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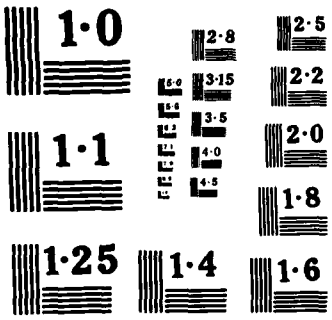

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James H. Bigelow

July 1985

N-2317-A

Prepared for

The Department of the Army

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To support logistically the present combat force during a major war.

This Note describes a conceptual design for Army Logistics Assessment--Extended (ALA-X), a methodology for assessing the readiness and sustainability of the U.S. Army. The methodology is intended for use in the Planning, Programming, and Budgeting process, so that those parts of the Army program dealing with logistics functions and resources can be better prepared and justified. The ALA-X methodology will relate resources among 38 categories of logistics resources to specific measures of combat capability and will treat them simultaneously so that tradeoffs and substitutions can be performed.

A RAND NOTE

CONCEPTUAL DESIGN FOR AN ARMY LOGISTICS ASSESSMENT--EXTENDED (ALA-X) METHODOLOGY

James H. Bigelow

July 1985

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PREFACE

This Note describes a conceptual design for Army Logistics Assessment--Extended (ALA-X), a methodology for assessing the readiness and sustainability of the U.S. Army. The methodology is intended for use in the Planning, Programming, and Budgeting process, so that those parts of the Army program dealing with logistics functions and resources can be better prepared and justified. The conceptual design was prepared in anticipation of further work to implement a prototype methodology. Accordingly, the Note should be of interest mainly to those with a direct involvement in the project. The work reported here was supported by Contract No. MDA903-84-C-0137 with the U.S. Army.

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SUMMARY

The Army Logistics Assessment (ALA) Coordination Center currently assesses the Army's capability to provide 38 categories of logistics support to its present combat forces during a major war. The ALA Center also points out which logistics categories will be short in the event of war. The information displayed by the ALA Center originates with a group of "functional proponents," one for each category of logistics resources or functions.

When first begun, the ALA Center produced only one assessment each year, which served as guidance for programmers in the Planning, Programming, Budgeting, and Execution System (PPBES). But more and more the ALA Center has been called upon to support the daily deliberations of the programmers concerned with logistics. Much of the work of these programmers is done in several panels. Each of the approximately ten panels considers those parts of the program that fall within a particular subject area. For example, the Sustain Panel considers the parts of the program that are intended to affect the sustainability of the forces in wartime. The panels mostly concerned with logistics are Sustain, Equip, and Mobilize and Deploy.

The ALA Center needs an enhanced methodology to perform well in its expanding role. ALA-X is intended to provide the analytic capability that the Center now lacks. The prototype ALA-X methodology will not initially consider all 38 categories of logistics resources and functions now considered in ALA; a few of the most important will be selected.[1] The ALA-X methodology will relate the resources considered to specific measures of combat capability and will treat them simultaneously so that tradeoffs and substitutions can be performed.

---

[1]We intend ultimately to consider every category, although for some we may be unable to improve on the current ALA Center procedures. In the immediate future, however, we will restrict our attention to a few of the more important categories, including POL, some types of ammunition, selected major items of equipment (e.g., tanks, artillery pieces), and the functions needed for their supply and maintenance.

Many characteristics needed by an ALA-X methodology derive from the fact that the ALA Center operates within the PPBES. The Army program is built during the PPBES process from Program Development Increment Packages (PDIPs). Each PDIP includes an action to be taken (such as buy 300 forklifts), a justification for the action (preferably the resulting increase in combat capability), and an estimate of the cost (dollars and manpower). The ALA-X methodology will be used to suggest PDIPs to remedy shortcomings in Army logistics capabilities and must therefore estimate costs as well as assess capabilities. Second, the ALA Center must interface with databases used in the PPBES (particularly the PDIP file) and with other elements of the Army Staff (especially the appropriate panels). The ALA-X project must pay due attention to designing these interfaces. Finally, the panel deliberations are highly dynamic and must cope with new information, ideas, and questions on a daily basis. Thus, the more responsive the ALA-X methodology can be made, the more useful it will be.

We have chosen to base the ALA-X methodology on existing, widely accepted Army models that are housed and exercised at the U.S. Army Concepts Analysis Agency (CAA). These models are used in the PPBES process to: (1) help design force structure; (2) compute wartime requirements for POL, ammunition, personnel replacements, and replacements for major items of equipment; and (3) assess, in a limited way, the operational readiness of the Army's current force. The methodology consists of several models. The Transportation Model (TRANSMO) determines whether a force can be delivered to the theater in a timely fashion. The Force Evaluation Model (FORCEM) simulates a theater-wide conflict and determines whether the forces can successfully prosecute the scenario. (The FORCEM model is replacing another theater-wide wargaming model called CEM--Concepts Evaluation Model.) The Force Analysis Simulation of Theater Administrative and Logistics Support (FASTALS) estimates what units are needed to support the combat force.

The assessment of the operational readiness of the Army's current force (one of the uses of the CAA models cited above) is of particular interest to ALA-X. It takes place in the annual U.S. Operational Readiness Analysis (OMNIBUS). Unfortunately, OMNIBUS for the most part

only compares resources on hand with requirements and fails to estimate the effects of resource shortfalls on combat performance. In principle, the CAA models are capable of assessing the effects of resource shortfalls on combat performance for the resources considered in OMNIBUS, which includes many of the categories considered by the ALA Center. They would do so by simulating pairs of cases, one in which the resource in question is short and the other in which it is abundant. The combat losses of men and materiel could be compared between the two cases, as could the land area lost to the opposing forces. However, the CAA methodology is so complex that only an occasional capability assessment can be done.

The CAA methodology is also too complex to permit the rapid responses to daily questions that an ALA-X methodology should be capable of. Thus, instead of using this methodology directly, we propose building a "repro" model, a simplified and aggregated model that reproduces the important features (particularly logistics features) of the more complex FORCEM model's behavior. It has proved possible to build repro models in numerous previous projects and to validate them successfully against the larger models they mimic. Usually the costs of using the repro model are 1 percent or less of the costs of using the larger model, which opens avenues for analysis that would be unthinkable with the larger model alone.

The ALA-X project therefore has four tasks. The highest priority is to build a repro model of FORCEM. CAA has already decided that such a model is needed for other purposes, and we will consult and cooperate with them in this effort.

A second task is to design a cost estimating capability for the ALA Center. This involves locating data and existing cost estimating relations. It may eventually require that we develop new cost models.

A third task is to design interfaces with the PDIP data base and with selected panels. The Force Management Impact Analysis System (FMIAS) provides those with the appropriate hardware access to a number of data bases, which in future will include the PDIP data base. The project believes FMIAS should be the starting point for our interfaces.

Finally, the ALA-X methodology must eventually consider each of the 38 resource and function categories of interest to the ALA Center. Not all of the categories are modeled in FORCEM; alternative means are needed to deal with some of them, but that task is for the future.

GLOSSARY

AFPCH	Army Force Planning Cost Handbook
ALA	Army Logistics Assessment
ALA-X	Army Logistics Assessment--Extended
AMC	Army Materiel Command
AMIP	Army Model Improvement Program
AMS	Army Management Structure
APC	Armored Personnel Carrier
AR	Army Regulation
ATCAL	Attrition Model Using Calibrated Parameters
AURA	Army Unit Readiness/Sustainability Assessor
C3I	Command, Control, Communications, and Intelligence
CAA	Concepts Analysis Agency
CAORA	Combined Arms Operations Research Activity
CEM	Concepts Evaluation Model
CE	Cost Element
COA	Comptroller of the Army
CONUS	Continental United States
COSAGE	Combat Sample Generator
CSR	Chief of Staff Regulation
CSS	Combat Service Support
DCSLOG	Deputy Chief of Staff for Logistics
DOSS	Days of Sustainability Study
FASTALS	Force Analysis Simulation of Theater Administrative and Logistics Support Support
FEBA	Forward Edge of the Battle Area
FLOT	Forward Line of Own Troops
FMIAS	Force Management Impact Analysis System
FORCEM	Force Evaluation Model
FSS	Force Stratification System
FY	Fiscal Year
FYDP	Five Year Defense Plan
LEA	Logistics Evaluation Agency
MACOM	Major Command
MFP	Major Force Program
MPA	Military Personnel, Army
MSC	Major Subordinate Command
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological, Chemical
OMA	Operations and Maintenance, Army
OMNIBUS	U.S. Army Operational Readiness Analysis
Oplans	Operational Plans
OSD	Office of the Secretary of Defense
OSMIS	Operating and Support Cost Management Information System
PBC	Program Budget Committee
PDIP	Program Development Increment Package
PE	Program Element
POC	Point of Contact

POL	Petroleum, Oil, and Lubricants
POM	Program Objective Memorandum
POMCUS	Prepositioning Of Materiel Configured to Unit Sets
PPB	Planning, Programming, and Budgeting
PPBERS	Program Performance and Budget Execution Review System
PPBES	Planning, Programming, Budgeting, and Execution System
SELCOM	Select Committee
TAA	Total Army Analysis
TLR/S	Total Logistics Readiness/Sustainability
TOW	Tube launched, Optically tracked, Wire guided
TPFDL	Time Phased Force Deployment List
TRADOC	Training and Doctrine Command
TRANSMO	Transportation Model
TRASANA	TRADOC Systems Analysis Activity
USAFAC	U.S. Army Finance and Accounting Center
USAMSSA	U.S. Army Management Service Support Agency
VAMOSC	Visibility and Management of Operating and Support Costs
WARRAMP	Wartime Requirements for Ammunition, Materiel, and Personnel

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This project was conceived by Col. William Mitchell, U.S. Army. He is now retired, but throughout most of the first year he was Chief of the Army Logistics Assessment Coordination Center. His help was invaluable, especially his steering us to important insights and information. His successor as Chief of the ALA Center, Lt. Col. Michael Sivigny, has continued the tradition. Lt. Col. Robert Wittemund of the ALA Center has arranged uncounted meetings and tracked down numerous publications on our behalf.

Morton B. Berman of Rand has provided overall guidance, both substantive and administrative. John B. Abell of Rand reviewed the draft of this Note and made many helpful comments.

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I. INTRODUCTION

The Army Staff created the Army Logistics Assessment (ALA) Coordination Center[1] to assess the capability of the Army to support logistically its present combat forces during a major war.[2] The Center serves as a clearing house for information and assessments provided by "functional proponents" for each of 38 categories of logistics resources and functions. It forms its logistics assessments by expressing the information for the 38 categories in mutually comparable terms (so far as possible), and presenting it in a single display. The Center has little capability to perform its own independent assessments.

When first begun, the ALA Center produced only one assessment each year, which served as guidance for programmers in the Planning, Programming, Budgeting, and Execution System (PPBES). But more and more the ALA Center has been called upon to support the daily deliberations of programmers concerned with logistics. The ALA Center needs an enhanced methodology to perform well in its expanding role. The purpose of the Army Logistics Assessment--Extended (ALA-X) project is to design that methodology.

This Note describes the conceptual design for the ALA-X methodology. The remainder of this Note is divided into two Parts. The first Part examines the current status and use of the ALA Center, including how the ALA Center currently operates (Sec. II), what its role is in the PPBES process (Sec. III), and where the Center obtains the information on which it bases logistics assessments (Sec. IV). From this discussion we will highlight some ALA Center weaknesses and deduce some features that an ALA-X methodology should possess (Sec. V).

---

[1]The ALA Coordination Center is an office within the Army Staff, under the Deputy Chief of Staff for Logistics (DCSLOG).

[2]The wartime scenario used to test this capability is the one found in the Defense Guidance, which envisions a conflict beginning in the Southwest Asia and spreading to Europe, with a Korean conflict breaking out shortly thereafter.

The second Part outlines an approach to building major portions of the ALA-X methodology. For many of the 38 categories, the proposed methodology can build on existing Army models (Sec. VI). Other categories need other approaches (Sec. VII).[3] The ALA-X methodology must also estimate costs of resources and must interface with existing procedures and databases of the PPBES process (Sec. VIII). The Note will close with a list of tasks for the ALA-X project (Sec. IX).

---

[3]We intend ultimately to consider every category, although for some we may be unable to improve on the current ALA Center procedures. In the immediate future, however, we will restrict our attention to a few of the more important categories, including POL, some types of ammunition, selected major items of equipment (e.g., tanks, artillery pieces), and the functions needed for their supply and maintenance.

PART I

CURRENT STATUS OF THE ALA CENTER

II. DESCRIPTION OF THE ALA COORDINATION CENTER

The ALA Coordination Center has the responsibility of producing logistics assessments for the Army Staff (particularly the DCSLOG)--assessments of the Army's ability to support itself in combat; 38 categories of logistics resources and functions have been identified as essential to this support. An office in the Army Staff is responsible for each category, and that office designates one of its members, a colonel or the equivalent, as the ALA Functional Proponent for that category.[1]

The functional proponent provides information to the ALA Center on the Army's requirements for his category's resources or functions. He also collects information on the Army's current status as regards these resources and functions and any measures currently approved for remedying shortfalls. He also identifies shortfalls that currently approved measures will not fully remedy.

The ALA Center organizes the information into a Time-Slice Model, which is actually more of a display format than a model. For each category the Time-Slice display identifies when (if ever) its requirements cannot be met during the Defense Guidance planning scenario. An accompanying worksheet for each category describes the shortfalls, if any, outlines what is being done to remedy the shortfalls, and identifies what more needs to be done.

THE 38 ALA CATEGORIES

Table 1 shows ALA's 38 categories of logistics resources and functions, in a format used by the ALA Center. The Warfighting Categories at the top have nothing to do with support; they show the kinds of capabilities being supported. The Support Functions are resources or functions that provide more or less direct logistics

[1]There are fewer than 38 functional proponents, because some offices are responsible for more than one category and can designate the same person as functional proponent for all their categories of responsibility. Together, the functional proponents make up the ALA Board of Governors.

Table 1

ALA DISPLAY FORMAT

Warfighting Categories

Infantry	Armor	Artillery	Air Defense	C3I

Support Functions

Deploy	**Man**	**Move**	**Shoot**	**Command & Control**
Active	Troop Support	POL	Conventional Ammunition	Intelligence
National Guard	Rations	POL Handling	Ammunition Handling	Strategic Comm
Reserve	Clothing & Equipment	Engineer Cbt Svc Supt	Engineer Cbt Supt	Tactical Comm
CONUS Outload	NBC Protection	Major Items	Chemical Ammunition	Automation
Strategic Lift	Medical Service	Recovery & Evacuation	Nuclear Ammunition	CAPSTONE
Overseas Reception	Personnel Replacements	Repair Parts	Missiles	Inventory Control
Intra-Theater Lift	Logistics Training	Maintenance	Aviation Logistics	Host Nation Support

CONUS Base

—	Mobilization Training Base	AMC	Industrial Base	—

support to the engaged combat units and are grouped according to whether they support the deployment, manning, mobility, firepower, or command and control of those units. The CONUS Base consists of the remaining, more indirect supporting resources or functions.

Deploy *(First Column of Table 1)*

In the Active, National Guard, and Reserve categories, the issues dealt with are those of ensuring that Army units can be manned, equipped, and trained in time to be deployed according to the Time Phased Force Deployment List (TPFDL). The resources needed to affect these issues include personnel, training devices, practice ammunition, and funding for field exercises.

The remaining four categories deal with various aspects of the transportation problem. Units and their equipment, as well as supplies and replacement personnel and equipment, must be moved from mobilization points and depots to ports of embarkation in CONUS (CONUS Outload); then transported to ports of debarkation in theater (Strategic Lift); loaded onto trucks, trains, or barges in theater (Overseas Reception); and moved within theater to the Corps rear boundary (Intratheater Lift). The resources available to do this include handling equipment at mobilization points and at Army depots, handling equipment at ports (both air and sea), transportation facilities in CONUS (mostly road and rail), transoceanic air and sea transport, and port facilities and transportation in theater. Also included are the command, control, and communications facilities needed to coordinate all the movements.

Man *(Second Column of Table 1)*

The Troop Support category deals with various services provided to troops, such as laundry and bathing facilities, and graves registration. Matters dealt with in the Rations, Clothing and Equipment, NBC Protection, and Medical Service categories are well described by the category titles.

In the Personnel Replacements category are issues of recruiting and training replacements for casualties in a timely fashion. Logistics Training has been split out from other personnel replacements issues

because so much of the logistics manpower is in the Reserve and National Guard components of the Army, and there they have little opportunity to train with the modern equipment that Active Army units possess.

Move *(Third Column of Table 1)*

The POL and POL Handling categories are described by their titles.

Engineer Combat Service Support includes repair of port facilities, locks, roads, bridges, and the like, generally at some distance removed from the battle zone.

Major Items involve replacements for major items of equipment (such as tanks and trucks) that break down or are damaged or lost in combat. Recovery and Evacuation deal with problems of recovering broken major items from the battlefield, and transporting them to locations where they can be repaired. Repair Parts and Maintenance deal with the aspects of the repair process that their titles suggest.

Shoot *(Fourth Column of Table 1)*

Of all the categories in this column, only Engineering Combat Support and Aviation Logistics call for elucidation. The Engineering Combat Support category includes the same sorts of activities as Engineering Combat Service Support. However, they are performed closer to the line of battle and more directly in support of the frontline forces, and they include activities more closely allied to combat, such as the laying and clearing of minefields.

Aviation Logistics include all the resources and functions for Army aircraft that are included for other kinds of equipment in the categories Major Items, Repair Parts, and Maintenance.[2]

---

[2]There is an Army Staff office responsible for all aspects of aviation logistics and separate from the several offices responsible for various different aspects of support for other major items of equipment. The selection of categories for the ALA Center parallels the structure of the Army Staff.

Command and Control *(Fifth Column of Table 1)*

The Intelligence, Strategic Communications, and Tactical Communications categories seem self-explanatory. The Automation category seems to be concerned mostly with the problems of computers on the battlefield. There are problems not only with supporting the computers themselves but also with the transmission of the potentially enormous amounts of data the computers will demand.

CAPSTONE is a program that preassigns each reserve or guard combat service support unit to the combat unit in the active forces that it is expected to support. Then the reserve and guard combat service support unit can train with the same kinds of equipment as its assigned combat unit possesses, assuring that the active and reserve forces will fit together properly in the event of war.

The Inventory Control category is involved with the problems of keeping track of all the myriad items the Army will use in wartime. Communication and data processing systems are to be developed to ensure that inventories are positioned and (at need) repositioned close to the points of heaviest demand and that inventories are replenished as required.

The Host Nation Support category deals with international agreements for a host nation to provide various logistics resources and functions. The resources and functions involved can be from any of the other categories of Table 1.

CONUS Base *(Table 1, Bottom)*

The issues dealt with in the Mobilization Training Base category involve mobilizing and training new recruits in the event of war and forming them (or some of them) into new units.

The AMC and Industrial Base categories involve providing equipment to old and new units. The equipment may come from new manufacturing or by repair or modification of already existing equipment. The AMC category deals with resources organic to the Army that can produce equipment, such as the depot system. These resources are controlled by the Army Materiel Command (thus explaining the category's title). The Industrial Base category deals with contractor-owned resources that produce equipment.

FUNCTIONAL PROPONENTS

For each category there is a functional proponent, who together constitute the ALA Board of Governors. The functional proponent for a category is assigned from whichever office of the Army Staff has responsibility for the resources and functions of that category. There is no ambiguity concerning which office should be responsible for a category; the categories were chosen to parallel the structure of the relevant parts of the Army Staff.

Each functional proponent is responsible for collecting and verifying information about his category and providing it to the ALA Center. The information includes:

- requirements for the resources and functions included in the category;
- the current status of those resources and functions--how much does the Army currently possess, how much is on order, what is its condition, etc.;
- currently approved measures to remedy shortfalls (when the current status falls short of satisfying requirements); and
- any shortfalls that currently approved measures will not fully remedy.

Later sections will describe where much of this information comes from.

ALA CENTER PRODUCTS

The ALA Center displays this information in a format called the Time-Slice Model, which is really a display technique rather than a model. The time slice model takes the form of a series of tables with the same format as Table 1. Each table in the series reports on the status of the 38 logistics categories at a different point in the scenario, the first table corresponding to D-day, the second table to D+10, the third table to D+20, and so on. Requirements in each category are established for each day of the scenario, and in each category, the functional proponent determines what percentage of the requirement can

be met on each day. Then the category is color-coded on the various time-slice tables to show those percentages roughly: red if 50 percent or less of the requirement is met on the given day, amber if between 51 and 80 percent is met, and green if more than 80 percent is met.

Accompanying these displays is a package of Warfighter Constraint Worksheets, one for each category. Each worksheet identifies for its category the deficiencies in the three theaters mentioned in the Defense Guidance Scenario (Southwest Asia, Europe, and Korea). The worksheet also outlines what is being done to remedy the deficiencies and identifies what remains to be done.

The ALA Center briefs its findings annually to the Chief of Staff of the Army and also publishes them as an appendix to the Army Guidance, Vol II. (In the future, it is planned that the ALA Center's findings will constitute the whole of Vol. II of the Army Guidance.)

III. THE USES OF THE ALA CENTER IN THE PPBES

The ALA Center is intended to support the Planning, Programming, Budgeting, and Execution System (PPBES), which the Army Staff uses to plan for the Army's future and to design a program that will achieve those plans step by step. The annual proposed Army budget is assembled from the first year of the program. Classically, execution has not been considered part of this system, which has therefore been known as PPBS. The Army has added the "E" in recognition of the Army Staff's responsibility to oversee in broad terms the implementation of the program they have decided upon.

The ALA Center currently provides support for the programming stage of the PPBE process, during which the Army program is designed. Initially, the ALA Center provided a "snapshot" of logistics deficiencies of the present-day army for the guidance of programmers, but more and more it has been called upon to support the daily deliberations of programmers concerned with logistics and must therefore continually reevaluate the probable effect on the Army of proposed remedies for logistics deficiencies.

THE STAGES OF THE PPBES

Traditionally, PPBS consisted of three stages--planning, programming, and budgeting--to which the Army has recently added execution (thus the term PPBES). The purpose of Army planning is to enunciate broad goals, which should then guide the programming and budgeting stages of the PPBES by providing a basis for assigning priorities to conflicting needs. However, planning has traditionally paid little heed to resource constraints, so formal planning has not had much influence on the later stages of the PPBES.

The purpose of programming is to construct a five-year program to achieve the short- and long-term objectives established in planning and/or mandated by OSD. The Army builds its program from Program Development Increment Packages (PDIPs).[1] Each PDIP identifies a specified increment of capability or activity and the resources needed

to achieve it. Ideally, PDIPs should be independent, so that each can be accepted or rejected regardless of how other PDIPs fare. In practice, of course, this is not always possible.

Each year, the Army collects PDIPs from various sources: baseline PDIPs from the previous year's program, perhaps repackaged (consolidated or broken apart); PDIPs submitted by the major commands (MACOMs) to identify resource shortfalls that impair their abilities to perform their day-to-day missions; PDIPs written to implement OSD guidance; and PDIPs generated internally by the Army Staff to reflect the needs and priorities identified in planning. Then the PDIPs are sorted in priority order. Once the Army Staff decides on the proper order for the PDIPs, the Army program (which is the Army part of the Five Year Defense Program, or FYDP) is constructed from as many of the highest priority PDIPs as will fit within the fiscal guidance. These surviving PDIPs become the next year's baseline PDIPs.

Budgeting translates the resource requirements of the Army program into a request for budget authority. The PDIPs are recast in terms of Major Force Programs (MFPs) and Program Elements (PEs), which are the program categories used in the FYDP. The costs of the PDIPs and PEs must be broken out by appropriation category and cost element (CE), the cost categories found in the FYDP.

The Army has added a systematic review of execution to determine how well the intentions of the planners, programmers, and budgeters are achieved. This review, called the Program Performance and Budget Execution Review System (PPBERS), takes the form of a quarterly briefing to the Program Budget Committee (PBC) and the Select Committee (SELCOM). The briefing compares planned and actual obligations and outlays, and planned and actual progress in program implementation. The briefing suggests corrective actions when actual obligations and outlays, or progress in carrying out the program, stray far from plans; and the SELCOM can (and sometimes does) direct that the suggested actions be taken.[1]

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[1]The PPBERS briefings necessarily present information at a rather high level of aggregation, as does the ALA Center. Thus PPBERS and the ALA Center will consider a few categories of ammunition at most, perhaps tank main gun, artillery (possibly by caliber), small arms, and one or two more. There is a more detailed side to execution, where 155 mm high

ALA AS A LINK BETWEEN PLANNING AND PROGRAMMING

Before 1982, when the Army began work on the five year program for FY 84-88 (the FY 84 POM),[2] the planner's job was complete when he had described the threat and an unconstrained "planning force" with which to meet it. Planning ignored the realities of resource limitations, but the programmers needed guidance to help make allocations of scarce resources among competing objectives. In addition, planning considered only the ultimate shape of things to come, whereas programming dealt with marginal changes (increments and decrements described by PDIPs) to an existing program. Thus formal planning could not much influence programming and budgeting.

According to the 1982 PPBES Handbook, [2] the Army has tried to remedy these shortcomings by modifying the planning process and by adding a "planning-programming link" consisting of Total Army Analysis (TAA), the Army Operational Readiness Analysis (OMNIBUS), and Army Logistics Assessment (ALA). (Here, ALA refers to an annual study, not to the ALA Center.) The regulations governing TAA [3] and OMNIBUS [4] state that these studies are intended to identify deficiencies in force structure (TAA) or logistics support (OMNIBUS) that are not remedied in the current program and to suggest PDIPs that would remedy these deficiencies. The ALA Center receives information from both TAA and OMNIBUS, as well as from other sources (see Sec. IV), highlights logistics deficiencies in each of the 38 categories shown in Table 1, and identifies the PDIPs in the current program that are intended to correct those deficiencies. The ALA Center briefs its findings annually to the Chief of Staff of the Army and also publishes them in the Army

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explosive antitank rounds are considered separately from every other type of 155 mm ammunition. Such details cannot be routinely considered in PPBERS or the ALA Center, but when systemic problems show themselves at a detailed level, there must be mechanisms to bring those problems to the attention of the high-level managers served by PPBERS and the ALA Center. Further discussion of this issue is beyond the scope of this Note.

[2]The Army annually proposes a five year program to the Secretary of Defense. That program is described in a document called the "Program Objective Memorandum," or POM. The POM is dated according to the first year of the program it describes and not according to its date of issue, about 18 months earlier.

Guidance, Vol. II. This volume contains instructions and information for programmers that will help them design a program that implements the planners' intent.

The findings are displayed in the Time-Slice Model format described earlier (Sec. II). The time-slice display provides only a rough guide for assigning priorities to logistics deficiencies. It is assumed that every deficiency, particularly every serious deficiency (coded red), is a potential "warstopper." Thus, a deficiency coded red in the D-day time slice is given the highest priority, because unless it is remedied, the war may be lost before one arrives at the next time slice. Of course, this assumption is recognized as a gross oversimplification, and its application must be (and is) tempered by judgment.

What one truly wishes to know is how combat capability suffers from the various deficiencies. The ALA Center does not now collect the information, nor possess the methodology, to perform such capability assessments.

ALA AS SUPPORT FOR PANEL DELIBERATIONS

In recent years the ALA Center has become involved in deliberations of the various panels, whose task it is to assign priorities to the PDIPs. The PDIPs are segregated by subject and submitted to various "panels" with such names as Equip Panel, Mobilize and Deploy Panel, and Sustain Panel; and each panel places its PDIPs in priority order.[3] Then the panels send their prioritized lists of PDIPs to the PBC and the SELCOM, and those committees decide on the proper overall order for the PDIPs. The Equip, Sustain, and Mobilize and Deploy Panels are given most of the PDIPs that deal with any of the 38 ALA categories. Until January 1985, the Chief of the ALA Center co-chaired the Sustain Panel. Organizational changes have since shifted the Chief's responsibility to an advisory role. In either capacity, it is natural for the Chief to look to his Center to support the Sustain Panel deliberations.

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[3]The number and titles of the panels may change from year to year. In 1984, there were nine of them, including Structure, Man, Equip, Train, Mobilize and Deploy, Manage Information, Sustain, Facilities, and Manage.

The deliberations of the Sustain Panel compare PDIPs to determine their contributions to the "sustainability" of the combat forces in wartime. Analyses must be performed estimating the contribution of each PDIP to various aspects of combat capability. As the comparisons are made, it may become evident that certain program increments are too large or too small and should be revised. Other reasons for revising PDIPs might arise because of concurrent Congressional or OSD actions, or in the process of executing the current year's program. When a PDIP is revised, it is necessary to estimate its new cost, as cost information is a vital part of every PDIP. And the analyses and revisions of PDIPs must be done quickly, because the work of the Panels is done in the space of a very few weeks.

The ALA Center is not well equipped at present to provide this support. It lacks the necessary speed of response, and it has no capability to quickly estimate the costs of new or revised PDIPs.

IV. SOURCES OF INFORMATION FOR THE ALA CENTER

As stated earlier, the functional proponents are responsible for providing information to the ALA Center about their categories of logistics resources and functions. Information on requirements and on current Army status of logistics resources and functions generally comes from the Commands outside of the Army Staff. This is not to say that the Staff has nothing to do with requirements determination. The Staff must approve the detailed planning scenario (including a deployment schedule) as well as approve a multitude of assumptions and factors that affect requirements. But usually the data will be collected and the actual computation will take place in the Command responsible for managing the resource in question.[1] Similarly, assessment of the current status of the Army regarding a resource or function will take place in the responsible command. For many of the most important resources and functions, these estimates take place in the annual U.S. Army Operational Readiness (OMNIBUS) study.[4]

For information on currently approved measures for remedying shortfalls, the functional proponents must refer to the approved Army program. This is described in the file of PDIPs, [1] a part of the PPBES database maintained by the Directorate of Program Analysis and Evaluation, Office of the Chief of Staff of the Army.

THE PDIP FILE

Each PDIP describes an increment of the program. It includes a description of the purpose to be accomplished by the increment, the resources needed in each of the five program years plus two additional years, and estimates of the cost of the PDIP in manpower and dollars for each of the five program years.[2] Each PDIP is assigned to a Staff

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[1]For example, the Armament, Munitions, and Chemical Command, AMCCOM, will estimate ammunition requirements, using Staff-approved factors and the Staff-approved scenario.

[2]For example, the purpose of a PDIP might be to increase ammunition handling capability in the first 30 days of the scenario. The resources might be additional ammunition companies, to be activated over the next several years.

Proponent and a panel and placed in an electronic (computer) file resident in the PPBES database maintained as part of the automated Program Budget System.

Approved or baseline PDIPs constitute the portion of the PPBES database called the base file. Before consideration of new PDIPs, the Director of Program Analysis and Evaluation puts together this file and distributes data to the Army Staff for updating. Updating consists of repricing and repackaging (consolidation or breaking apart) some PDIPs.

New PDIPs not yet incorporated into the base file are maintained in a separate file within the PPBES database. During the PPBES process, these new PDIPs, compete with the older, updated PDIPs, and the successful rivals are incorporated. The result is a draft POM.

During the course of panel deliberations, the tentative order of PDIPs will change many times, and some PDIPs may be redefined. For example, a PDIP to buy 300 forklifts might be scaled back to 250, or the purchase of some of the forklifts might be delayed for a year. If the ALA Center is to support panel deliberations, it must maintain an up-to-date list of the prioritized PDIPs, and must therefore have rapid access to the PDIP file. Currently, the Center lacks such access.

U.S. ARMY OPERATIONAL READINESS (OMNIBUS) STUDY

The annual OMNIBUS study [4] is a major source of information on some of the most important of the 38 categories of resources and functions shown in Table 1 (including POL, some types of ammunition, some major items of equipment, personnel replacements, CONUS outload, and strategic lift). OMNIBUS uses a battery of models, housed and exercised at the Army's Concepts Analysis Agency (CAA). The central model in the battery is called FORCEM [5] (Force Evaluation Model), a two-sided warfighting simulation of an entire theater. This model will soon replace an older model, CEM [6] (Concepts Evaluation Model), which has been in use since 1974.[3] The other models include TRANSMO (a transportation model) and FASTALS [7] (Force Analysis Simulation of Theater Administrative and Logistics Support).

[3]This Note will anticipate events and assume that FORCEM has already replaced CEM.

The models are used together as illustrated in Fig.1. A combat force, together with an estimate of the support units it will require in theater, is fed to TRANSMO in deployment sequence, i.e., with desired dates of arrival in theater, as specified by the Time Phased Force Deployment List (TPFDL). TRANSMO determines whether the strategic lift is available to deliver the forces to the theater at the desired times. If not, adjustments must be made. Out of TRANSMO comes detailed arrival data for the force.

These arrival data are fed into FORCEM, along with a description of the enemy forces and various necessary parameters and scenario descriptors. FORCEM simulates a two-sided war, and estimates an outcome in terms of movement of the Forward Line of Own Troops (FLOT).[4] It also estimates support workloads generated by the combat force, including numbers of casualties (hence needs for medical services and personnel replacements), quantities of fuel and ammunition consumed, maintenance requirements, losses of major items of equipment (e.g., tanks, artillery), etc.

The support workloads from FORCEM are fed into FASTALS, along with factors describing the capacities of various kinds of Combat Service Support (CSS) units to perform their designated tasks. FASTALS applies other factors to the densities of people and equipment estimated by FORCEM, to estimate such workloads as maintenance other than battle damage repair, and transport and preparation of rations. FASTALS then calculates how many ammunition handling companies, POL companies, maintenance battalions, etc., will be needed. Adding these to the combat forces gives a fully structured deployed force. An estimate of this force was initially fed into TRANSMO to start the entire process, but the new force could be different from the initial one. If the differences were significant, it would be desirable to cycle through the process again, but this is seldom done. Once the force has been filled out with support units, it can be compared with the units already in the Army's program, and shortfalls can be identified.

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[4]This used to be called the Forward Edge of the Battle Area (FEBA).

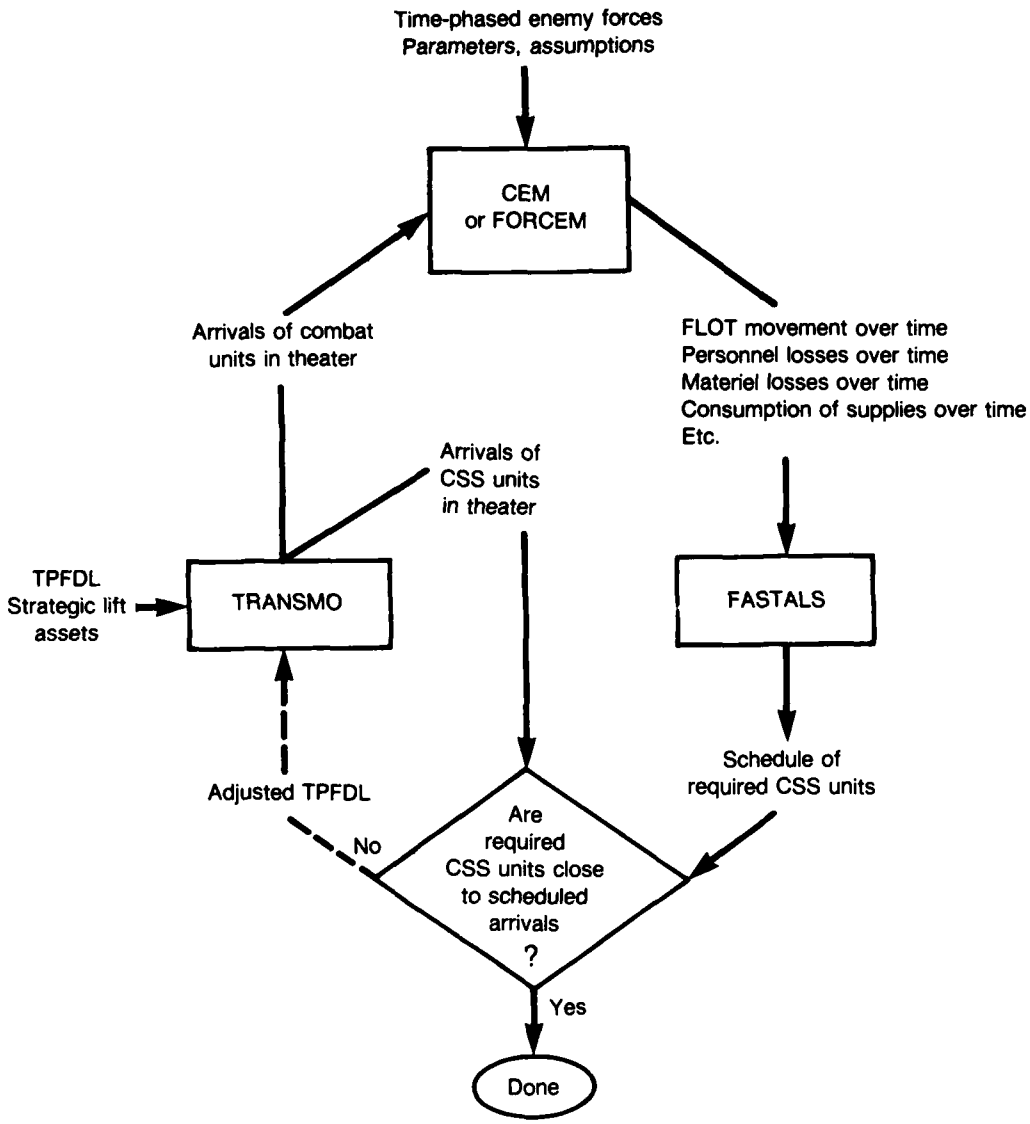

Fig. 1—Combined operation of TRANSMO, CEM or FORCEM, and FASTALS

THE SEVERAL USES OF THE CAA MODELS

For present purposes, three uses of the CAA models are particularly relevant. The Total Army Analysis (TAA) study uses the CAA models for force structure design. The models are provided with a description of the combat units of a force, and they determine: whether the force can be delivered to the theater in a timely fashion (TRANSMO); whether the combat forces can successfully prosecute the scenario (FORCEM); and what support units the combat units will require (FASTALS). Based on these results, TAA can potentially recommend adjustments to the combat and support units in the army as well as to strategic lift assets.[5]

The CAA models are also used to estimate certain requirements through a process called "Wartime Requirements for Ammunition, Materiel, and Personnel (WARRAMP)." The WARRAMP effort began in 1976, and according to Ref. 5 by 1981 had developed post-processors for CEM and FASTALS output that would estimate planning factors for ammunition consumption, personnel losses, and losses of major items of equipment. WARRAMP has since added a fourth post-processor to extract fuel consumption planning factors from CEM output. (The FORCEM model will generate consumption and loss rates for the same resources, because FORCEM is intended to replace CEM in all applications.) These planning factors vary by theater and by time during the scenario. WARRAMP is now the official source of Army logistics planning factors for these resources, including those used to estimate resource requirements for the PPBES process.

OMNIBUS is the most relevant use of the CAA models. The purpose of OMNIBUS is to assess the operational readiness--which encompasses some part of the combat capability--of the present army. As the first step in OMNIBUS, CAA runs their models to obtain a feasible deployment schedule for all units and to obtain attrition rates for the various major items of equipment that are represented in those models. The scenario used in OMNIBUS is that specified in the Defense Guidance,

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[5] In practice, TAA confines itself mostly to recommending adjustments to the support units. Adjustments to strategic lift assets are the responsibility of the Joint Chiefs and cannot be made through a purely Army study such as TAA. However, the TRANSMO model does provide Army inputs to deliberations by the Joint Chiefs on strategic lift.

currently consisting of a conflict breaking out in the Mideast and after a time spreading simultaneously to Europe and Korea.

CAA passes their results to the Logistics Evaluation Agency (LEA), which summarizes the densities of major items and of people in each theater over time. LEA sends the equipment and manpower densities by theater to the Major Subordinate Commands (MSCs) of the Army Materiel Command (AMC). The MSCs perform what used to be called the TLR/S (Total Logistics Readiness and Sustainability) analysis, but whose name is now Army Logistics Assessment, or ALA--not to be confused with the ALA Center. The MSCs use the density data to compute requirements for supplies of various resources as functions of time. The resources considered here include troop support items, rations, spare parts for major items of equipment, etc. Requirements for fuel, ammunition, and replacements for major items of equipment lost to attrition are also estimated by the appropriate MSCs using WARRAMP-derived factors. Supplies on hand can then be compared with requirements to determine how many days of support are available in each theater and in CONUS. The days of support estimates are returned to LEA, who compile them into the annual OMNIBUS briefing and report.

CAPABILITY ASSESSMENT: THE MISSING FUNCTION

Although the OMNIBUS study is intended to assess combat capability (or the aspects of capability one designates as readiness), in fact it merely compares resources on hand with requirements. Shortfalls are measured in terms of resource deficiencies, not in terms of deficiencies in combat performance. As long as the CEM model was used to simulate the theater campaign it was not possible to go further, because CEM assumes that resources are not constraining. In CEM, it is assumed that when a division fights, it will have as much POL and ammunition as it needs. When the division loses a tank or an artillery piece, CEM assumes it will be replaced. CEM therefore can only model a theater-wide campaign in which the available forces have all the resources they desire. This is useful for computing how much of each resource the force needs (for requirements estimation), but it is useless for estimating how serious it is to have resource shortages (capability assessment).

produce equipment.

FORCEM, by contrast, contains logic that enables it to restrict the consumption of resources when resources are scarce. Among the resources it can restrict are supplies--of POL, ammunition, replacement tanks, and the like. It can also restrict transportation or repair resources, so that even though supplies are in the theater, they cannot be placed in working condition in the hands that need them.

Once FORCEM replaces CEM, therefore, the models could be used for capability assessment, as illustrated in Fig. 2. No cycling would be necessary to make the FASTALS output match the TRANSMO output, because FASTALS would not be used at all. Instead, the available CSS units and available supplies (the TRANSMO output) would be directly input to FORCEM, which would estimate the outcome of the theater campaign under conditions of limited resources.

To perform capability assessments for the logistics resources and functions that can be constrained in FORCEM, one would make multiple runs of the CAA models, varying the levels of the several resources or the capacities to perform the several logistics functions. Comparison of the results would provide measures of the relative importance of incremental additions of different resources or of capacities to perform logistics functions (e.g., repair).

Of course, it is still possible to use FORCEM as CEM is used in Fig. 1. One need only provide FORCEM with abundant supplies and CSS units, rather than with the outputs of TRANSMO. FORCEM will use whatever it wants, as CEM would, and a later accounting can determine how much was thus required.

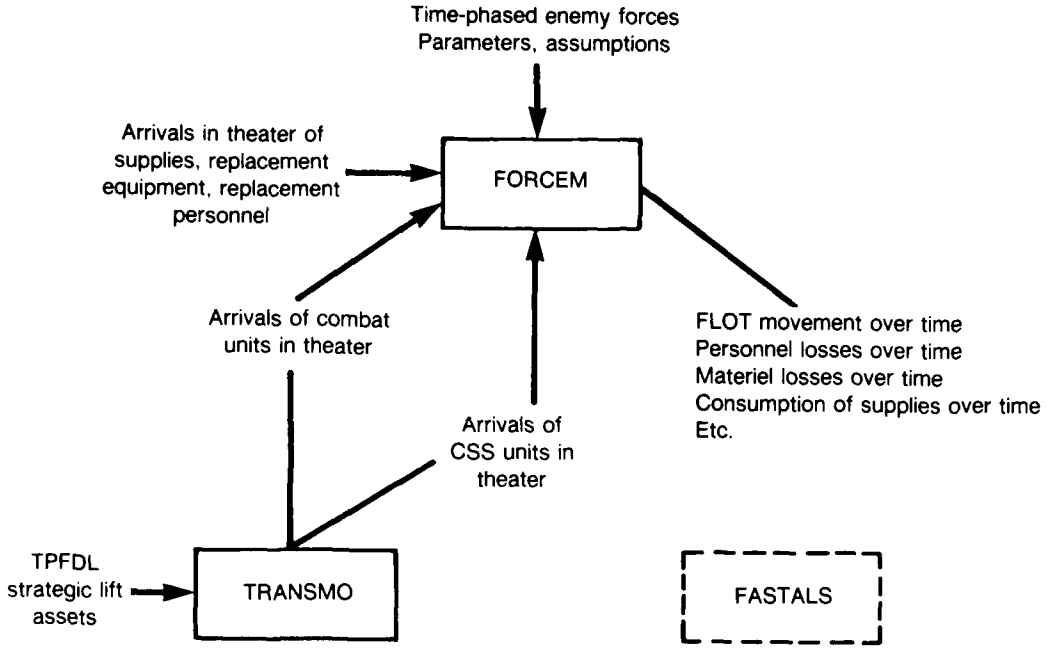

Fig. 2—Alternative operation of TRANSMO and FORCEM
(but not CEM)
(Note: FASTALS is not used)

V. STRENGTHS AND WEAKNESSES OF THE ALA CENTER

What one considers a strength or a weakness of the ALA Center depends on what one expects the Center to do. The Center is well designed for its original purpose of providing a single logistics assessment annually for the guidance of programmers. However, the role of the Center is expanding, and its current procedures, resources, and capabilities are not adequate to the new tasks.

ORIGINAL ALA CENTER PURPOSE

Initially, the ALA Center provided a single assessment annually of the logistics deficiencies of the present-day army, which was and is used for guidance in the programming stage of the PPBES. The current ALA Center structure and procedures are well suited to this task. It pulls together information on diverse categories of resources and functions that might otherwise never be compared systematically. It provides a forum for the people responsible for the different categories to make themselves aware of how each category fits into the larger scheme of things. Proponents can thereby become better informed and their proponency more thoughtful and effective. And it makes logistics concerns more visible and more substantial to non-logisticians.

In our our opinion, the single aspect needing major improvement is the criterion used to set priorities for logistics deficiencies. The time-slice display provides only a rough guide. It is assumed that every deficiency, particularly every serious (coded red) deficiency, is a potential "warstopper." Thus, a deficiency coded red in the D-day time slice is given the highest priority because, unless it is remedied, the war may be lost before the next time slice arrives. Of course, this assumption is recognized as a gross oversimplification, and its application in ALA is tempered by judgment.

What one truly wishes to know is how combat capability suffers because of various deficiencies. The ALA Center does not now collect the information, nor possess the methodology, to perform such capability assessments.

GROWING ALA CENTER RESPONSIBILITIES

More and more the ALA Center has been called upon to support the daily deliberations of the Sustain Panel, a role that may grow to include support for other panels considering resources or functions in any of ALA's 38 categories. The deliberations of the Sustain Panel are aimed at comparing PDIPs to determine their relative contributions to the sustainability of the combat forces in wartime.

Currently, the ALA Center is ill-equipped to provide this support. PDIPs should be compared in terms of their relative contributions to various aspects of combat capability. But this calls for a methodology for performing capability assessments, which the ALA Center lacks. It also calls for access to and coordination with the file of PDIPs, with which the ALA Center currently interfaces only manually, through the functional proponents.

As the comparisons are made, it may become evident that certain program increments are too large or too small and should be revised. When a PDIP is revised, it is necessary to estimate its new cost, as cost information is a vital part of every PDIP. But the ALA Center does not now have the data or methodology to estimate costs.

Finally, the assessments and revisions of PDIPs must be done quickly, because of the Panels' work is done in the space of a very few weeks. But today's ALA Center relies on the functional proponents and other outside sources (especially the OMNIBUS study) to perform assessments. The Center will never be able to produce assessments rapidly enough to support day-to-day panel deliberations unless it has its own in-house methodology.

POTENTIAL FUTURE ROLES FOR ALA

The ALA Center has the potential to expand in the future into still more roles. We have already mentioned that the Army has added an execution review step, PPBERS, to the traditional Planning, Programming, and Budgeting process. At present, PPBERS appears to have little input on logistics matters. If ALA-X succeeds in tapping information sources regarding execution, the ALA Center could surely provide better logistics inputs to PPBERS. However, for the ALA Center to perform this

task well would require greater attention to the current year.[1] In addition, the Center would need more frequent or timely updates of information. There is a new PPBERS briefing each quarter, and a requirement to contribute to each briefing would add a new set of deadlines and schedules to the ALA Center agenda.

Another direction in which the Center's role may expand in the future involves the reorganization of the Army Materiel Command (AMC) currently in progress. This reorganization is intended to concentrate all of the offices and functions at AMC Headquarters that are in any way responsible for assuring readiness of the combat forces. Similar reorganizations are taking place at all of AMC's major subordinate commands (MSCs). In effect, the reorganization is creating centers at AMC and at each MSC that look like smaller, more specialized ALA Centers. Like the ALA Center, they will have the task of coordinating actions, each within its own sphere of influence, to achieve the greatest overall improvement in combat capability per dollar expenditure. One can readily imagine the ALA Center as one node in a network of centers, with the attendant need for interfaces between them.

These potential uses of the ALA Center lie in the future, and the ALA-X project will not design a methodology that will support them. However, because future growth is possible, the ALA-X methodology will be designed to be as versatile and expandable as possible.

TASKS FOR THE ALA-X PROJECT

From the foregoing we can define four major tasks defined to be performed by the ALA-X project. The first is to build capability assessment tools consistent with the CAA models used in the TAA, OMNIBUS, and WARRAMP studies. (We value consistency here because results from TAA and OMNIBUS are already used in the PPBES.) They would be owned by the ALA Center and implemented on the Center's own computer. Thus it would not be necessary to request runs of an outside agency. However, the tools might be regularly recalibrated and the databases updated, either by or with the aid of CAA. The tools would be very fast

[1]To support the panels, the ALA Center would look primarily at the five program years. At the start of the programming stage of the PPBES, the first program year lies nearly two years in the future.

and flexible, so that a wide range of "what-if" queries could be answered quickly. As a corollary, the tools would be rather aggregate, probably representing resources in fairly broad categories.

The second task is to build a cost estimating capability in the ALA Center. The Comptroller of the Army already collects cost data and maintains a database of cost factors and estimating relationships for a variety of purposes. Building this capability is probably a matter of arranging that the ALA Center keep an up-to-date copy of the relevant parts of this data bank and develop or borrow the software to use it.

The third task involves designing interfaces. There will be an important interface between the ALA Center and the official file of Army PDIPs, so that changes suggested by the Sustain Panel using the ALA-X methodology will get into the official system, and so the ALA Center will quickly be made aware of changes in PDIPs. There may be interfaces with other databases or sources of information, so that the Center can properly account for the effects of Congressional or OSD action and problems that arise during execution.

The fourth task involves surveying the ALA categories not considered by the CAA models. The ALA Center must generate logistics assessments for every category. Eventually, the ALA-X project should suggest how each category's assessment might be improved.

PART II

CONCEPTUAL DESIGN OF THE ALA-X METHODOLOGY

VI. BUILDING TOOLS FOR CAPABILITY ASSESSMENT

CURRENT ARMY MODELS FOR ASSESSING COMBAT CAPABILITY

The first ALA-X task is to design a model that will assess the effect of logistics factors on the combat capability of the Army. With the development of FORCEM, the Army's Concepts Analysis Agency (CAA) has a battery of models that can be used to assess combat capability. FORCEM generates several outputs that one might use as indexes of combat capability. Losses of both personnel and materiel are estimated for both sides of the warfight, and one might use the losses themselves, their differences, or their ratios as capability indexes. Movement of the battle front (called the Forward Line of Own Troops, or FLOT)[1] is also estimated, so the area of land lost or gained at various points in the simulated conflict might also be used as a capability index.

Because the Army uses the CAA models so extensively, and because their results are embedded so deeply in the PPBES process, the methodology designed in the ALA-X project should be consistent with the CAA models. That is, if a question could be answered, at least in principle, by running one or more cases through the CAA models, the ALA-X methodology should be so constructed as to arrive at approximately the same answer. If it were possible, therefore, it would be desirable to use the CAA models directly as the ALA-X methodology.

To see what questions the CAA methodology could answer, it is necessary to briefly describe the FORCEM model. Each combatant is represented in FORCEM by a hierarchical structure. At the lowest level, the FORCEM model considers divisions. (Individual brigades within the division are not separately identified.) Each division owns personnel and equipment with which to fight, including tanks and tank crews, armored personnel carriers and crews, and the like. In FORCEM, each division can be of a different kind--armored, infantry, etc. In practice most red divisions are represented as identical, while each blue division is unique. Each division also owns a support command to provide five Combat Service Support functions: transportation, medical,

[1]This used to be called the Forward Edge of the Battle Area (FEBA).

maintenance, supply, and recovery and evacuation. The division support command owns certain resources needed to perform these functions, including equipment and personnel, and it also owns pools of other kinds of equipment and personnel that can be used to replace losses and consumption from the division.

Several divisions will form a corps, which has its own independent support command with the same functions as the division support command. The corps also has its own communications, intelligence, engineer, artillery, and air defense units. Units owned by the corps generate workloads for the corps support command, and some work from the divisions is also passed along to the corps support command. Several corps form an army, which once again has a support command, communications, etc. with the same functions as the analogous units at the corps level. Finally, the armies are all under a single theater command, which also has a support command, a communications unit, and so forth. The theater commander also has control over tactical air resources.[2]

FORCEM operates on a 12-hour cycle. It first develops the situation, as seen by each unit on each side. A division knows what resources it owns and has some information--incomplete and possibly erroneous--about the enemy units directly in front of it. The division passes selected information to its corps headquarters, but some of the information may be lost or delayed, thus introducing noise into the corps perception of the situation. Similarly, each corps communicates imperfectly with its army, and the armies all communicate imperfectly with the theater headquarters.

On the basis of its perceptions about its own forces and those of the enemy, the simulated theater commander assesses the situation and decides upon a plan of operations. This plan is conveyed to the various Army headquarters, who expand upon it and send it to the various corps headquarters, who expand upon it and send it to the various divisions.

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[2]These air resources include only the tactical forces supplied by the Air Force. Army air--helicopters--are assigned to individual divisions just like any other Army weapon system.

The divisions now try to execute the plan. A division will first attempt to engage in combat, if it is ordered to do so and has the necessary resources. After the results of its combat are assessed, FORCEM considers movement of the division. Finally, FORCEM simulates such support activities as maintenance and resupply, to replenish the POL, ammunition, personnel, and major items of equipment. Replenishment of these resources is contingent not only on the presense of adequate supplies, but also upon the capability of the support commands to perform the necessary transportation, repair, and other functions. The model records the consumption of ammunition, fuel, and other resources; losses of major items of equipment; losses of personnel; and so forth. Then it is ready for its next cycle.

FORCEM simulates division-level engagements using a model called ATCAL (Attrition Calibration), [8] which is first calibrated to a model that simulates a division-level engagement in detail[3] and is then embedded in FORCEM and used to estimate the outcome of a division-sized combat. ATCAL has a provision for imposing munitions constraints, to prevent it from using more of any munition than is available. It has no direct provision for constraints on fuel or crews, but it is sensitive to the number of vehicles of each type sent into combat. So FORCEM introduces constraints on fuel and crews by limiting the number of vehicles in combat to the number that can be fueled and crewed to specified minimum levels. The combat effectiveness of an individual vehicle is not reduced in the model when it has less than a full crew or load of fuel.

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[3]The detailed model now in use is called COSAGE (Combat Sample Generator), a model developed by, and residing at, CAA. It is planned that a newer model called CORDIVEM (Corps and Division Evaluation Model) will replace COSAGE in the future. CORDIVEM, however, was developed and now resides at the Combined Arms Operations Research Activity (CAORA). Can proper coordination be achieved if CAA is not given a copy of CORDIVEM for its own use?

A REPRO MODEL OF FORCEM

It is impossible to use the CAA models themselves as the ALA-X methodology, because the CAA models are so large and complex that they cannot conceivably respond quickly to queries. For example, to simulate a 180-day NATO conflict, with about 150 divisions engaged on each side, requires 20 hours of computer time. A methodology is needed that reproduces the relevant aspects of the behavior of the CAA models but is much faster and requires much less elaborate and detailed inputs.

Building a repro model has overcome similar difficulties in previous projects; some examples are described in the appendix. A repro model is a small aggregate model that mimics a larger, more detailed, more costly-to-use model--that is, it "reproduces" relevant aspects of the larger model's behavior, hence the name. For the ALA-X project, it is proposed that a repro model be built that will mimic FORCEM.[4] A repro model of FORCEM could handle the same logistics resources and functions as the FORCEM model itself handles. Once such a repro model has been constructed, it may be possible to extend it in several directions, to deal with resources or functions not considered in the present FORCEM, or even to deal with issues of strategy or doctrine.[5]

Study a Dump of FORCEM Inputs and Outputs

It is too early to determine the form that a repro model of FORCEM ought to take, but a systematic exploration of FORCEM's behavior should reveal large-scale regularities and should suggest ideas for the repro model. Therefore, as a first step in building the repro model, all the inputs and all the standard output files from one FORCEM run should be

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[4]As of this writing, CAA has begun an effort to build a repro model of FORCEM themselves. The ALA-X project will consult and coordinate with them, and not independently construct its own repro model.

[5]According to the Army Model Improvement Program (AMIP), [9] under which FORCEM is being developed, one of the purposes of the model is to "demonstrate the effect of changes in resources, environment, strategy, doctrine, priorities, and assumptions" on theater operations and their outcome. The present version of FORCEM appears to have much of doctrine and strategy built in and hard to change, but later versions, including a planned interactive version, should allow the user to vary strategy and doctrine more easily.

dumped into a dataset. Later, of course, dumps from additional FORCEM runs will be needed, and almost certainly they will have to include additional FORCEM outputs.

One of the things that might be learned from a FORCEM dump is what level of aggregation might be appropriate for the repro model. FORCEM models many different types of tanks, helicopters, armored personnel carriers (APCs), and artillery pieces, but for our purposes it may be enough to aggregate them into fewer, but less homogeneous, groups. Similarly, some aggregation across types of ammunition may be possible. Any resource may be a candidate for aggregation.

A similar tactic is to reduce the time resolution below that of FORCEM. The ALA Center currently displays their logistics assessment in ten-day slices. Perhaps a model could be built that moves from one slice to the next in a single ten-day step, rather than requiring the twenty 12-hour steps that FORCEM uses.

We would also seek to reduce the geographical resolution below that of FORCEM. We would check for units or for parts of the FLOT whose consumption and attrition rates were atypically high or low, or that typically used different modes of transportation, or required different amounts of time, manpower, and equipment to accomplish deliveries of supplies. We would check whether supplies or repair or transportation (or other) resources are ever grossly malpositioned for substantial periods of time. When dumps from several FORCEM runs become available, we would compare them, seeking differences in FLOT movement, casualties, and other quantities. We would also look for particular sections of the FLOT that all the FORCEM cases indicated had especially great vulnerability. Such observations would suggest how much geographical resolution to retain in the repro model.

We would try to develop empirical relations that estimated various FORCEM outputs from its inputs. For example, it ought to be possible to relate FLOT movement to force ratio at some level of aggregation. Such a relation is built into FORCEM at the division level, and studying a FORCEM dump will reveal whether the relation persists at the Corps or Army levels of aggregation. By looking at the theater average FLOT movement over time, one might even develop a FLOT movement estimator for the theater level of aggregation, although it would be better to have

several FORCEM dumps for this purpose. Similarly, one ought to be able to develop relations to estimate POL consumption, ammunition consumption, the use of repair and transportation facilities, losses of equipment, casualties, and many other quantities.

We would also try to identify from the FORCEM dump a small number of activities that caused the bulk of the changes in the amounts, locations, and conditions of the various resources. (Taking tanks as the resource, for example, we might separately keep track of the number in each corps area that were battle-ready, awaiting minor maintenance, and awaiting major repair.) Activities would include engagements between red and blue units, transportation of people or supplies, repair activities, and so forth. We would define each activity in terms of the changes it caused in the amounts of resources at each location and in each condition. Thus a repair activity might reduce the number of tanks awaiting major repair in a particular area, and increase the number of battle-ready tanks in the same area. Each activity would cause resources to change in fixed proportions. The resources affected by an activity might include manhours, numbers of tanks, ammunition by type, and others.

We could then view FORCEM as merely an elaborate mechanism for sampling activities--for determining how many of each type of activity will take place during the campaign and how the mix of activities changes over time. FORCEM determines the mix by simulating divisional combats and movements by 12-hour steps, but any mechanism that determined essentially the same mix could replace FORCEM, even if it looked nothing like a warfighting model. The heart of an alternative mechanism could consist of a set of relations that constrain the mix of activities during various time periods. We could develop some of these relations empirically from the FORCEM dump.

Develop Quantitative Engagement Activities

We would not develop these activities solely by examining the FORCEM dump. Rather, we would use our knowledge of FORCEM's structure to generate candidate activities. For activities that correspond to engagements between Red and Blue units, for example, we will try to use the ATCAL model. [8]

FORCEM uses ATCAL to simulate engagements between a division-sized Blue force and a Red force, not necessarily the same size. The main ATCAL inputs are the numbers of various different kinds of opposing vehicles engaged. The main outputs are losses of each vehicle type by each side, and expenditure of ammunition. As implemented in FORCEM, there are augmenting relations that estimate POL consumption and FLOT movement during the engagement.

Using the equations described in Ref. 8, we could program our own standalone version of ATCAL. There should be several ATCAL calibration datasets in the FORCEM dump, corresponding to engagements in which the two sides had different missions (attack, defend, or delay), or fought on different kinds of terrain, or in which other factors were varied. With these in hand, we could use the standalone ATCAL to generate sample engagement activities. We might be fortunate enough to identify a fairly small number of "model" engagements that would closely match the engagements represented in the FORCEM dump.

Develop Quantitative Support Activities

There should be little difficulty in developing quantitative support activities to represent transportation, repair, recovery and evacuation, medical activities, and many more. Standard planning factors often dictate how much fuel, how many manhours, and what kinds and amounts of equipment are needed to accomplish a given task. (Equipment is not consumed, but equipment hours are, in much the same way as manhours.) It is undoubtedly possible to construct a wide variety of quantitative support activity descriptions from them. Because FORCEM uses many of these planning factors as inputs, activities defined in this way should match the FORCEM dump fairly well.

Many of these standard planning factors could be obtained from the input datasets of FASTALS, a model that estimates required CSS units from a specification of the workloads they must process. We can also draw upon the Days of Sustainability Study (DOSS), which was recently completed by CAA. [10] This study has examined only a few resources, namely fuel, ammunition, and one or two major items of equipment. DOSS identified the tasks and ancillary resources (e.g., trucks) needed to

deliver each resource to combat units and identified relevant sources of data. One data source of potential interest is the Force Stratification System (FSS), which is owned by the TRADOC Systems Analysis Activity (TRASANA) in White Sands, New Mexico. Evidently, this system assigns combat service support units to functional categories such as intelligence, movement, communications, supply, maintenance, etc. FSS may provide an alternative basis to the FASTALS data for developing the capacities of the support commands in FORCEM to process their various workloads.

The question remains of how much transportation or repair capacity goes unused because of limitations on the support of one division by its neighbor's support units.[6] A possible, and very simple, way to deal with this problem is by means of an "inefficiency factor." There is also the question of bottlenecks in the support structure. To determine that a particular bridge or tunnel or port is the limiting factor, one must somehow represent that particular bridge, tunnel, or port in one's model. The repro model may not represent such details. More specialized studies should pinpoint bottlenecks, rather than having the ALA Center "do it all."

Representing Doctrine

Some of the relations that constrain the mix of activities will have a simple, logical basis. They will merely require that there should never be a negative amount of any resource at any location in any condition. For example, the Blue forces would not be allowed to fire more ammunition by day ten of the scenario than could be supplied them. We can call these constraints the "non-negativity constraints."

The non-negativity constraints would not by themselves completely determine the mix of activities, because they would lack a specification of command and control doctrine and of the doctrine for distributing support resources. But they would define limits on the mix of activities within which any theater commander would have to operate, regardless of doctrine. To complete the specification of the mix of

[6] In agreement with Army doctrine, FORCEM assumes that there is no lateral support. All supply, repair, etc. are provided vertically, following the echelon structure of theater forces.

activities actually chosen, one might impose additional constraints or rules that represent doctrine; as yet we have no firm thoughts on how this might be done. Some of the ALA categories, particularly those under col. 5 of Table 1, Command and Control, would be represented in these doctrinal constraints.

Alternatively, one might use an optimization procedure to select the actual mix of activities--for example, minimizing the area given up to Red forces subject to the constraints suggested above.[7] The most likely candidate for an optimization procedure is game theory's "minimax" procedure, in which the Red and Blue forces compete for land area (or some other suitable objective). Blue attempts to choose the tactics that will minimize the area that Red gains by using his (Red's) most successful tactics, while Red attempts to select the tactics that maximize the area he gains when opposed by Blue's best tactics.

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[7]An optimization approach could not be expected to reproduce the behavior of FORCEM. However, the result might prove worthwhile on its own merits.

VII. COVERAGE OF THE 38 ALA CATEGORIES

The conceptual design for the ALA-X methodology thus has as its centerpiece a repro model of FORCEM. This repro model can only assess the effects on combat capability of those categories of Table 1 that FORCEM considers in sufficient depth. Table 1 is repeated here as Table 2, this time highlighting the categories dealt with in great measure by FORCEM. Categories that are partially set off are dealt with less completely in FORCEM.

We intend ultimately to consider every category, although for some we may be unable to improve on the current ALA Center procedures. In the immediate future, however, we will restrict our attention to a few of the more important categories, including POL, some types of ammunition, selected major items of equipment (e.g., tanks, artillery pieces), and the functions needed for their supply and maintenance.

DEPLOY

Covered Categories. FORCEM represents ports, whether sea or air, and hence has the potential to consider the effect of varying overseas reception capacity on the outcome of the battle. For the Red side, FORCEM has land "ports," at which resources can enter the theater. FORCEM also simulates ground transportation within the theater (road, rail, barge), but not air transportation. This gives it the capability to consider a large part of the intratheater lift category in Table 2.

Categories Not Covered. FORCEM can simulate the effect of deploying active, guard, or reserve units on a different schedule, but it does not simulate the factors that might cause the deployment of a unit to be delayed or changed. Nor does FORCEM consider CONUS outload or strategic lift; these are modeled in TRANSMO. Like FORCEM, the TRANSMO model is unable to respond quickly to queries, but perhaps a repro model approach applied to TRANSMO could remedy this--a subject, perhaps, for a future project.

Table 2

COVERED ALA CATEGORIES

Warfighting Categories

Infantry	Armor	Artillery	Air Defense	C3I

Support Functions

Deploy	Man	Move	Shoot	Command & Control
Active	Troop Support	POL	Conventional Ammunition	Intelligence
National Guard	Rations	POL Handling	Ammunition Handling	Strategic Comm
Reserve	Clothing & Equipment	Engineer Cbt Svc Supt	Engineer Cbt Supt	Tactical Comm
CONUS Outload	NBC Protection	Major Items	Chemical Ammunition	Automation
Strategic Lift	Medical Service	Recovery & Evacuation	Nuclear Ammunition	CAPSTONE
Overseas Reception	Personnel Replacements	Repair Parts	Missiles	Inventory Control
Intra-Theater Lift	Logistics Training	Maintenance	Aviation Logistics	Host Nation Support

CONUS Base

—	Mobilization Training Base	AMC	Industrial Base	—

= Not dealt with by FORCEM

= Dealt with in large measure by FORCEM

= Dealt with in limited measure by FORCEM

MAN

Covered Categories. FORCEM could perform capability assessments for both the medical service and personnel replacement categories of ALA. FORCEM represents pools of personnel replacements at all echelons, as well as the effect of medical services on returning casualties to service in those pools. The availability of manpower affects the capacity of each support command to perform its functions, and of each combat unit to field equipment.

Categories Not Covered. FORCEM outputs could be used to estimate consumption of troop support items, rations, and clothing and equipment. One need only multiply total time-phased manpower in theater (a FORCEM output) by the appropriate standard planning factors. But there is no provision in the model to reduce the capability of a unit to perform its assigned tasks in the event that resources in these categories are in short supply. Without such a provision, the effect of resource shortfalls on combat capability cannot be estimated, but perhaps it is not of critical importance. The costs associated with these categories cannot be large compared with the cost of, say, major items of equipment. Thus it may be perfectly satisfactory to use the rough-and-ready method now used by the ALA Center, namely an index of the ratio of resources on hand to requirements.

The current version of FORCEM does not model nuclear, biological, or chemical warfare, although it is intended that later versions will do so. Thus neither requirements estimates nor capability assessments can be performed at present for NBC protection.

FORCEM contains no provision for training logistics personnel. Such an activity might be added to later versions of FORCEM and could be made to affect the sizes of personnel replacement pools.

MOVE

All categories in the Move column of Table 2 are dealt with in FORCEM, at least to some degree. FORCEM represents POL and POL handling in considerable detail, estimating both how much POL can be supplied to users and what effect POL shortfalls may have on the amount of equipment that can be sent into battle.

The support functions included in the Engineer Combat Service Support module of FORCEM are currently limited to the repair of damaged ports, air bases, and POMCUS sites. Repair of roads and bridges may be added to later versions of FORCEM.

FORCEM represents the effect of major item availability, particularly of combat equipment such as tanks and artillery, on the outcome of the battle. It also has a fairly detailed and complete representation (compared with other theater-wide models) of the processes by which damaged equipment is returned to service. These processes include the ALA categories Recovery and Evacuation, and Maintenance.

FORCEM also simulates the use of repair parts, albeit in gross fashion. In effect, each support command has only one kind of part, which is used in all repair jobs that need a part. If the supply of this part is exhausted, all jobs that need parts must await resupply. This approximation overestimates the capability to perform repairs as long as any of the simulated repair part is available. Once the supply of the simulated part is exhausted, repair capability is underestimated. In practice, a higher or lower fraction of jobs will be awaiting parts, never all jobs or no jobs. In a later version of FORCEM, modeling the effects of repair parts might be improved by means of a function relating the average time that a job must await a part to the remaining supply of the single, simulated part. Detailed simulations using other models could probably provide such a function. But FORCEM is probably already too large to countenance adding multiple kinds of repair parts to later versions of the model.

SHOOT

Covered Categories. FORCEM simulates conventional ammunition supplies and handling in detail, and could be used, in principle, to assess capability for these categories.

Engineer Combat Support, such as the laying and clearing of minefields, is not explicitly represented in FORCEM. It can only influence the FORCEM results through its effects on ATCAL. Thus coverage of Engineer Combat Support in FORCEM depends directly on its

coverage in the higher resolution model that is used to calibrate ATCAL. This is COSAGE at the present time but is planned to be CORDIVEM in the future.

In the "missiles" category of Table 2, FORCEM represents both small, short-range TOW missiles as yet another tank killing weapon and longer range missiles as artillery to be used for deep interdiction.

FORCEM has only a minimal representation of logistics for tactical aircraft (aircraft owned by the Air Force). It simulates the supply of POL, ammunition, and replacement aircraft, but it does not simulate aircraft maintenance. So long as FORCEM can take the Air Force contribution to the battle as given, this should not prove a serious handicap. But it will prevent FORCEM from being used to trade off resources between the Army and the Air Force.

FORCEM simulates Army air--helicopters--as just another weapon system, like a tank or an artillery piece (of course with its own mobility, lethality, and vulnerability parameters). Thus the same logistics functions are available to helicopters as to the other weapon systems.

Categories Not Covered. As mentioned above, FORCEM does not currently consider chemical, nuclear, or biological warfare, and hence it does not model chemical or nuclear ammunition. It does, however, contain a provision (unused to date) to track "special" ammunition, which can be interpreted as chemical or nuclear.

COMMAND AND CONTROL

Covered Categories. A considerable amount of attention is paid to intelligence and communications in the FORCEM model. Indeed, one of the principal reasons for replacing CEM is that model's limited representation of command functions. Unfortunately, the effect of command and control resources on the outcome of the battle undoubtedly depends strongly on how they are used, and our information suggests that the representation of command and control functions in FORCEM needs improvement. We understand that CAA has plans to improve this part of the model. In addition, the Army Model Improvement Program (AMIP), [9] under which the FORCEM model has been developed, calls for versions of the model to be used interactively, with humans making the command

decisions. Over time, this use of FORCEM should lead to a succession of improved command and control routines.

Host nation support is an umbrella for virtually all logistics resources and functions. There is no reason that the portion of any resource or function provided by the host nation cannot be included in FORCEM, if that resource or function is represented at all. Indeed, it would be difficult to proceed if that portion were not included. It would be necessary, however, to keep track of what parts of the force relied on host nation support, and to what degree, in order to estimate the effect of shortfalls. Generally, logistics functions are performed in FORCEM by CSS units, which are representations of actual military units. Support provided by civilians of the host nation might not fit the model and would therefore be more difficult to include. Also, any issues of coordination between own-country and host nation support would have to be dealt with outside of FORCEM.

Categories Covered Indirectly. The remaining categories in the Command and Control column of Table 2 deal with issues that are not directly modeled in FORCEM. But their effects can influence FORCEM's inputs and therefore FORCEM's results.

The automation category deals generally with the problems of supporting computers on the battlefield, both with data links and with maintenance resources. Policies affecting these issues would influence FORCEM through their effect on weapon effectiveness parameters.

CAPSTONE is the program under which support units in the National Guard and Reserves are assigned to active combat units. This means that they know the kinds of equipment they will have to support in wartime, and can train to do so. Without such an assignment, the training of reserve and guard support units might not prepare them for their wartime duties. The effects of CAPSTONE are captured in the schedule according to which support units from the guard and reserve can be readied for deployment.

The Inventory Control category deals with the development of information systems to manage stocks of spare parts, POL, ammunition, and so forth. Such systems will influence FORCEM results through their effect on the speed and precision with which supplies can be moved to units that need them. Over the past several years, Rand has

investigated aspects of this problem for the Air Force [11, 12, 13, 14] and for U.S. Naval air forces [15]; perhaps some of that experience could be used to estimate the probable size of this effect.

CONUS BASE

FORCEM is a theater model and does not represent resources or processes outside the theater. Thus it does not include any representation of the three ALA categories included under CONUS Base in Table 2. However, if an independent study were to establish how the CONUS Base categories affect the delivery of resources to the theater, FORCEM could carry on the assessment from there.

VIII. REMAINING ALA-X TASKS

This Note has discussed how a model might be devised to assess the effect of many of the ALA categories of resources and functions on combat capability. But assessing capability is only part of the job. The task remains of using the capability assessment to help design or redesign PDIPs. Capability assessment--asking what an additional increment of a given resource is worth in terms of increased combat performance--is only half of the PDIP. The other half consists of estimating the cost of the resource increment. Nor is it enough merely to design or redesign PDIPs. The ALA Center must also support day-by-day panel deliberations. This requires interfaces with data systems and with elements of the Army Staff.

COST ESTIMATION

Each PDIP proposes that certain activities be carried out and certain resources procured and employed. Cost and resource categories used for accounting and financial management in the Army can be found in AR 37-100-XX (the XX standing for the current fiscal year), the Army Management Structure (AMS) regulation. AR 37-100-XX dictates how these resources and activities shall be categorized in the PDIPs and how they should be cross-referenced to the program elements of the Five Year Defense Plan. This regulation is updated annually by the U.S. Army Finance and Accounting Center (USAFAC).

Cost data come from three main sources, according to the PDIP procedures manual.[1] *The Army Force Planning Cost Handbook* (AFPCH) contains planning factors to estimate resource requirements due to changes in force structure, force deployment, activity rates (e.g., annual flying hours), training requirements, equipment modernization, and manpower. The handbook is maintained by the Comptroller of the Army (COA). MACOM costing guides are published by individual commands and operating agencies. They contain factors and cost estimating relationships for Operating and Maintenance, Army (OMA) and Military Personnel, Army (MPA) expenses. Copies are available in DCSLOG. Life

Cycle Cost Guides are designed to help estimate costs of materiel systems in particular phases of their life cycles. Some examples are DA Pamphlet 11-2, *Research and Development Cost Guide for Army Materiel Systems*; DA Pamphlet 11-3, *Investment Cost Guide for Army Materiel Systems*; and DA Pamphlet 11-4, *Operating and Support Cost Guide for Army Materiel Systems.* These cost guides are maintained by the same office that maintains the AFPCH.

In addition to these sources, OSD has required of each of the military services that it construct a database consisting of operating and support costs. The OSD name for the requirement is VAMOSC, for Visibility and Management of Operating and Support Costs, but the Army has designated their database OSMIS, for Operating and Support Cost Management Information System. The Army Materiel Command (AMC) is the agency responsible for constructing OSMIS; they expect a handbook of factors relating cost to performance to be published in July 1985.

The Army is also moving to consolidate cost data in the U.S. Army Cost and Economic Analysis Center, located in the Pentagon. They will be responsible for maintaining the Contractor Cost Data Reports, which are a source of R&D and procurement costs, and the Force Cost Information System, from which the AFPCH is produced.

INTERFACES

The database with which the ALA Center must most obviously interact is the PDIP database. Administratively, this is owned by the Program Analysis and Evaluation Directorate, which is directly under the Army Chief of Staff. Physically, the database is located at the U.S. Army Management Service Support Agency (USAMSSA), the Army's computer center in one of the Pentagon basements. The Force Management Impact Analysis System (FMIAS), currently under development, is scheduled soon to provide remote access to the PDIP database via secure terminals. If the ALA Center possessed one of the FMIAS terminals, at least part of the problem of interfacing with the PDIP database would be solved.

FMIAS might help solve other interface problems for the ALA Center as well. It is being designed to access and cross-reference many databases in addition to the PDIP file, including data describing the present and future Army force structure, the distribution of major items

of equipment, and funding for R&D and procurements. FMIAS claims to be the "seed" from which will grow the Army corporate database. This database will describe the present and planned future Army, including descriptions of all units in terms of manpower and equipment, all keyed to the PDIPs, the Five Year Defense Plan, and to the accounting and reporting systems used in the field.

FMIAS is a "read only" system, allowing the user to look at a database and to generate reports and graphs from the data therein, but not to change it. The current avenue for changing a PDIP leads through the PDIP Point of Contact (POC), and it would be simplest to continue using it. That would automatically happen if the various PDIP POCs came to view the ALA Center as a resource for helping them build and defend their PDIPs.

IX. SUMMARY OF ALA-X PROJECT ACTIVITIES

ACTIVITIES TO BUILD A REPRO MODEL OF FORCEM

Study a Dump of FORCEM's Inputs and Outputs

We will arrange with CAA to obtain a dump of FORCEM's inputs and outputs and will study the dump with an eye to answering three general kinds of questions.

- What aggregations are reasonable, in the dimensions of resources, time, and geography?
- What empirical relations are there between aggregated inputs and aggregated outputs?
- Is there a small number of quantitatively defined activities, some reasonable mix of which will serve to account for the bulk of the changes in the amounts, locations, and conditions of the various resources?

We will seek to define the activities (postulated in bullet three above) using what is known of the structure of FORCEM and not rely solely on an empirical study of the FORCEM dump.

Develop Quantitative Engagement Activities

We propose to build, or acquire from CAA, a standalone version of ATCAL. The FORCEM dump should contain several ATCAL calibration datasets. We will request CAA to provide the supplementary equations by which FORCEM estimates POL consumption and FLOT movement during an engagement. With our standalone ATCAL, we might be able to define a fairly small number of "model" engagements to use as engagement activities in accounting for resource changes in the FORCEM dump.

Develop Quantitative Support Activities

The project will formulate activities that describe the quantitative use of manpower and equipment to recover, evacuate, and repair major items of equipment and to supply and transport POL and ammunition to combat units. To do so it will need standard factors describing logistics requirements generated by various workloads and factors for estimating capacities to process workloads. One source for these factors is the FASTALS input data. Another is the input data for the Combat Service Support module of FORCEM. Another source, for manpower factors only, is the Manpower Requirements Criteria (MARC) database, maintained at the Logistics Center, Ft. Lee, Virginia. A fourth source is the Days of Sustainability Study (DOSS).[10] This activity will be carried out initially for only a limited set of resources, so that we may devise and demonstrate a successful approach. Eventually, we expect to consider every resource modeled in FORCEM.

Add Doctrine

Formulating the doctrinal equations of the repro model must wait until we have defined a reasonable set of activities. It should also wait until documentation is available for the Command and Control module of FORCEM.

ACTIVITIES SUPPORTING THE COST ESTIMATION TASK

Determine Sources of Cost Estimates

In this activity, we will interview selected PDIP Points of Contact to determine where they obtain cost estimates or the data from which to make them, and what office(s) must "sign off" on the estimates. Every PDIP must include an estimate of cost for each of the five program years. The Army must have standard models for estimating certain kinds of costs, and official sources for certain cost factors, such as those mentioned in Ref. 1. These interviews will help to identify them.

Arrange Access By ALA Center to Cost Data and Models

Once sources of cost data and models have been identified, it will be primarily the responsibility of the ALA Center staff to arrange ready access to them. This may be done by building a library in the ALA Center, or (preferably) by arranging remote access to computerized databases kept elsewhere.

ACTIVITIES SUPPORTING THE DESIGN OF INTERFACES

Survey the PDIP File

The PDIP file is particularly important to the ALA Center. In this activity, we wish to determine specifically what kinds of resources are most frequently mentioned in PDIPs of importance to the Center, and in what combinations they appear. We also wish to familiarize ourselves with the format of the file, what background material is included and what must be sought elsewhere, and so forth.

Arrange Access to FMIAS

The Force Management Impact Analysis System (FMIAS) was described in the previous section. It promises future access to the PDIP file, as well as present access to several other data sources. We will further investigate the present and planned capabilities of FMIAS, but it is our preliminary opinion that the ALA Center would find it useful to possess a FMIAS terminal. Arranging for this would be the responsibility of the Center staff.

Monitor Selected Army Initiatives

The Army has certain efforts under way that may in time prove to be of importance to the ALA Center. Previously mentioned was the Program Performance and Budget Execution Review System (PPBERS). Another is Documentation Modernization (DOCMOD), which seeks to modernize and unify the management information systems involved with major item management. Related to this is the Army Materiel Program Modernization (AMPMOD), whose purpose is to provide better information about, and better control over, the Army procurement program for major items. And there is the Army Management Structure Redesign (AMS-R), which seeks to restructure

the categories in which the Army reports its resources, activities, and expenditures.

Displays

The ALA Center currently uses the Time-Slice model as one means to display information. The Logistics Evaluation Agency (LEA) has standard displays for presenting results of the OMNIBUS study. The PPBERS briefing has its displays. But these displays are designed to evaluate a given program and not to compare two or more programs or program increments (PDIPs). Activities to build the repro model of FORCEM and to estimate costs of PDIPs must bear fruit before we can start in earnest to design displays for these purposes. But as soon as we have some data to put into them, we will begin to design effective displays.

OTHER ALA CATEGORIES

The suggested approach will not deal with several categories of the ALA Time-Slice model, but we will continue to gather information about these categories and to give thought to how they might be assessed. The ALA-X project will not, however, attempt to deal with them in the immediate future.

Appendix
REPRO MODELS

INTRODUCTION

A repro model is a small, flexible, easy-to-use model that reproduces selected aspects of the behavior of a larger, more complex, more cumbersome model. Generally speaking, the repro model will be less detailed than the larger model, either because it considers only a limited number of the variables in the larger model, or because it considers aggregations of the variables. The repro model may exhibit the full range of behavior of the larger model, but the reduced detail will result in a loss of behavioral nuances. This is illustrated by two of the examples below, in which geographical detail present in the larger model is lost in the repro versions. Or the repro model may focus in on selected behaviors of the large model, the reduced detail being achieved by the loss of part of the range of responses of which the larger model is capable. This is a less interesting possibility for our purposes.

The most straightforward way to create a repro model is to run the larger model many times with different input sets, save the corresponding output sets in a database, and then fit a simple model to the points in the database thus generated. The fitting can be done, for example, by standard regression techniques. This method of creating a repro model is sometimes effective, but in many cases the cost of creating a rich enough database will be prohibitive, or the opportunity to run the larger model enough times will not exist. Then one must use, often invent, other methods that are less straightforward.

This appendix presents three examples of repro models that were built using other methods: a model of urban passenger transportation, a model of the hydrology of a Dutch estuary, and a model to estimate budgetary requirements for aircraft spare parts.

TRANSPORTATION AND AIR QUALITY

In 1971 and 1972, Rand undertook to study measures to improve the air quality in San Diego County for the Environmental Protection Agency (EPA) and the San Diego County Board of Supervisors. Because the automobile was responsible for a great deal of the emissions of air pollutants, the study had to consider several traffic reduction measures that had been suggested as air quality control tactics.

The transportation model available at the time was a traffic planning model maintained at the California Department of Transportation in Sacramento, used largely to help plan additions to the freeway system. Versions of the model existed for several areas in California. The San Diego version represented the street, highway, and freeway system of San Diego County as a network with approximately a thousand nodes and many thousands of links. Inputs included numerous demographic factors for about 700 "traffic zones," so that numbers of trips of several types from each zone to every other could be estimated. Data preparation for the model was a major undertaking; and Rand was told that once the data were prepared, the Department of Transportation would be unable to run the model and give us outputs for a further six months.

Model operation involved three major steps. First, trip tables were generated based on socioeconomic and demographic data describing the traffic zones. There were five trip tables, one for each of five trip purposes (home-to-work, home-to-shop, etc.), and each table contained the number of trips taken from each traffic zone to each traffic zone--a total of 700 × 700 (approximately a half million) trips in each table.

The second step involved splitting the trips in each table between the two travel modes, bus and auto. The fraction of travel by bus depended on the time and cost of a trip by bus compared with the time and cost of the same trip made by auto. The times and costs of each trip made on each mode had to be estimated by calculating shortest paths through the street network.

Third, the trips were loaded into vehicles and onto the street network. Auto occupancy factors for each trip purpose were specified outside the model--for example, 1.2 people per auto for home-to-work

trips. Trips in each auto trip table were divided by the appropriate occupancy factor to convert them from person trips to vehicle trips, and each vehicle trip was loaded onto the links of the network that constituted the quickest route for the trip. Bus routes were also specified outside the model, together with bus headways--the length of time between successive busses. This was enough to determine how much bus traffic passed over each link of the network. Loading the bus trip tables onto bus routes was merely a way of estimating bus occupancy factors. By these means the model estimated the amount of auto and bus traffic on each link of the network, a complete geographical distribution of the major source of air pollution in San Diego County.

In our project we needed to test many hundreds of alternative policies for reducing traffic, and we could not afford to use such a huge model. We had to build a much smaller model to serve our purposes. [16] It was evident that the major factor governing the size of the model was its geographical resolution--that is, the elaborate street network and the many traffic zones. But we concluded that we did not need much geographical resolution, and what we did need we could obtain merely by assuming that the traffic distribution was the same as the population distribution--i.e., traffic is heavy where there are lots of people.

Thus, our repro model represented the street network statistically. Instead of concerning ourselves with trips from each traffic zone to every other, we considered all trips of approximately the same length as a single category, ending with 50 length categories. We retained the same two modes of travel as the larger model (auto and bus), but went from five trip purposes to two. In place of 5,000,000 different categories of trips,[1] the repro model considered only 200.

The large model, however, used the street network to estimate trip times by auto and bus, which were used in splitting trips between the two modes. For both bus and auto, trip times were times by the fastest route. Because the repro model had no street network or bus route network, we had to estimate trip times in another way.

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[1]Two modes × five trip purposes × 700 × 700 origin-destination pairs.

To estimate times for auto trips, we developed a "street mix usage function." We selected random origins and destinations in San Diego County and traced out reasonable routes on a street map. The street mix usage function recorded that on the average, a trip of such-and-such a length would use so many miles of local streets, so many of arterials, and so many of freeways.

To estimate times for bus trips, we conceived of the bus routes as forming a rectangular grid. The spacing between east-west routes was one design variable, the north-south spacing another. The distance between successive stops on a route was a third design variable, and bus headway, or the length of time between successive buses, a fourth. Given these, plus the average bus velocity, it is straightforward to estimate the average walking distance, and waiting and travel time, involved in a bus trip of a given overall distance.

Once one selects a total area served by the bus system, this conceptual design also allows one to readily estimate the numbers of buses required by the system, as well as bus hours and bus miles accumulated. These are sufficient to permit a good estimate of the cost of the bus system. We needed this information for our project, both to estimate the cost to San Diego County of improving bus service and to estimate the fares that would have to be charged given limits on the allowable subsidy.

Direct validation of the repro model against the large model was impossible, because too few cases had been run with the large model, and these all had essentially identical bus service, street networks, and overall traffic volumes. In repro model terms, in other words, they were not different. Nevertheless, there are reasons for expecting the two models to agree. For example, for most individual trips, bus and auto travel times in the two models match closely. Also, we took the overall distribution of trip lengths directly from the large model. And the modal split equations are the same in the two models.

The repro model as described above was not completely adequate for our purposes. To be sure, it was small enough and inexpensive enough to use that we could run hundreds of different cases. But it could not consider as wide a range of possible cases as we wished. It shared with

the larger model the shortcomings that the total number of trips was not responsive to the cost or time penalties of traveling, and that auto occupancy was assumed constant.

To repair these shortcomings, we extended the repro model. We introduced a third "mode" of travel, that of forgoing trips. When the cost of auto travel increased, for example because of a rise in the price of gasoline, some people switched to the bus and others simply traveled less. We also introduced a carpooling option, so that in response to a rise in the price of gasoline, the average auto occupancy (for home-to-work trips only) would increase. Thus, the repro model in its ultimate form no longer reproduced the behavior of the larger model in all circumstances. However, it continued to reproduce the larger model's behavior in those circumstances for which the large model had been calibrated and tested.

FLOOD CONTROL IN THE NETHERLANDS

A second example of a repro model arose during a Rand study of flood control for the Dutch government. In 1953, a storm caused the waters of the North Sea to pile up against the southern coast of the Netherlands. This storm surge coincided with a particularly high tide. Dikes were overtopped, thousands of acres of land were flooded, and thousands of people lost their lives. The Dutch, determined to prevent a recurrence, drew up a plan to shorten the vulnerable coastline by damming off several estuaries in the southwestern part of the Netherlands, and by 1974, only one estuary--the Oosterschelde--remained to be closed. At this point, the question of whether to dam off the Oosterschelde was reopened, for to dam it off would eliminate the tidal flats used as feeding grounds for many species of migratory birds, would close off a nursery area for several species of North Sea fish, and would make it impossible to continue culturing oysters and mussels in the Oosterschelde.

An alternative solution was proposed and eventually accepted, which entailed building a "storm surge barrier." This structure consists of a series of huge gates suspended between pillars. During calm weather, the gates are left open and the tide can flow more-or-less freely in and out of the Oosterschelde, thus preserving the ecological values that led

to the replacement of the old solution by the new one. During a storm, however, the gates could be lowered to prevent the surge from entering the basin.[2]

There were several variations of the barrier alternative to consider. First of all was the question of how large the aperture of the fully open barrier should be. If it were too small, the tide in the basin would be greatly reduced, with a proportionate decrease in the area of tidal flats. Also, the current velocity at the mouth of the estuary would be greatly increased, possibly damaging the barrier by scouring the bottom sand out from under it. But the larger the aperture, the more costly the structure, and perhaps the more likely at least one gate would jam open at a critical moment.

In addition, there was a treaty with Belgium that promised that the Rhine-Scheldt Canal, which passed through the easternmost end of the Oosterschelde, would be tideless, and to achieve this the Dutch determined to dam off the eastern end. The question was, how far west should the dam be placed. The farther west it was placed, the smaller would be the area still affected by the tide, but for any barrier aperture, a smaller tidal area meant a greater tidal range and a lower current velocity at the estuary's mouth.

In order to investigate these questions, and to test strategies for controlling the barrier (e.g., when during the tidal cycle should the gates be closed, and when opened), it was necessary to model tidal movements in the Oosterschelde. There was an existing model called IMPLIC, because it used an "implicit" solution scheme to solve a set of two-dimensional differential equations describing the hydrology of the Oosterschelde. This model required that quite small step sizes be used in both time and space, lest the solution technique became unstable. Thus solutions could be obtained only at high cost in terms of input preparation and computer resources.

Accordingly, Rand developed SIMPLIC (for Simple IMPLIC). [17,18] IMPLIC estimated water levels at all points in the estuary, at all times during the simulation. SIMPLIC, on the other hand, treated the entire basin as a huge bathtub, which filled and emptied as a unit.

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[2]This barrier is currently under construction and is truly one of the engineering wonders of the world.

Mathematically, if h(x,y,t) is the water level at latitude x, longitude y, and time t, then IMPLIC assumed nothing in particular about the form of the function h(x,y,t), whereas SIMPLIC assumed its form would be:

$$h(x,y,t) = h_o + K(x,y)*h_1(t)$$

To account for differences in tidal range in different parts of the basin, we developed a calibration function that adjusted the solution depending on geographical location, (x,y). This calibration function, which was estimated from several runs of IMPLIC, appears in the above equation as K(x,y).

With this simplification, the SIMPLIC model becomes an ordinary differential equation. The well-known Bernoulli's Equation describes the rate of flow of water into the estuary at any moment as a function of the water levels just outside and just inside the barrier, and the effective aperture of the barrier. The rate of change in the water level in the estuary is the rate of flow divided by the surface area. The surface area of the estuary and the effective barrier aperture can both depend on the water level at that moment. The water level outside the barrier is specified by the user of the model; it represents the tide in the North Sea plus a storm surge, if any, both as functions of time.

The water level inside the barrier at the start of the simulation is also specified by the user, but for later times in the simulation the inside water level is calculated from moment to moment. One first calculates the water flow through the barrier, divides it by the surface area, and multiplies the result by a predetermined time interval to obtain an incremental water level. The water level at the end of such a computational cycle equals the water level at the start of the cycle plus the increment. The computational cycle is repeated until the desired amount of time has been simulated.

Both IMPLIC and SIMPLIC calculate water levels throughout the estuary, but only IMPLIC calculates water velocities everywhere. SIMPLIC calculates water velocities only through the barrier. But this

is enough for our purposes, for it is here that the barrier will constrict the flow and hence increase the velocity, and it is here that high current velocities might damage the barrier by scouring the bottom sand out from under it.

Numerous tests showed that SIMPLIC predicted water levels that were within a few centimeters of those calculated by IMPLIC, for a variety of different storms and storm surge barriers. But SIMPLIC could be run hundreds of times for the same cost in time and effort as was required for a single run of IMPLIC.

AIR FORCE BUDGETARY REQUIREMENTS FOR AIRCRAFT SPARE PARTS

A final example of a repro model concerns the estimation of required budgets for aircraft spare parts. The Air Force manages its aircraft repairable spare parts with a huge data and management information system called D041: The Recoverable Consumption Item Requirements Computation System. This system was built to estimate the requirements for buying and repairing each individual part. Over the years D041 had been asked to estimate budgetary requirements to buy and repair these parts as well. However, D041 is so large and cumbersome that it can be exercised only once each quarter, and then only for a single set of peacetime flying schedules, planned wartime sortie rates, and other program quantities that affect the requirements for spare parts. It could not be used to estimate how the budget requirements would change when these program quantities were altered, as often happens while the proposed Air Force budget is being prepared.

To make such flexible response possible, Rand built a repro model of D041 called ORACLE--Oversight of Resources And Capability for Logistics Effectiveness.[19,20] The approach used was to develop a first degree Taylor's approximation of the functions used in D041 to estimate buy and repair requirements for individual parts. This is a standard technique taught in elementary Calculus, in which a given function is approximated by a linear function--in the simplest (one-dimensional) case, a curve approximated by a straight line. The straight line passes through a selected point on the curve, the point at which the approximation is constructed, and the slope of the straight line--technically its derivative--is taken to be the same as the slope

of the curve. So long as one does not move too far from the point at which the approximation is constructed, the straight line will be close to the curve and the approximation will be a good one.

The functions used in D041 to estimate buy and repair requirements are quite simple. First, D041 estimates a total gross requirement for a part, which is the total amount that will be used in an interval of time. The various pieces of this total are related to different program quantities. For example, the number of a part in transit from a wholesale supply point to users in the field (the order-and-ship requirements) is the product of flying hours per day for that part (this is the program quantity), failures per flying hour, the fraction of failures that cannot be repaired by the user in the field, and the number of days needed to send a part from the wholesale supplier to the user. It is easy to calculate the derivatives of this and other segments of the gross requirement with respect to program quantities.

D041 satisfies as much of the total gross requirement as possible from serviceable stock on hand, as much of the remainder as possible by repairing and reusing parts, and the rest by purchasing new parts. Derivatives of buy and repair requirements are as easy to calculate as derivatives of gross requirements. If a part must be bought, the derivatives of its buy requirement will be the same as the derivatives of its gross requirements. If the part is instead in a surplus position and need not be bought, all derivatives of its buy requirement are zero. The situation is only slightly more complicated for the repair requirement, made so by the fact that the very activities that generate part of the requirement by breaking parts also generate a stock of parts that can be repaired to meet part of the requirement.

The ORACLE methodology thus consists of a few equations for calculating derivatives that must be added to the existing D041 software. Each time D041 is run, these equations calculate, for each individual part, derivatives of its buy and repair requirements with respect to program quantities. The derivatives of an individual part are then weighted by the part's purchase price or repair cost, as appropriate, and aggregated over various subsets of parts (e.g., all C-5 parts) to obtain derivatives of various budget quantities with respect to program changes. These aggregate derivatives constitute an ORACLE

database that can be used to estimate what D041 would have calculated the buy and repair budgetary requirements to be if the program quantities had been different.[3] Moreover, the ORACLE database can be installed on a microcomputer and can provide these estimates in seconds, whereas D041 can run only on a main-frame computer, and is exercised only once each quarter.

We performed a validation of the ORACLE methodology against a special version of D041. We used a database consisting of several thousand parts, belonging to a dozen aircraft or engines, and calculated derivatives with respect to their flying programs, depot level maintenance programs, and planned wartime activity rates. We calculated buy and repair requirements for a wide range of different programs by running our version of D041 many times, and we estimated the same requirement by means of the derivatives we had calculated. The budgetary requirements approximated using the derivatives compared extremely well with those obtained from the various D041 runs.

CONCLUDING REMARKS

The above examples of repro models illustrate some useful approaches to building repro models. In the transportation model, we encountered the idea of sampling. There, instead of considering all possible trips, we looked at only a few "typical" trips and weighted them according to their relative frequency among all trips. In the SIMPLIC model, we chose a fairly simple form for the solution of our problem and selected its parameters to obtain the best fit. For ORACLE, we used a Taylor's approximation scheme, which might be considered another instance of selecting a simple form for the solution.

In all the examples, we relied heavily on aggregation, across locations in the transportation model and SIMPLIC, and across classes of aircraft parts in ORACLE. Aggregation or, more generally, loss of detail, is impossible to avoid in a repro model. Of course, loss of detail has its dangers--one may know only how many tons of ammunition are available but may need to know how many rounds of 155 mm HEAT are

[3]The change in the buy requirement, for instance because of a change in peacetime F-15 flying hours, is calculated as the product of the flying hour change and the derivative of the buy requirement with respect to F-15 flying hours.

available. Someone must see to it that the details are not ignored completely. Equally, however, someone must take a broad view of things. It is in this role that repro models can often be useful. Policymakers must provide overall direction and not attempt to make the day-to-day decisions about what kinds of ammunition ought to be bought.

In the transportation model, we encountered another useful technique. Once we had constructed the repro model, we extended it to consider factors and responses that the larger model could not consider. It is typical of large models that in order to include so much detail, simplifying assumptions are made. For example, it was assumed that the total amount of travel depended on the socioeconomic characteristics of the travelers but not on the cost of travel. It is often possible to add flexibility to a repro model by relaxing restrictive assumptions of this kind. Of course, the repro model thereby ceases to faithfully reproduce the behavior of the larger model, but one can argue that the assumptions made the larger model behave wrongly anyway. Such an argument suggests also that the larger model might never have been suitable to be used in a policy study.

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