mm Tank (F-15)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
370mm Tank (F-15)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Figure A.3—Expenditure Rates by Role

Aircraft Load Assumptions		Combat					
		A-10	C-130	F-15C	F-15E	F-16CG	F-16CJ
AIM-7				2	2	2	2
AIM-9				4	2	2	2
AIM-120					2	2	
AGM-65	Maveric				6	6	
AGM-88	HARM						2
AGM-130							
B-61							
BLU-107							
CBU-	WCMDe				8	4	
CTU-2							
GBU-10					2	2	
GBU-15							
GBU-24							
GBU-27							
GBU-28							
HLM-SSB					6	6	
20mm HEI				940	510	510	510
MJU-10 (Flare)				24	24		
MJU-7 (Flare)						30	30
RR170/180 (chaff)				120	120	60	60
ALQ-xxx	ECM POD						
BRU-47/A (F-15)					4		
LANTERN					1	1	
LAU-88 (3xAGM-65)						2	
LAU-118/A (AGM-88>F-16)							2
LAU-128/A (F-15)				6	4		
LAU-129/A (F-16)						4	4
TER-9/A (F-16)						2	2
600gal Tank (F-15)				2	2		
370gal Tank (F-16)						2	2
VAES Loads		2		2	4	3	3

Figure A.4—Aircraft Loads

number of sorties in a given role). The total expenditures for the operation can then be determined by multiplying by the number of days for which the operation is planned. By using data on the weight and cost of individual types of munitions, the spreadsheet can also compute the lift required to move the required munitions and the cost of the munitions expended. This is summarized by type of munition in the Munitions Summary panel, shown in Figure A.5. This panel serves as one of the primary outputs of the munitions requirements determination model for disaggregated data on munitions.

Munitions requirements are summarized in more aggregated form in a final Summary panel shown in Figure A.6. This breaks out the requirements by general type. Note that we have not yet included data on TRAP (tanks, racks, and pylons), so these requirements are zero.

Munitions Summary	Program Expected Consumption	IOC #s		3 days		Total Value (\$K)	Total Lift
		IOC	IOC Lift	Daily Value (\$K)	Daily Lift		
AIM-7	0	\$0	0.00	\$0	0.00	\$0	0.00
AIM-9	182	\$5,184	0.29	\$1,872	0.10	\$12,672	0.70
AIM-120	756	\$109,968	2.44	\$37,564	0.83	\$240,304	5.78
AGM-65 (Maveric)	0	\$0	0.00	\$0	0.00	\$0	0.00
AGM-88 (HARM)	168	\$14,400	1.78	\$4,800	0.59	\$33,600	4.16
AGM-130	0	\$0	0.00	\$0	0.00	\$0	0.00
B-61	0	\$0	0.00	\$0	0.00	\$0	0.00
BLU-107	0	\$0	0.00	\$0	0.00	\$0	0.00
CBU	0	\$0	0.00	\$0	0.00	\$0	0.00
CTU-2	0	\$0	0.00	\$0	0.00	\$0	0.00
GBU-10	280	\$1,948	7.69	\$649	2.69	\$4,544	18.46
GBU-15	0	\$0	0.00	\$0	0.00	\$0	0.00
GBU-24	0	\$0	0.00	\$0	0.00	\$0	0.00
GBU-27	0	\$0	0.00	\$0	0.00	\$0	0.00
GBU-28	0	\$0	0.00	\$0	0.00	\$0	0.00
HLM-SSB	0	\$0	0.00	\$0	0.00	\$0	0.00
20mm HEI (500ea)	61460	\$0	0.47	\$0	0.17	\$0	1.16
MAU-10 (flare) (24ea)	6720	\$123	0.23	\$42	0.08	\$290	0.54
MAU-7 (flare) (30ea)	2520	\$23	0.09	\$8	0.01	\$54	0.08
RR170/180 (c) (120ea)	38640	\$195	0.18	\$66	0.06	\$460	0.43
TEAL	0	\$0	0.00	\$0	0.00	\$0	0.00
ALQ-XXX ECM POD	0	\$0	0.00	\$0	0.00	\$0	0.00
BRU-47/A Bomb rack (F)	0	\$0	0.00	\$0	0.00	\$0	0.00
LANTRIN	0	\$0	0.00	\$0	0.00	\$0	0.00
LAU-88 3xAGM-65	0	\$0	0.00	\$0	0.00	\$0	0.00
LAU-118/A Launch rail	0	\$0	0.00	\$0	0.00	\$0	0.00
LAU-128/A Launch rail	0	\$0	0.00	\$0	0.00	\$0	0.00
LAU-129/A Launch rail	0	\$0	0.00	\$0	0.00	\$0	0.00
TER-9/A Multiple-eye	0	\$0	0.00	\$0	0.00	\$0	0.00
600gal Tank (F-15)	5.6	\$0	0.00	\$0	0.02	\$0	0.08
370gal Tank (F-16)	1.68	\$0	0.00	\$0	0.02	\$0	0.09
Munitions Total		\$131,840	13.11	\$45,021	4.59	\$311,924	31.47

Figure A.5—Munitions Summary

	IOC \$K	IOC Lift	Dust \$K	Dust Lift	Total \$K	Total Lift
Missiles	\$129,552	4.51	\$44,256	1.53	\$106,576	10.64
Bombs	\$1,948	7.69	\$649	2.69	\$4,544	18.46
Chaff & Flares	\$341	0.91	\$116	0.32	\$803	2.20
TRAP	\$0	0.00	\$0	0.04	\$0	0.17
TOTAL	\$131,840	13.11	\$45,021	4.59	\$311,924	31.47
non-load mun	\$129,893	5.42	\$44,372	1.90	\$307,379	13.01
in-size loads		5.93		2.08		14.24

Figure A.6—Aggregated Munitions Summary

Build Schedule

The second model task is to determine the personnel, munitions equipment, and time needed to prepare the munitions to meet the operational needs. This requires a more detailed picture of when sorties are scheduled, rather than just the total number of sorties flown in a day. One (very demanding) sortie schedule is shown in Figure A.7. The panel lists the time when each set of aircraft is

Total Sorties	20	20	12	0	0	0
---------------	----	----	----	---	---	---

Figure A.7—Daily Sortie Schedule for AEF Operation

scheduled to launch, and the number and role of aircraft launched at that time. The unshaded area indicates that the analyst has complete flexibility in scheduling sorties.

Based on this schedule, the mission expenditure rates, and the aircraft loads, the model can compute the bombs, missiles, and other ordnance required as a function of the time of day. Figure A.8 shows the Munitions Build Requirement panel, which lists the demands over time for bombs only. A similar table (not shown) is computed

Journal of Management Education 30(6)p.789-804

Figure A.8—Bomb Requirements by Time of Day

The determination of the lead time for buildup is the most complex part of the model; it is done by the Build Start Time panel, shown in Figure A.9.

[illegible]

Figure A.9—Build Start Time Panel

quired to build the amount needed by that time and computes the setback needed from the start of the day's sorties. The maximum setback over the entire day is the earliest time at which building must start for each munition type to meet the day's flying. At the top of the panel, the analyst can set the number of teams (actually production lines) for each munition type. This determines the amount of munition build equipment required: for example, each bomb team requires one buildup table. The analyst then decides how many teams of personnel are assigned to that task (up to the number of production lines). In this case, teams are assigned to bomb, missile, and chaff buildup. Flares and 20-mm rounds are prepared by the same personnel when their primary buildup tasks are done. These team assignments determine the total number of buildup personnel required. At the bottom right hand of the panel, the down times are positive, indicating that the buildups and loads can be completed in 24 hours or less; there is therefore enough people and equipment so that the munitions buildup operation can be sustained indefinitely. If the buildup time took more than 24 hours, the down times would be negative. This would signal to the analyst that each day of operation would add an increment to the setback before the first sortie of the operation to ensure that all rounds for the planned duration were built in time for the sortie for which they were scheduled.

The data at the top of the panel are summarized from data panels listing the buildup times for specific munitions. Note that the buildup times are averages.

The buildup computation is summarized in the Setback Summary panel shown in Figure A.10.

Setback Summary						
Load time assumption:	Combat					
Drive time to flightline:	20 min (4 mph max)					
	1.33 mile					
WDS:	F-15C	F-15E	F-16CJ	0	0	0
Weapons load offset	0.75	1.00	0.75	0.00	0.00	0.00
longest build lead time	-13.83 hours from the FIRST weapons load time each day					
down time	0.17 hours from last build one day to build start next day					
daily catchup	0.00 hours of build time NOT available each day					
total catchup	0.00 hours to make up across the total program					
latest build start	15.17 hours before the first launch of the f. 15:20					
	(this may be as much as 0.25 hours early)					
buffer storage requires	4 M-110 trailers daily 4					
	5 M-141 trailers daily 5 TOTAL					

Figure A.10—Build Time and Equipment Summary Panel

The personnel determined by the analyst from the computations in the Build Time panel are combined with the people needed for loading munitions and for receiving, controlling, transport, and other jobs in the Teams panel in Figure A.11. At the upper-left corner, the build team requirement of 34 is imported from the Build Start Time panel. The flightline delivery drivers are computed from the number of trailers needed to haul munitions for a single sortie. The load teams are determined by the number of aircraft launched at one time and by the assumption (which can be changed—see the box in the lower-left corner of the panel) that the load crews are not shared across MDS.

The final step is to compute the lift and cost requirements for munitions equipment. Based on the computation of production lines and storage trailers from the Build Time panel and Storage panels (not shown), the analyst can select certain pieces of equipment in the Inventory panel in Figure A.12 (this selection allows the inclusion of alternative pieces of equipment that perform the same function). A

Teams									
Receiving and Storage 10 pers									
Control for 2 shifts Accounting Controller Inspection									
at 2 pers 2 2									
10									
Build Teams Build Time 23.47 hours									
Down Time 0.53 hours									
for 2 shifts RAM Missiles Chaff Flares 20mm Supervision									
at 52 pers 42 6 0 0 0 0									
104 Augmentees: 0 0 0 0 0 0									
Flightline Delivery 5 pers									
Flightline Crews Dedicated Teams:									
MDS: F-15C F-15E F-16CJ 0 0 0									
Load teams are shared First Go 6:30 6:30 7:00									
across MDS? Last Go 16:00 16:00 16:30									
Load time 0:45 1:00 0:45									
No teams: 4 4 2									
shifts: 1 1 1									
pers: 5 5 5									
50 Dedicated 20 20 10									
40 Shared Teams (see worksheet)									
Load Team Personnel: 50 Load Teams 10 *									
BOR team Response Maintenance Rest									
teams: 2 1 2 1									
shifts: 1 1 1 1									
pers: 2 2 2 5									
6 3 6 5									
Other Team Personnel: 20									
Total 199									
* Go spacing may be infeasible or additional teams may be required.									

Figure A.11—Teams Panel

	Include?
9	Yes
9	Yes
	Yes
	Yes
	Yes
1	Yes
	Yes
	Yes
	Yes
	Yes
	Yes
	Yes
	Yes
	Yes
	Yes
	Yes
	Yes
	Yes

Figure A.12—Inventory Panel

secondary data sheet that contains the characteristics of the listed equipment is used to compute the total size and weight of the equipment and its cost.

The personnel and equipment computations are brought together in a final Summary panel (Figure A.13) together with munitions output that contains the aggregate metrics. As with the munitions summary, this panel is used to feed the metrics to other spreadsheets for tradeoff analysis on aggregate metrics for various support options (see Appendix B).

IOC #		3 days		Daily Value (\$)		Daily Life		Total	
Number for IOC		IOC Value (\$)	IOC Life	For Maintenance	For Maintenance	Value	Life		
Vehicles	55	\$6,987	15.01			\$6,987	15.0		
Non-vehicle Equipment	80	\$1,144	6.68			\$1,144	6.6		
Munitions		\$131,840	13.11	\$45,021	4.55	\$311,924	31.3		
TPAF		\$0	0.00		0.00		0.0		
TOTAL	135	\$139,871	34.81	\$45,021	4.55	\$319,955	53.1		
PAX	199				Day		Time		
Latest build start	15.17 hours before first launch, the				-1		15:20		

NOTE: Go spacing may be infeasible or additional time may be required.

Figure A.13—Summary Panel

VALIDATION AND EXTENSION

As noted above, this description is not a detailed documentation of all aspects of the model, although it has treated all of the inputs from the analyst, as well as the major data needed on weapons and equipment characteristics. The overall structure of the model is quite simple and, we would argue, treats the most important and time-consuming aspects of munitions buildup and loading. In particular, significant discrepancies (on the order of 20 percent for buildup times) should be traceable to specific data elements that should be resolvable by consulting with subject-matter experts. In building the spreadsheet and using it for our analyses, we have informally validated many of the inputs with personnel in the field and on headquarters staffs.

Several extensions have been suggested for the model. One concerns the fact that the model specifies a single set of roles (and hence munitions) for the entire operation. More typically, the Air Tasking Order (ATO) might change roles and missions from day to day. The model could accommodate multiple specifications for different days (at a considerable increase in complexity), but it should be adequate for the study of small expeditionary operations that would have a limited role and hence arguably more stability in the types of missions flown.

SUPPORT OPTIONS ANALYSIS: MUNITIONS

INTRODUCTION

Requirements determination models, such as the munitions model discussed in Appendix A, focus on the internal workings of the processes supplying various resources. The models are also linked directly to operational parameters of potential scenarios such as number and type of aircraft, sortie schedules, and so forth. These models can be used to evaluate the effects on weight, cost, etc., of internal modifications (such as new technology equipment or different manning plans) to the support process. However, there are other support alternatives that use the output of the model to examine options for providing requirements. Examples of support options are those for positioning equipment at various locations for use by a deploying AEF. In such cases, it is convenient to use a separate companion set of calculations that can compare the options according to their ability to satisfy the previously computed resource requirements.

We have developed such a complementary evaluation tool for prepositioning options and applied it to the output of our munitions, POL (petroleum, oil, and lubricants), and shelter requirements determination models. Like them, it is written in EXCEL, not only to facilitate access to the outputs of those models but also because the structure of the tool depends on the structure of the support options, and EXCEL provides a convenient way to experiment with different ways of making the computations.

SUPPORT OPTIONS

Our support options analysis focused on positioning alternatives for resources such as munitions, POL, and shelters. The options are listed below with a brief description and the label that was used in the spreadsheet.

- Warm Base ("BASES,W"). All equipment and resources are located at the Forward Operating Location (FOL) from which the AEF will operate, which is an active, operating air base (e.g., a host nation air force base).
- Cold Base ("BASES,C"). All equipment and resources are located at an inactive, secure base in cold storage.
- Forward Logistics Location ("Regional"). All equipment and resources are at a regional FSL close to the theater of operation, from which they are trucked or flown to the FOL for an AEF operation.
- Prepositioning ship ("AFLOAT"). All equipment and resources are in storage on a ship at sea, which docks and unloads when the materiel is needed for an AEF.
- CONUS storage ("CONUS"). All equipment and resources are stored in CONUS and moved to the FOL by strategic airlift.
- FSL/FOL ("Mixed regional"). All missiles are stored at an FSL, along with sustainment bombs. An initial set of bombs and all munitions equipment are stored at the FOL.
- CONUS/FOL ("CONUS missiles"). All (high-value) missiles are in CONUS and shipped to the FOL. All bombs and munitions equipment are at the FOL.

INPUTS AND OUTPUTS

As inputs, we have the lift requirements, costs, and time to buildup rounds from the munitions requirements model described in Appendix A. As an example, we will use the "ground attack" scenario with F-15Es dropping GBU-10s, supported by F-15Cs and F-16CJs, that was presented in Appendix A. As outputs, the primary metrics are the total time to get a base up and operating with all of the

munitions processes functioning, the costs of buying sets of equipment and munitions for storage, and the amount of strategic and tactical airlift needed (if any) to get the equipment and munitions into place.

TIME TO CLOSURE

The Timelines panel of the analysis tool computes the time required for equipment and materiel to get to the FOL and be ready to support combat missions. A part of this panel is shown in Figure B.1.

At the bottom-left corner, there is a set of cells that import results from the munitions requirements determination model. They include the lift required for the total package of munitions and equipment, and divide the package into an IOR (all of the production and loading equipment and three days of munitions) and sustainment (the munitions needed daily for the rest of the planned

BASE:	BASE:W		BASE:C		BASE:G		BASE:V	
AFI:	AFI:W		AFI:C		AFI:G		AFI:V	
TIMELINES	Event	Duration	Per	Variability	Units	BASE:W	BASE:C	Tactical air Vee
	build first load	0.63			1	0.63	0.63	0.63
	retrieve munitions	0.58			1	0.58	0.58	0.58
	construct build up area	0.33			1		0.00	0.33
	activate cold asset	1.00			1		1.00	
	offload tac airlift	1.45			1			1.45
	download linehaul	0.50			1			0.50
	deploy people	0.92			1	0.92	0.92	0.92
	tac airlift from LPOR/SPOR	0.50			1			0.50
	linehaul from LPOR	3.00			5			3.00
	linehaul from SPOR	1.00			1			1.00
	onload tac airlift	0.04			1			0.04
	upload & LPOR/SPOR	0.50			1			0.50
	debarb & SPOR	0.50			1			0.50
	steam	2.00			5			2.00
	strange linehaul	1.00			1			1.00
	offload* strat air	1.45			1			1.45
	fly* strat air	0.75			2			0.75
	onload strat air* APOE*	0.08			1			0.08
	download & APOE	0.50			1			0.50
	linehaul to APOE	2.00			1			2.00
	upload at COMUSC	0.50			1			0.50
	IOC is	Program	MOG			2.05	3.05	4.23
	0	7	2			1.00	1.00	11.00
	Latest build start:	15.17				3.05	4.05	15.33
	IOC	Sustain	Total					
	C-141 eq ...	34.81	4.59	53.17	NOUGS	49.17	73.17	103.98
	..vehicles	15.01	0.00	15.01	POC	49.17	73.17	103.98
	..non-vehicle	6.68	0.00	6.68	Worst POC	73.17	87.17	387.98
	..bombs	7.69	2.40	10.09				
	..missiles	4.51	1.53	10.64				
	..other ammo/	0.91	0.37	2.38				
	Vehicle count	55		55				
	Mont net val	\$191,640	\$45,921	\$311,524				
	..bombs	\$1,948	\$260	\$4,544				
	..missiles	\$129,552	\$44,256	\$306,576				
	..ammo	\$331,509	\$44,905	\$311,120				
	..non-ammo	\$341	\$116	\$803				
	Rolling stock			self propelled				

Figure B.1—Timelines Panel (Partial)

operation).¹ Also included is the number of hours in advance of the first sortie at which munitions buildup must start.

The events in the upper-left corner are the activities that must be performed to set up the munitions production processes and build up the first loads, expressed in fractions of a day. Some, such as “building first load” or “deploy people” must take place for any option. Others, such as “arrange linehaul” or “offload strat air,” will be relevant only for options that use trucking or strategic airlift, respectively. For some events, they can be computed (the time to build the first load comes directly from the cell at the bottom of the panel, which is computed by the munitions model). For other events, such as the time to retrieve munitions and equipment, we have used expert judgment. The “variability” column has increments for events that are added to the standard time to produce a (rough) pessimistic estimate of the duration of that event.

Three of the options are on the right of the panel. For some options, some events can be done in parallel—for example, in the BASES,C option the construction of the buildup area and the activation of the cold assets can be done together and so the time to do both is the maximum of the two (1.0). For each option, the relevant times are entered into the column to be summed at the bottom for the optimistic estimate. Relevant “variance” numbers are added to obtain a pessimistic number. For munitions, IOC and FOC (full operating capability) are the same, since all of the equipment must be in place for the munitions processes to be operational at all.

COSTS

The Cost panel shown in Figure B.2 (with three of the options) computes some of the transportation and setup costs. For example, the setup costs of the afloat option is computed by multiplying the fraction of a full shipload occupied by munitions by the cost of an entire ship. Similarly, costs are computed for the linehaul of resources (in terms of the number of trucks and drivers needed) from

¹These were called IOR and FOR in the main text. In the panels reproduced here from the model, the equivalent terms are IOC and FOC.

COST						Lift	IOC	Dist	Total
Assume									
	AFLOAT full load	122	C-141 sq			Bombs	7.69	2.69	10.46
	Mun Load	53.12	C-141 sq			Missiles	4.51	1.52	10.64
	AFLOAT proportion	0.44	proportion in this case			Tot Ammo	13.11	4.55	31.30
	AFLOAT allocation standard	0.37				Equip	21.70	0.94	21.87
Investments (\$F)									
	AFLOAT setup	\$3,000	\$1,110	one time					
	ammo set		\$211,120	per munl set			\$211,120	\$211,120	\$211,120
	...bombs	\$4,544					\$4,544	\$4,544	\$4,544
	...missiles	\$306,576					\$306,576	\$306,576	\$306,576
	...other	\$0					\$0	\$0	\$0
	non-ammo set		\$803	per munl set			\$803	\$803	\$803
	Munl set	\$211,924					\$211,924	\$211,924	\$211,924
Yearly (\$F)									
	carabaker force	\$185		per munl set			\$185		
	warehouse O&M per set	\$74		per munl set ashore			\$74		
	AFLOAT O&M p	\$9,000	\$3,330				\$0	\$0	\$0
Per Event (\$F)									
	AFLOAT/event	\$100	\$27	per event / one way			\$0	\$0	\$0
	LINDBERG			per event / one way			\$0	\$0	\$0
	Rolling stock is self propelled								
	55 self-rolling stock								
	3 non-vehicle truckloads per C-141 load								
	6.48 C-141 loads of non-vehicle								
	21 linehaul trucks for non-vehicles								
	0 linehaul trucks for rolling stock								
	\$600 daily truck rental rate								
	\$12,600 daily linehaul truck rental								
	76 total linehaul vehicles								
	1.3 driver allowance								
	114 drivers								
	\$200 daily driver rate								
	\$22,800 daily driver cost								
	daily linehaul cost (\$)			per truck					
	\$35,400			\$0.47					
	AIRLIFT:			per event / one way			\$0	\$0	\$0
hours one way	18		\$193 C-141 r/c charge?						
hourly rate	\$5.34		\$3.12 C-141 loads						
r/c one cost	\$122,264		\$10,239 C-141 airlift charge						
SAAM						Regional Airlift			\$1,138
hourly rate	\$9,630					hrs one way	2		
r/c SAAM cost	\$145,630								

Figure B.2—Cost Panel (Partial)

either the FSL or seaport or for strategic or tactical airlift, in terms of C-141 equivalents. These costs are then listed under the appropriate option.

SUMMARY OF COMPARISONS

Finally, the computations are brought together into a Summary panel (Figure B.3) so that the options can be directly compared. In the upper-left corner are the basic assumptions about the number of FOLs and FSLs. In this case, we assume one region with three FOL bases. The system must be prepared for two AEFs simultaneously, and makes one demonstration AEF per year with full shipment of all needed resources. The comparisons below are parameterized by these assumptions so that changes in the assumptions change the estimated costs and airlift.

[illegible]

Figure B.3—Summary of Options

The first row is investment costs—the costs of equipment and munitions that would be needed under that option.² For example, for the warm and cold bases options, three sets of equipment and munitions would need to be provided, one for each of the three FOLs. In contrast, for the regional, afloat, and CONUS options, only two sets would be needed, to cover the potential two simultaneous AEFs.

The second row is recurring costs, which would be incurred in operating the option from year to year. For example, for warm bases and regional facilities, warehouses would have to be staffed, and for cold bases, maintenance people would need to be provided to periodically test stored materiel. More important, the options that depend on transportation to move munitions to an FOL would have yearly costs because of the requirement to conduct demonstration AEFs to maintain the proficiency of the force in conducting expeditionary operations. The annualized cost is the yearly cost of operating the given option for 10 years (the recurring cost plus one-tenth the investment cost).

²This is not necessarily a buy requirement. Much of the required munitions-handling equipment may already be in the inventory, particularly after substantial withdrawals from Europe. GBU-10s, which are assumed to be the ground-attack munition in this example, are in plentiful supply. However, when considering new or future munitions, some of the investment cost may have to be spent on procurement.

The IOC numbers are repeated from the Timelines panel, and the airlift requirements come directly from the munitions requirements model output (if relevant to the option).

**SUPPORT REQUIREMENTS DETERMINATION MODEL:
MINIMUM MAINTENANCE PERSONNEL AND
SUPPORT EQUIPMENT**

This appendix describes the features and characteristics of the Minimum Maintenance Personnel and Support Equipment Requirements Model. This model was used to generate minimum aviation support package and support equipment requirements for the F-15E (see the example in Chapter Three). The aim is to provide an overview of the model structure, inputs, and outputs.

BASIC MODEL STRUCTURE

Primary maintenance activities to support combat sortie generation include: launch (including end-of-runway (EOR) and electronic countermeasure (ECM) flow-through inspections), recovery and inspection, refueling, and munitions uploading and downloading. Secondary functions include troubleshooting and repair of inoperative aircraft systems. Tertiary functions include avionics component repair, jet engine intermediate maintenance (JEIM), and major aircraft (phase) inspections.

The minimum maintenance personnel and support equipment model (an EXCEL spreadsheet) determines requirements for the primary maintenance activities described above. The model determines aviation support package requirements by deriving maintenance personnel and equipment capabilities from the number of Primary Assigned Aircraft (PAA) tasked for deployment and other important parameters. Rules that determine personnel and equip-

ment requirements allow the user to adjust the output of the model by modifying the rules to compare options.

As shown in Figure C.1, the basic scenario inputs are the number of deployed aircraft and their roles, the number of sorties per day, the number of turns (the number of times specific sets of aircraft are launched), and the type of maintenance capability that will be supported from the deployed location.

Personnel requirements include all maintenance Air Force Specialty Codes (AFSCs) associated with aviation support Unit Type Codes (UTCs). Support equipment requirements include powered and nonpowered Aerospace Ground Support Equipment (AGE), and all tools or test equipment associated with aviation support UTCs. Major components of support equipment are identified by National Stock Number (NSN), acquisition cost, and approximate pallet positions required to move each piece of equipment. The data on support equipment characteristics are then used to determine lift and cost requirements. The final products of the model are the numbers of people and the amount of support equipment required to support a proposed tasking.

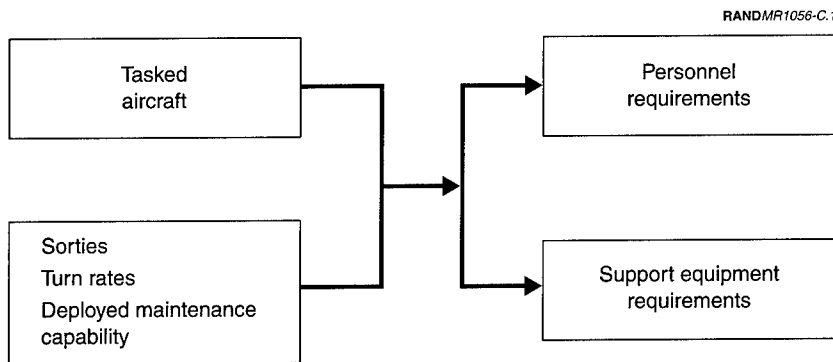


Figure C.1—Structure of the Minimum Maintenance Requirements Model

DETAILED DESCRIPTION

Selected parts of the model illustrate how underlying processes are represented and how the model can be used for widely varying scenarios. In Figure C.2, we show F-15E data. Work is in progress to include other Mission Design Series (MDS).

Aviation support requirements for any operation flow directly from the number of aircraft deployed, desired maintenance capability at the deployed location, and sortie rates. Figure C.2 shows the Program panel of the spreadsheet, where the number of deployed aircraft (PAA) is specified, along with sorties per day and desired maintenance capability for a given scenario. In this example, the force consists of 12 F-15Es, the daily number of sorties is 28 (a stressing scenario), and avionics component repair is not accomplished at the deployed location.

In general, the white areas designate cells where the analyst can input scenario data. This scenario could be varied as to number of aircraft deployed, desired maintenance capability, and turn scheme or required sorties. The remaining parameters such as the number of turns and utilization rates (UTE) are computed from the input parameters.

PERSONNEL REQUIREMENTS

The employment-driven model computes personnel requirements for alternative sortie requirements. As stated earlier, the model is populated with F-15E data, UTC 3FQK10. The rules in the model were developed to include only those tasks that pertain directly to

F-15E Personnel Support for Minimum Maintenance Requirement			
Required Inputs			
PAA	12	UTE	2.5
Sorties/day	28	Launch/Turn	8
Turns	4		
GBU-10 Capability	no		
AGM-65 Capability	no		
Avionics Backshop	no	Total Personnel	120

Figure C.2—Scenario Input in Model Program Panel

combat sortie production in austere operating environments. In other words, the model was developed to produce lean and mean requirements. This employment-driven model does not now include requirements for pilots, intelligence, or life-support functions. Nor do the rules include estimates for extra duties, days off, nuclear, biological, and chemical (NBC) environmental impacts, or allowances for sickness or absence from duty, nor have we included three-level training requirements. The model is designed to produce requirements for a seven-day operation in a highly tasked environment. Rules could be added to incorporate the above conditions, but were not developed for our initial AEF work. The absence of allowances for these conditions may, of course, limit operational flexibility.

The rules in this model, as in our other models, were developed from a number of sources: review of written documentation such as regulations and pamphlets that specify resource relationships, observation of unit preparation activities, and discussion with experts in the field. Unit-, MAJCOM-, and USAF-level functional experts have validated our rules and models. Figure C.3 shows a portion of our personnel requirements model.

In our example, we have tasked 12 F-15E aircraft for deployment flying 28 sorties per day. We have identified the requirements in terms of function to be performed, required AFSC, number required based on the scenario, and a brief description of the function. Inside the model, we have defined rules for the required numbers. As an example, under the heading SMO/NCOIC/OIC, the AFSC required is 21A3 and the requirement is one per deployment of less than 20 aircraft. The rule could be adjusted, and up to five could be deployed (maximum authorized per UTC 3FQK10) if that adjustment was justified. The same adjustments can be made throughout the model. Figure C.4 is an example of how we determine requirements for the component repair and equipment repair squadrons.

Requirements for munitions build/load and delivery teams are imported from the munitions model described in Appendix A. The requirements for avionics component repair are all or nothing—either the entire capability is deployed or the function is supported in a different manner. Other functions have been tailored to support the seven-day scenario.

Required Operations	AFSC or Position	# Required	Remarks	3FQK10 Max Auth
FIGHTER SQUADRON MX				
Supervision				
SMO/OIC/NGOIC	21A3	1	* Officer	5
	2A300	1	* SNCO	1
PRO Super/Expeditor			(1 ea per shift)	
	2A390	2	* Pro Supers	3
	2A373A	2	* Crew chief Expeditors	see E35
	2W171	2	* Weapons Expeditors	see E52
	2A371	2	* Specialist Expeditors	8
Flight Chiefs (Spec, APG, Weapons, Support)	2A373A	1	* Crew chief	see E35
	2W171	1	* Weapons	see E52
	2A371	1	* Specialist	see E21
	2A373A	1	* Support	see E35
Others (QA, P&S)		1	* Plans & Scheduling	
		1	* Quality Assurance	
		2	* Maintenance Operations Center (1 per shift)	
APG Repairs (Hydraulics, Tire R2, inspections pre and post flight)				
	2A373A	6		28
	2A353A	22		75
Specialist Flight Repair (Acft T/S, LRU R2)				
A-shop (Fire Control)				
	2A351A	4		10
B-shop (Instruments and Navigation)	2A351B	3		6
C-shop (Communications and Pods)	2A351C	4		8
E&E (electric and environmental)	2A876	2		3
	2A656	2		8
Engine (R2 motor, T/S Acft and components)				
	2A6X1A	2		6
Weapons Flight Repairs				
Weapons Maintenance (Acft T/S, component R2)				
	2W171	8		15
	2W151	16		53
Support Section				
CTK (tool and equipment issue)				
	2A353A	4	* (2 per shift)	see E36
COSO (supply and Bench stock)	2S051	2	* (1 per shift)	6

Figure C.3—Minimum Fighter Squadron Maintenance Requirements Model

Required Operations	AFSC or Position	# Required	Remarks	3FQK10 Max Auth
EMS				
Armament Shop (racks or guns system repair)	2W1X1	2		see E52, E53
AGE Shop (delivery and repair)	2A672	1		2
	2A652	1		7
Munitions Flight	2W0X0	FALSE	see MunMaster sheet	
Fabrication Flight (could be ABDOR by CLSS)				
Structural Maintenance (Sheet Metal/Corrosion)	2A773	1		2
	2A753	1		10
Metals Technology (Welding/Machinist)	None W/O Equipment			
NDI (Inspection and Joap)	2A772	1		1
	2A752	1		3
Survival Equipment (chute and life support repairs)	None W/O Equipment			
Maintenance Flight				
R&R (Flight Control, Landing Gear, Heavy Maintenance)	2A3X3A	4		see E35, E36
Wheel and Tire (build-up)	None R&R can do some			
CRS				
Avionics Flight				
Sensors (Pod maintenance, targeting and navigation)	2A171	0		3
	2A151	0		6
	2A131	0		5
AMEWS (Automatics, Manuals, Electronic Warfare, LRU testing/repair)	2A071A	0	Full UTC authorization required if backshop support is deployed	7
	2A051A	0		15
	2A031A	0		8
Accessories Flight				
Electro/Enviro (Battery shop) No Batteries on F-15E	NONE take adequate spares to support Initial			
Fuels (T/S Acft, repair leaks)	2A674	2		3
	2A654	2		5
Egress	2A673	1		3
	2A653	1		5
Propulsion Flight				
JEIM (Engine tear down/rebuild)	NONE take adequate spares to support Initial			
Test Cell (trim pad)	NONE take adequate spares to support Initial			
Accessory Repair	NONE take adequate spares to support Initial			

Figure C.4—Minimum EMS and CRS Maintenance Requirements Model

EQUIPMENT REQUIREMENTS

The employment-driven model also computes equipment requirements for alternative sortie requirements. Like the personnel portion of the model, the equipment portion is populated with F-15E data, UTC 3FQK10. Once the tasked number of aircraft has been determined, the model will compute requirements. Figure C.5 shows some of the data contained in the model.

A portion of the rule base is visible in the far-right column of Figure C.5. After reviewing the deployment data, we concentrated our attention on support equipment. Support equipment represents the largest portion of the deployment requirement, about 60 percent. Figure C.6 is an example of the support equipment portion of the model.

The pallet positions for required tools and test equipment are identified at the top of this chart. We have not explored reducing single items inside of individual pallets because of the anticipated negligible gains. Pallet position requirements for support equipment are rough estimates utilizing characteristics from each individual piece of equipment. Once an entire package has been determined and a load plan developed, some savings may be realized by reconfiguring equipment to reduce required airlift.

AGE EQUIPMENT

A large percentage of the support equipment is classified as AGE, and this is where we concentrated our efforts. AGE characteristics we considered include overall weight, approximate pallet position(s) required for airlift, acquisition cost, and use. Use is rated one through three—one = used daily, three = used only occasionally. With the characteristics, we can then review options to support the requirement. As shown in Figure C.6, NF-2 light carts represent the largest airlift requirement. Each individual cart requires approximately 1.2 pallet positions; the rule we built into the model requires one cart per deployed aircraft or a total requirement of 14.2 pallet positions.

Nomenclature	Description	Dimensions (LxWxH)	Weight	Pallet pos (approx)	Rule-Base
TTU-228	Hydraulic Test Stand, 3 Phase, 5000 PSIG, 15 GPM	*128 x 66 x 66	7875	1.2	2 per 12 Act, 4 per 24
MUJ-13	Munitions Lift Truck	*185 x 69.5 x 41.5	6360	2.1	2 per 12 Act, 4 per 24
M32A-86D	Generator, 3 Phase, 115/200V or 230/400V, 400Hz	100 x 79 x 69	5675	1.1	2 per 12 Act
MEP-105	Generator	102 x 68 x 69	5185	1.2	Req. 5 for Avionics support (1-AMEVS, 2-LANTIRN, 2-spares)
Data Pod Trailer		138 x 91 x 94	5000	1.6	Req. for GBU-15 capability
MUJ-110	Engine Trailer (4000/5000) Stacked	202 x 91 x 71	4200	2.3	Included with MunMaster input
MJ-1AG	Bombfit	*155 x 82 x 87	3820	1.8	1 per 12 Act, plus 1 for ESTA
V2 Cart		*144.75 x 52.25 x 42	3800	1.6	6 per 12 Act, 9 per 24
AM32A-60A	Generator, 3 Phase, 120V, 400Hz, Bleed Air	172 x 60 x 57	3500	2	1 x 12 Act, plus 1 ESTA, 2 x 12 Act (2 max.)
Tester AFM3271	(cabin press)	119 x 61 x 69	3450	1.4	1 per 2 Act, plus 2 for bare-base infrastructure
Welder Machine		110 x 60 x 68	3235	1.3	1 per deployment
MUJ-141		138 x 80	3090	1.6	1 per deployment
MC-7	Air Compressor, 100 PSI	138 x 74 x 78	2900	1.6	Included with MunMaster input
NF-2D	Light Cart	102 x 66.5 x 80	2840	1.5	2 per 12 Act
CFT Dolly		*102 x 66.5 x 80	2275	1.2	1 per Act, 14 per 24 (14 max.)
MUJ-194		149 x 66 x 67	1995	1.7	1 per deployment
F-2A	Trailer	143 x 60 x 60	1905	1.6	2 per 24 Act
AM32C-10D	Air Conditioner	167 x 53 x 54	1875	1.9	1 per 12 Act, 2 per 24
400 Gal Fuel Bowser		*108 x 70 x 69	1325	1.2	6 per 12 Act, 10 per 24
LOK Tank		125 x 75 x 77	1190	1.4	1 x 16 Act for overruns
B1	Maintenance Stand	88 x 53 x 40	1125	1	1 per 6 Act, plus 1 ESTA
MC-2A	Air Compressor, 250 PSI	*131 x 44.5 x 123	1085	1.9	3 per 12 Act, 5 per 24
Oil Servicing Tr		89 x 54 x 40	850	1	3 per 12 Act, 5 per 24
Data Pod Lift Truck		89 x 65 x 59	835	1	1 per deployment
Tank Dolly		145 x 44 x 37	800	1.6	Req. for GBU-15 capability
Canopy Crane		137 x 61 x 38	688	1.6	4 per 12 Act, 6 per 24 (assume double-stacked for pallet pos.)
Tow bar		205 x 81 x 45	685	2.3	1 per 12 Act
Jump Start Cart		173 x 58 x 42	604	2	1 per 12 Act, plus 1 ESTA
B4	Maintenance Stand	81 x 54 x 41	560	1	1 per deployment
Wash Cart		*77.6 x 36 x 84	550	1	2 per 12 Act (2 max.) (assume double-stacked for pallet pos.)
C1	Maintenance Stand	88 x 40 x 40	195	1	1 per deployment
		*48 x 40 x 94	165	0	3 per 12 Act, 4 per 24 (assume stacked on other equipstand for pallet pos.)

Figure C.5—Support Equipment Data and Rules

TOTAL REQUIREMENTS CHARTS

The model provides summary requirements charts for the user. Figure C.7 provides examples.

By reviewing total requirements, the user is able to quickly assess the effects of changes to the scenario on support requirements. Such review also allows the user to concentrate on evaluating options for satisfying requirements with the largest reductions in airlift.

VALIDATION AND EXTENSION

The overall structure of the aviation support requirements model is quite simple and yet, we would argue, it treats the most important and time-consuming aspects of maintenance support to an aviation package. In building the spreadsheet and using it for our analyses, we have informally validated many of the inputs with personnel in the field and on headquarters staffs.

Several model extensions have been suggested. We will develop similar models for the F-15C, F-16 MDS, and B-1 as part of our AEF research. Armstrong Laboratory is developing a UTC tailoring tool

Pallet Position Requirements for PAA:		12	
Loaded 463L Pallets:	CRS	6	
	EMS	8	
	FS	18	
TOTAL		32	
AGE			
Total Pallet Pos.(approx)		84	
Total Short Tons		75.3	
Nomenclature	Quantity	Total weight(lbs)	Pallet pos.(approx)
NF-2D	12	27300	14.2
MJ-1A/B	6	22800	9.6
MC-7	2	5680	3
Tank Dolly	4	2752	3.2
CFT Dolly	1	1995	1.7
MC-2A	3	2550	3
AM32A-60A	6	20700	8.4
Tow bar	2	1208	4
AM32C-10D	6	7950	7.2
MEP-105	0	0	0
B4	2	1100	1
MHU-194	1	1905	1.6
TTU-228	2	15750	2.4
F-2A	1	1875	1.9
Oil Servicing Tlr	1	835	1
N2 Cart	1	3500	2
1-H1		0	0
LOX Tank	2	2250	2
Jump Start Cart	1	560	1
B1	3	3255	5.7
C1	3	495	0
MHU-83	2	12760	4.2
M32A-86D	2	11350	2.2
Canopy Crane	1	685	2.3
400 Gal Fuel Bowser	1	1190	1.4
Wash Cart	1	195	1

Figure C.6—Support Equipment Portion of the Model

for the Air Force, and we believe many of the ideas discussed here will be applicable to Armstrong's effort.

Much work remains to be done to integrate our various models. For example, this model can receive selected inputs from the POL and munitions models. These inputs allow the model to identify aggregate personnel and equipment requirements.

RAND MR1056-C.7

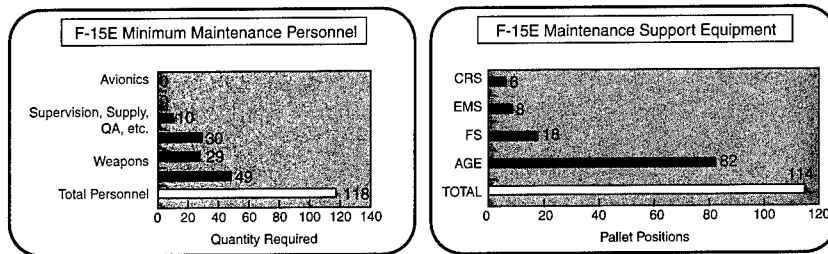


Figure C.7—Total Requirements Charts

SUPPORT REQUIREMENTS DETERMINATION MODEL: AVIONICS MAINTENANCE

This appendix describes the F-15 intermediate maintenance shop requirements model. The model generates the minimum number of testers required at a given intermediate repair facility. The manpower requirement follows directly from the tester requirement.

BASIC STRUCTURE OF MODEL

The basic structure of the maintenance shop requirements model, shown in Figure D.1, consists of three components. The first determines the required maximum sustained demand on the shop. The second determines the available capacity in the shop. And the third compares the demand to the capacity and then adjusts the number of testers until the available capacity hits a target level designed to accommodate demand and capacity variability.

Demand consists of the number of test station hours per day required to repair all line replaceable units (LRUs) that will be tested on a given type of test station. Daily demand is determined by the daily arrival rate at the test station and the test station's usage duration per arrival of each LRU tested on that test station. Arrivals are determined by a combination of the number of aircraft to be supported, the operating tempo, and LRU removal rates. The analyst inputs the first two based upon the maintenance support plan being modeled and the operational employment model. LRU removal rates depend upon the operating tempo and are based upon historical data.

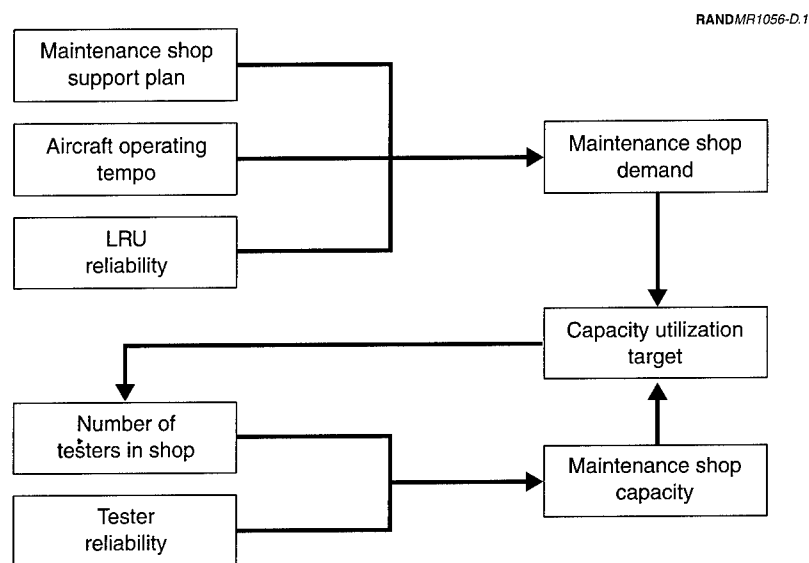


Figure D.1—Basic Structure of the Tester Requirements Model

Capacity consists of the number of test station hours available per day. The number of test stations of the given type, the uptime of each tester, and the work hours of the shop determine capacity. Historical data provide test station uptime, which is integral to the model. Shop work hours is set at a default value of 24 hours per day, but the model allows the analyst to vary this number.

DETAILED DESCRIPTION

Demand on a Test Station Type

Figure D.2 displays the demand data required by the model and how the data are used to determine the daily demand on a given type of test station. The flow inside the large box describes the demand determination for one type of LRU. The calculation starts with the daily demand rate from the Air Force's supply history. Depending on the operating tempo, this either uses the peacetime demand rate estimated in the Air Force supply history database (D041) or the decel-

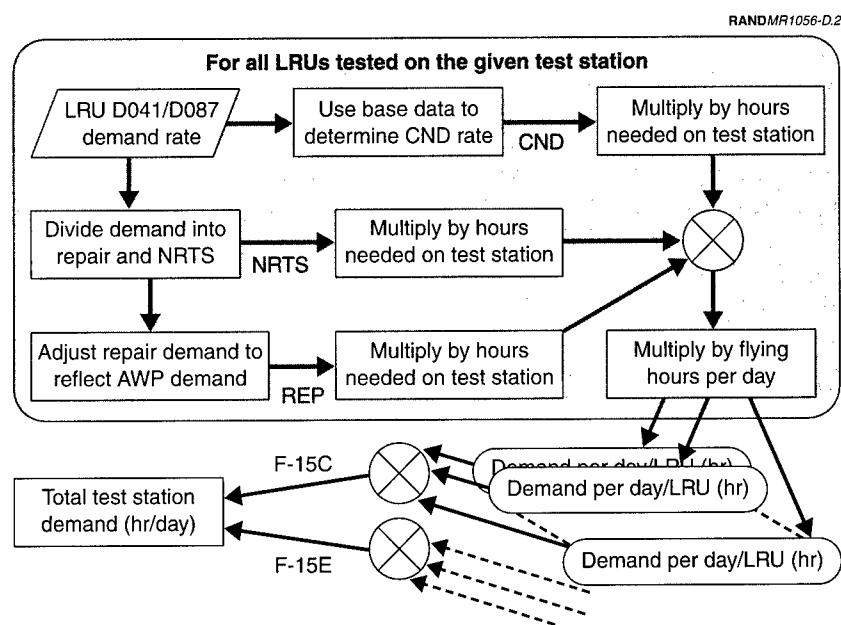


Figure D.2—Test Station Demand Calculations

erated wartime demand rate using wartime planning factors.¹ From the supply system data, we can break the demand rate into repair and not-repairable-this-station (NRTS) components. However, there is additional demand not captured in the supply data, so-called cannot duplicate (CND) conditions. CNDs occur when a problem cannot be found in an LRU and it is returned to supply with no action taken. Manual data collection efforts at several bases captured this demand relative to repairs. Using this relative rate with the D041 repair rates produces a CND rate. Additional demand comes from repairs that had to await parts (AWP), because the LRU has to be put

¹Previous research has suggested that LRU failure rates do not have a simple relationship to flying hours. To convert peacetime failure rates into projected wartime demands, the Air Force determined deceleration factors to convert longer wartime sorties into their equivalent peacetime durations in terms of LRU failures. The deceleration factors are specific to flying-hour scenarios.

back on the tester a second time when the part arrives. This rate is estimated in a similar manner to the CND rate.

The three rates—CND, NRTS, and repair (adjusted upward for AWP)—are then multiplied by an estimate of the average duration on the test station. For CNDs, this is simply the CND time, and for the other two streams it is estimated as two times the CND rate.² This estimates the daily demand on the test station per flying hour for the LRU. Multiplying by the flying hours in the operating scenario produces the average daily demand on the test station by the LRU. This procedure is repeated for all F-15C and F-15E LRUs tested by the given station. Summing the daily demand for all of these LRUs produces the total daily demand on the test station.

Test Station Capacity

Test station daily capacity is the number of test station hours available per day for a given test station type. In the model, the uptime rates for each tester of a set of collocated testers are considered to be the same. The overall uptime rate for each tester is estimated through a demand-weighted average of the mission-capable rates for each LRU tested on the tester.

Actual uptime by LRU for each test station was available at two bases, Seymour Johnson and Lakenheath. The average uptime of the collocated testers at the bases serves as the average uptime for any number of collocated testers in the model. Depending upon the tester type, these bases have one, two, or three testers. Therefore, the uptime represents the expected uptime by tester for either one, two, or three collocated strings (corresponding to the number of each tester type at these two bases) with the peacetime level of cannibalization practiced by these shops. Essentially, the data are used to empirically replicate the shop behavior rather than trying to fit a theory of cannibalization to the data.

²For repairs, this time includes running through the test until the tester indicates a problem, making the repair, and then running through the complete test to verify that the LRU is serviceable. For NRTS events, a significant amount of time is often spent trying to make the repair before declaring the LRU NRTS. Personnel at several shops considered the estimates of twice the CND time reasonable. Actual total time on test station was not available.

Higher numbers of collocated testers would probably offer greater cannibalization benefit, so the model may slightly overestimate the number of necessary testers for support plans that consolidate maintenance resources. Likewise, if a squadron had to deploy independently with one string, the uptime would probably be lower than used in the model, because of the likelihood of some level of cannibalization when all of the squadrons are at home.

In future work, we will study methods to correct this modeling weakness by explicitly accounting for the effect of cannibalization.

Tester Quantity Calculation

The test quantity is set to maximize the capacity utilization subject to a capacity utilization constraint. The maximum capacity utilization factor depends upon the number of test stations and is set to provide a target wait time in queue. The Air Force computes spares requirements using a model called Dyna-Metric.³ This model assumes an approximate four-day average for the time to repair an LRU on base. To produce consistency, the capacity utilization factors in the tester requirement model are designed to produce an average maintenance queue time of 72 hours.

MODEL OUTPUT

To quickly size a number of locations under different operating parameters, we created a spreadsheet model to automate the demand-and-supply calculations. The cells at the top (see Figure D.3) are the input cells. The operating tempo inputs include the number of F-15Es and F-15Cs, the flying hours per day for each based upon sorties per day and hours per sortie, and whether they are flying combat or peacetime missions. The combat input cell determines whether the model uses the wartime planning flying hour deceleration factors to compute demand. An additional input cell allows the analyst to model the effect of a combat situation without using the deceleration factors. Shop work factor cell inputs include the number of hours

³See Pyles (1984), and Air Force Materiel Command (1997).

Operating Tempo		
	F15E	F15C
Aircraft	24	24
Sortie Rate	1	1
Hours / Sortie	3.19	6.06
Combat	Yes	
Use Deceleration Factor for Combat	Yes	
Maintenance Shop Work Factors		
Work Hours Per Day	24	
Days Per Week	7	
Do not test 2 levels	No	
Test Station Capacity Factor	0.8	
Test String Requirements		
Number of Testers Required to Avoid AWM		
EARTS	2	
TISS	3	
EAU	1	
Displays	2	ESTS 6
Microwave	2	
METS	2	
Computers	2	
Indicators & Controls	3	
Comm, Navigation & Identification	1	

Figure D.3—Spreadsheet Model Input and Output Screen

worked per day, the number of days worked per week, and whether the shop tests two-level items. Additionally, the analyst can determine the effects of varying the required daily average excess capacity.

The output cells in white are the number of testers required based upon the operating tempo and shop work inputs. Notice that the outputs include all three potential tester configurations. For the

testers that are substitutes in the various configurations, the quantities for each are alternatives and not additive.

VALIDATION AND EXTENSION

To build confidence in the model results and to evaluate the robustness against the actual maintenance system variability, the next step in the modeling process is to build a Monte Carlo simulation model. The closed-form maintenance model discussed here is designed to determine the number of testers to provide identical operating performance for any support concept. But many elements in the F-15 avionics maintenance system have large amounts of variability that we could not fully model with closed-form solutions. Therefore, the models produce initial estimates of the requirements. Only through a Monte Carlo simulation can we determine if the support structures should work as planned with the calculated resource levels or if the resource levels require slight adjustments. Simulation can also quantify the effect of operational risks such as having only one tester in a location and resupply performance shortfalls.

Appendix E

AEF DEPLOYMENT AND PLANNING TOOL (ADAPT)

ADAPT models the mobility processes at CONUS, en route, and at forward operating locations.¹ As shown in Table E.1, five types of CONUS bases are modeled, along with the flows of aircraft and personnel between them.

Table E.1
CONUS Base ADAPT Processes

Lead fighter unit base	Prepare aircraft for deployment; place crews in crewrest; process unit personnel and equipment (mobility); load airlift aircraft; when tankers are ready, deploy fighters and unit cargo.
Follower fighter unit base	Prepare aircraft for deployment; place crews in crewrest; process unit personnel and equipment (mobility); load airlift aircraft; when lead unit has departed, deploy fighters and unit cargo.
Garrison base	Generate stored resources; load airlift aircraft; airlift aircraft depart.
Airlifter base	Generate TALCE ^a resources; prepare aircraft; place crews in crewrest; load airlift aircraft; deploy TALCEs; move airlift aircraft to onload bases.
Tanker base	Prepare aircraft for deployment; place crews in crewrest; process unit personnel and equipment (mobility); load unit equipment; deploy tankers.

^aTanker-Airlift Control Element.

¹The model is programmed using *ithink Analyst* software. See *ithink Analyst Technical Documentation* (1997).

The model allows the dependencies between activities to be explicitly represented. The sequence of these dependencies constrains the overall performance of system, as shown below in Figure E.1 for the airlifter base. When a warning order is received, crews are placed in crewrest, aircraft generated, and TALCE equipment loaded. When these processes are completed, the airlifters can depart to deploy the TALCEs at en route and destination locations, but only after an execute order is received. Also on warning, airlifters can move to the lead, follower, and garrison onload bases, but only if the aircraft and crews are ready and if the MOG status at the onload bases allows it. At the onload bases, the departure of the loaded airlifters cannot take place until the TALCEs have been deployed or tankers are available to support aerial refueling operations. Similarly, the fighter aircraft cannot depart until the tanker air bridge has been set up.

To represent the en route system, ADAPT models the en route bases, tanker forward bases, aerial refueling points, and a theater airlifter home base. The processes occurring at these bases are listed in

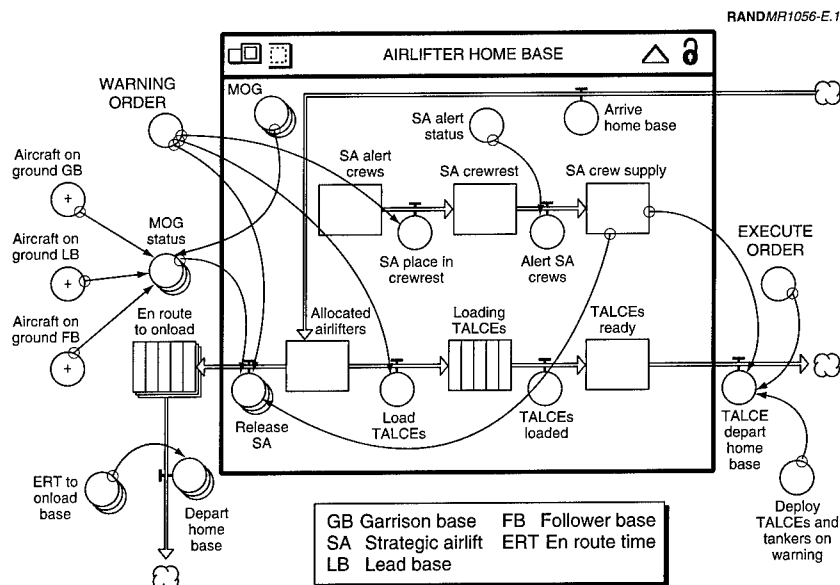


Figure E.1—CONUS Airlifter Home Base Processes

Table E.2. When the TALCEs have been deployed to en route locations, they allow the departure of airlifters from the CONUS onload bases. The deployment of tankers to forward locations enables the departure of fighters being “dragged” by tankers to the forward location. Finally, theater airlifters are readied and deployed forward.

In the forward area, ADAPT models a forward operating location (FOL) and a forward support location (FSL). The processes at these bases are shown in Table E.3. The FSL provides a centralized, regional location for the storage of AEF resources. The theater airlifters arrive at the FSL and begin round-robin flights between the FSL and FOL to move the resources forward. At the FOL, the incoming fighters are received and regenerated. The airlifters are unloaded and released to the en route system for return to CONUS. When enough resources are received to provide an initial operating capability, fighter sorties are flown. These sorties expend fuel and munitions that must be subsequently replenished if operations are to be sustained.

ADAPT models the AEF deployment system at a level of detail that captures the essential dependencies among air mobility activities.

Table E.2
En Route System ADAPT Processes

Airlifter en route base	Receive TALCEs; set up en route support operations; process deploying and returning airlifters.
Forward tanker base	Receive tankers; set up deployed tanker operations; place crews in crewrest; tankers depart to aerial refueling points.
Aerial refueling points	Aerial refuel airlifter and fighter aircraft.
Theater airlifter home base	Place crews in crewrest; generate aircraft; load unit cargo; deploy theater airlift to forward support location.

Table E.3
Forward Base ADAPT Processes

FSL	Receive theater airlifters; load regionally stored cargo; loaded theater airlifters depart for FOL; return to FSL.
FOL	Receive deploying fighters; receive strategic and theater airlifters; offload airlifters; generate fighter sorties when sufficient resources received; sorties expend resources; replenish resources from CONUS or FSL.

We used the integrating model to identify candidate support concepts, but that model incorporates only a rough representation of the transportation system. We used ADAPT to confirm the transportation feasibility of the support concepts as we developed them. Also, by modeling AEF deployment concepts in a model like ADAPT, insight can be gained into any weaknesses and constraining factors inherent in the concept.

BIBLIOGRAPHY

Air Force Materiel Command, *The D041 User's Manual*, AFMCMAN 23-1, Wright-Patterson Air Force Base, Ohio, 1997.

Banks, Steve, *Exploratory Modeling and the Use of Simulation for Policy Analysis*, RAND, N-3093-A, 1992.

Banks, Steve, *Exploratory Modeling for Policy Analysis*, RAND, RP-211, 1993.

Brooks, Arthur, Steve Banks, and Bart Bennett, *Weapon Mix and Exploratory Analysis: A Case Study*, RAND, DB-216/2-AF, 1996.

Crowley, Adrian M., and Richard L. Smith, *Development of Process Definitions for War Reserve Materiel Management and Force Package Paring and Tailoring for the Exploitation of Integrated Information Systems and Their Impact on Combat Readiness*, Thesis, Air Force Institute of Technology, AFIT/GLM/LAL/98S-12, Wright-Patterson Air Force Base, Ohio, 1998.

Davis, Paul K. (ed.), *New Challenges for Defense Planning*, RAND, MR-400-RC, 1994.

Davis, Paul K., and Manuel Carrillo, *Exploratory Analysis of "The Halt Problem": A Briefing on Methods and Initial Insights*, RAND, DB-232-OSD, 1997.

Galway, Lionel A., Robert S. Tripp, Timothy L. Ramey, and John G. Drew, "Supporting Expeditionary Aerospace Forces: New Agile Combat Support Postures for the EAF," RAND (forthcoming).

Headquarters, U.S. Air Force, *War Reserve Materiel (WRM) Programs: Guidance and Procedures*, AFI 25-101, Washington, D.C., October 1, 1997.

Hosek, James R., and Mark Totten, *Does Perstempo Hurt Reenlistment? The Effect of Long or Hostile Perstempo on Reenlistment*, RAND, MR-990-OSD, 1998.

ithink Analyst Technical Documentation, High Performance Systems, Inc., Hanover, New Hampshire, 1997.

Khalilzad, Zalmay M., and David A. Ochmanek (eds.), *Strategic Appraisal 1997: Strategy and Defense Planning for the 21st Century*, RAND, MR-826-AF, 1997.

Killingsworth, Paul, Lionel Galway, Eiichi Kamiya, Brian Nichiporuk, Timothy Ramey, Robert Tripp, and James Wendt, *Flexbasing: Achieving Global Presence for Expeditionary Aerospace Forces*, RAND, MR-1113-AF, 1999.

Los Angeles Times, "U.S. May Need New Battle Plan, Experts Say," February 25, 1998, p. A10.

Pyles, Raymond, *The Dyna-METRIC Readiness Assessment Model: Motivation, Capabilities, and Use*, RAND, R-2886-AF, 1984.

Pyles, Raymond, and Robert S. Tripp, *Measuring and Managing Readiness: The Concept and Design of the Combat Support Capability Management System*, RAND, N-1840-AF, 1982.

Richter, Paul, "Buildup in Gulf Costly: Expenses, Stress Surge for Military," *Los Angeles Times*, November 17, 1998.

Ryan, General Michael E., *Evolving to an Expeditionary Aerospace Force*, Commander's NOTAM 98-4, Washington, D.C., July 28, 1998.

Slay, F. Michael, et al., *Optimizing Spares Support: The Aircraft Sustainability Model*, Logistics Management Agency, AF501MR1, Washington, D.C., October 1996.