

A Personal History of Logistics

By Murray A. Geisler

LMI 

A PERSONAL HISTORY OF LOGISTICS

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Felix qui potuit rerum cognoscere causas.

—Virgil

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CONTENTS

Page

Foreword	v
Preface	vii
Introduction	1
Project SCOOP	3
First Approaches	
The “Simplex” Method	
The “Triangular” Model	
The Berlin Airlift Model	
Spare Parts Computation	
Discovery of Excess Spares	
Computation of Engine Life	
Project SCOOP: Summation	
A Logistics Department	13
Cost-Effectiveness	
Centralized Control of Inventory	
Logistics Systems Laboratory	19
A Simulation Laboratory	
Comparison of Two Logistics Systems	
ICBMs and Logistics	
AMC Management: WSM Versus ICM	
Management of Base-Level Maintenance	
The LSL in Summation	
Inventory and Supply Research	35
Characterization of Demand	
Base-Depot Simulation Model	
Base Stockage Model	
METRIC	

MOD-METRIC	
Introduction of Availability	
DYNAMETRIC	
Low-Cost, Low-Demand Items	
Centralized Management	
Advent of Advanced Computers	
The Present State of Research	
Historical Review	51
Maintenance	
Transportation	
Procurement	
Manpower	
Other Subjects of Research	
Vietnam	
Civilian Problems	
Logistics Career Environment	61
Joint Logistics Review Board	65
Logistics Management Institute	70
Assessment of the State of DoD Logistics	
Review of Support for New Weapon Systems	
Assessment of Methods for Measuring Readiness	
Evaluation of LMI's Service to Sponsors	
Guide to Management of Multinational Programs	
Installations Management	
Modeling of Information and Support Activity	
Highlights	83
Biographical Notes	85

FOREWORD

We at LMI had the pleasure of sharing with Murray Geisler the last seven years of his active career. We learned from him and were enriched by his experience.

When he retired, we wanted to capture some of that experience so that others might benefit as we had. He indeed had something special to offer. He started applying his statistical tools to logistics when it seemed to most people a heterogeneous assortment of independent actions — requisitioning, transporting, storing, repairing — that defied analysis. When he laid his tool kit on the shelf, thirty-five years later, logistics had gained general acceptance as a fruitful field of formal analysis. Murray had played a key role in that change.

We asked Murray to chronicle his experience, and he responded with what he called “A Personal History of Logistics.” It was in manuscript form, but complete, when he became terminally ill.

This volume is that manuscript, readied for publication by our editor, Walter Golman. We release it in fond memory of Murray and in sincere appreciation of his contributions to logistics analysis.

Perkins C. Pedrick

President, LMI

April 14, 1986

PREFACE

The notes in this paper — one logistician's experience over 35 years — have been written along stream-of-consciousness lines. Little effort has been made to refer to sources to reinforce my memory. Also, the material is presented largely in chronological order, although there are departures from such order where the presentation could benefit as a result.

Of course, my experience is limited in many ways, having been gained in research, primarily at two institutions. There is much more to the logistics experience, particularly at the operating end, be it in the military organizations or in the commercial suppliers of logistics resources to the Department of Defense.

I have found my entire career both interesting and demanding and hope that others share these same feelings about the logistics profession, wherever they may have experienced it.

M.A.G.

January 1984

INTRODUCTION

This historical and personal account traces approximately the chronological pattern of my logistics career. It begins with my assignment to Project SCOOP (Scientific Computation of Optimum Programs) of the Air Force, which I joined in February 1948 and stayed with until February 1954, when I joined the newly formed Logistics Department at the Rand Corporation. My Rand career, which lasted 22 years until February 1976 — except for some absences, such as a year at Stanford University to complete my doctorate, a year with the Joint Logistics Review Board, and a year as Visiting Professor at the Sloan School of the Massachusetts Institute of Technology — is discussed in the next four sections.

The third of these sections, “Inventory and Supply Research,” extends into research efforts beyond those of the Rand Corporation, such as development of the Aircraft Availability Model at the Logistics Management Institute (LMI), to show the historical progress in logistics research. The fourth section, “Historical Review,” deals with the changes that went on in the Rand Corporation as a whole, as the effects of the 1960s’ and 1970s’ political and economic situation influenced its programs.

Because I feel that logistics is a much broader career field than I experienced, I discuss, in the section on “Logistics Career Environment,” some of the differences between my research experience and other logistics career interests. In the next two sections I resume my chronological description, picking up the Joint Logistics Review Board period and ending with my seven years at LMI.

In the short “Highlights” portion at the end, I pick out the high points of logistics progress as I see them, on the basis of my admittedly specialized viewpoint.

PROJECT SCOOP

Project SCOOP was born in the minds of George Dantzig and Marshall Wood. Their experiences in World War II had convinced them that better, more efficient techniques were required for resource planning and management in the Department of Defense. This was 1946-47, when the Air Force was taking stock of what had been learned during the war.

Marshall and George presented their thinking to General Ed Rawlings, who was then Comptroller of the Air Force. He was an intellectual type of person with ability to plan for the future.¹ He approved the proposal and provided the funds to set up a staff. The idea that Marshall and George presented was that advantage should be taken of electronic computers, whose development had begun in World War II; research was being pursued by a number of companies, including IBM, Remington-Rand, and Raytheon. In addition, George Dantzig had been thinking about mathematical formulations that would help in the optimum computation and allocation of resources. It was natural to describe the project as Scientific Computation of Optimum Programs, or SCOOP.

First Approaches

In addition to the mathematical and computational needs of SCOOP, it was recognized that data in the form of planning factors were required. Consequently, an effort was made to publish a planning factors manual — initially, for wartime conditions — to be used for planning purposes. This manual was built from hard data that had been collected and analyzed during World War II. George Dantzig had been in charge of the Combat Factors Branch, which included Robert McNamara at one time, when he was a captain in the Army Air Forces.

The nucleus of the Project SCOOP civilian staff came from this same Combat Factors Branch of the Army Air Forces, which had a strong role in the combat effectiveness and resource analysis business during World War II. It worked on such factors as combat attrition rates, sortie rates, crew-to-aircraft rations, fuel consumption

¹ After General Rawlings retired from the Air Force, he became President and Chairman of the Board of General Mills.

rates, ammunition consumption rates, maintenance man-hours per flying hour, and operationally ready rates. During the war, there was actual experience on which to base the planning factors, but, as the wartime period receded into the past, planning factors had to be based more on analytic and modeling approaches, taking into account the new conditions that would be encountered.

New aircraft — B-36s, B-47s, and B-52s, as well as jet engine fighters — were coming into the inventory. New weapons — rockets and early guided missiles — were also being developed. Coordinated use of information from many staff offices had to be used. This led to considerable interaction and negotiation about acceptable planning factors and assumptions. The important result, however, was that a single set of official planning factors did emerge. These would be used in all staff planning.

The “Simplex” Method

The mathematical developments were built around the concept of mathematical or linear programming. George Dantzig formulated the Air Force’s general planning problem in a mathematical programming model and used the linear form for feasibility of computation and interpretation. He was then able to develop computational techniques for solving the linear programming model; he named these techniques the “simplex” method. With the linear programming model, the object was to achieve a level of performance at minimum cost or to maximize performance within a given budget.

The simplex technique represented a true breakthrough in mathematical computation and use of electronic computers in solving large-scale problems. It gave birth to the whole field of mathematical programming, now one of the cornerstones of operations research and management science.²

Concurrently with the work on planning factors and mathematical techniques, efforts had begun to obtain a computer for Project SCOOP. The choice settled on the UNIVAC, which was then being developed by Remington-Rand. The UNIVAC looked attractive because a Government consortium, consisting of the Census Bureau, the Air Force, the Army Map Center, and the David Taylor Model Basin, had joined to buy the first UNIVAC at a fixed price. Delivery was planned for 1950-51.

² In 1975, a Nobel Prize was awarded jointly to Tjalling Koopmans of the U.S. and Leonid Kantorovich of the USSR for studies closely tied to mathematical programming. It is regrettable that Dr. Dantzig did not share in the award; he had made the theory available for practical use.

As Project SCOOP matured in 1949-50, it was named the Planning Research Division, with three branches: Standards Evaluation, Computation, and Mathematical Formulation. Standards Evaluation was responsible for planning factors and other data. Computation was responsible for operating the UNIVAC and the computer programming it required. Mathematical Formulation was responsible for the mathematical modeling, which concentrated at first on linear programming and the simplex method.

To pay its way in the Air Staff, the Planning Research Division assumed responsibility for managing the Wartime Planning Factors Manual and for initiating development of a Peacetime Planning Factors Manual. In addition, it carried out mobilization planning calculations of some major wartime supply items, such as fuel and ammunition, as well as manpower. These calculations went into mobilization planning documents. The early calculations of such items were done on desk calculators before the UNIVAC became operational.

The “Triangular” Model

Early in the program, it became clear that, although linear programming was a powerful technique, applying it to the Air Force would not be feasible, because of the magnitude of the Air Force linear programming model. Accordingly, an alternative technique was developed; it was called the “triangular” model. We found it possible to array the different resource groups in a sequence such that those which depended entirely on the operational program came highest in the triangle, followed by those that depended on only the operational program and the results from the first group, and so on. A small number of dependencies violated the triangular pattern, but these few could be handled as side calculations. This procedure became the mainstay of the system for computing resource requirements. We were never able to handle linear programs of the size that fitted the Air Force situation.

The Berlin Airlift Model

One small problem that was solved by linear programming became well known in the early literature. It was known as the Berlin Airlift Model. The model considered the optimal number of C-7 and C-54

aircraft and crews needed to satisfy the Berlin Airlift schedule at minimum cost. The calculation took account of the costs of fuel and spare engines, as well as crew costs. This problem, although never used in day-to-day planning, did serve as a good tutorial example to show the usefulness of linear programming. It also attracted academic attention and led to a number of dissertations, producing graduate students who concentrated on work in mathematical programming. These students specialized in mathematics and economics.

Spare Parts Computation

One large hole in the planning factor data base was the lack of factors representing consumption of spare parts for aircraft. As late as 1950, budget calculations regarding these spare parts were done manually. Project SCOOP offered to help the Air Materiel Command (AMC) convert to punch-card equipment and make its data accessible for use on the UNIVAC. In addition, we offered some new techniques that would add flexibility to the process of revising budget estimates. Even at that time, the Air Force was handling more than a million line items.

The proposal generated a major controversy within AMC. The property class managers, who supervised many clerks, thought they would lose control over the requirements and budget process. When the brigadier general who was Chief of Supply in AMC left his position, the Director of Supply and Maintenance accepted the SCOOP offer.

Project SCOOP assigned two people to work closely with AMC on the conversion to punch cards. The individual property class manager had to prepare punch cards on each line item in his class — showing the usual statistics about past issues and inventory — and, in addition, assign the item to a specific program element, such as B-47-peculiar flying hours and F-86-peculiar aircraft-months. It was assumed that such program elements would be correlated with observed demand.

One problem was how to deal with items common to more than one aircraft model, since the demand data gave only total issues for each item, without any breakdown by aircraft model. We therefore devised program elements, such as Boeing flying hours to handle

items common to two or more Boeing aircraft models, or fighter-months to cover items common to all fighters. Admittedly, this approach was approximate, but at least it tried to deal with a problem in estimating spares demand that still plagues the supply computation world.

The real problem that arose in the first efforts to mechanize spare parts requirements and budget computations was in the quality of the input data. Many errors were encountered in the consumption and inventory reports and in the assignment of program elements. The problem of inaccuracy continued to plague the program; it undoubtedly continues today with the even greater quantities of line items that must be handled.

After the punch cards for individual items were prepared and reviewed, the requirements were calculated centrally in Dayton. Under the SCOOP procedure, budget estimates could be calculated simultaneously for a wide range of program levels, a process comparable to what is now done with the Aircraft Availability Model of LMI, except that no measure of aircraft availability was produced. The LMI model permits calculation of aircraft availability because it handles demand as a probability variable; the SCOOP computation worked with expected values only. Computation of requirements simply followed the inventory-level policy established by the Air Force. Therefore, if the proposed budget derived from the calculation was cut by higher authority, program levels had to be reduced to fit the budget.

We simplified this adjustment effort by combining the separate program elements into composites, such as the F-86 aircraft program element, which was a composite of F-86-peculiar aircraft hours and portions of North American parts-hours, fighter parts-hours, general aircraft-months, etc. The result was a series of curves that showed the budget relationship between dollars of spares procurement and the F-86 program, B-47 program, etc. On each aircraft program curve, we could look at a program level and read the budget level, and vice-versa.

A similar scheme was worked out to calculate budgets for procurement of individual spare parts and depot component repairs, as LMI has attempted with its Aircraft Availability Model. Project SCOOP's experience with its model was similar to LMI's experience with its model.

The technique for spares budget calculations was the most successful, although it took several budget cycles within the Air Force to gain acceptance. It is not an exaggeration to say that there were efforts by the staff to sabotage and defeat the method. People tried to outguess the technique by “illegally” adjusting the base period program levels to show demand rates that would reach the amount of money they believed should be appropriated. However, when the program level was changed, the whole calculation was badly in error because of the arbitrary consumption rates that had resulted from use of the erroneous levels in the base period program.

To provide continuing technical assistance — which, in the beginning, amounted to virtually managing the entire computation — SCOOP assigned a technically trained military officer to serve as a full-time liaison person at Headquarters, AMC, in Dayton. He remained there for more than four years because his presence was essential to the momentum of the mechanized program of spares computation. As will be seen later, when Rand became closely involved with the later-named Air Force Logistics Command (AFLC), it, too, had to provide a liaison person for several years.

Here again, we see a parallel with LMI’s experience with its Aircraft Availability Model: It is hard to break away from having to provide continuing staff support. The one advantage that SCOOP had over LMI was in doing its work with AMC, the operating command for the spares budget computations.

All along, however, there was continuing controversy between Headquarters, AMC, and its Materiel Centers over the authority to draw up spares budgets and the Centers’ objections to a centralized method of computation. The Centers insisted that they needed to review the budget submissions — which, as now, had to be changed on very short notice — as the budget cycle proceeded. Such reviews by the Centers were impracticable because of the short deadlines for budget revision.

An interesting point is that punch-card computation was replaced by electronic computers about 1955, when AMC received its first UNIVAC. Its choice of computer was influenced by the satisfactory experience of Project SCOOP. The groundwork laid by the punch-card system made it much easier for AMC to move into the electronic age. The UNIVAC continued at AFLC until the 1960s. The background that SCOOP had developed with its own UNIVAC served

AMC well because SCOOP provided technical support during the transition and after.

Discovery of Excess Spares

One major payoff from the AMC application attributed to Project SCOOP was the discovery in 1952 that the Air Force had a large surplus in aircraft spare components, both on hand and on order, over programmed needs. About a billion dollars could be diverted from this supply account to others, a helpful outcome because the Korean War was causing large increases in Air Force budgetary demands.

The exposure of the SCOOP staff to AMC management problems led to an important contribution regarding spare engines. The Air Force procedure in the early 1950s was to buy spare engines on a life-of-type basis; that is, enough engines were to be bought during the initial provisioning period to last the life of the aircraft.

This procedure suffered from a number of faults that were realized by some members of AMC and others in the Air Force. First, the decision about the number of spare engines to buy had to be made early in the production period, when there were few real data on engine life. The situation was aggravated because engine technology was going through major developmental changes, from conventional to turbo-prop and jet, and from turbo-jet to fan-jet. Therefore, early predictions of expected engine life were subject to great uncertainty. This led the materiel managers to put in large amounts of safety allowance, resulting in larger buys of engines because there was no provision for follow-on procurement of engines.

Computation of Engine Life

In addition, the computation of expected engine life was heavily biased toward underestimating the mature life values, because the sample of engines from which the computation was made was drawn from the earliest period of production, when the rate of failure was high. During the provisioning period, many of the engines were still in place and operating, and the fact of their continued survival was not included in the computation of engine life. Clearly, this approach biased the calculation toward too-low estimates of engine life and therefore overstated total engine requirements.

Project SCOOP recommended use of an actuarial technique to compute engine life because many of the components in the engines used in the 1950s were subject to failure from wear with increasing age. The method of computation dealt with the state of the total engine inventory, not just the engines that had failed earlier. This actuarial method increased dramatically — by a factor of about 3 — the life expectancy values for the new jet engines going into the B-47s and F-86s then in production. Only a third as many spare engines had to be procured.

The great difference in engine requirements produced by the actuarial technique led to considerable soul-searching by AMC's Director of Maintenance, who was responsible for establishing the life-expectancy values. After being shown by means of the data analysis that the life expectancy of the engines might conceivably exceed the threefold increase in value, he accepted that value as the basis for computing spare engine requirements for the B-47 and F-86 aircraft. The result of the decision was to cause the closing, at least for many months, of two of the three plants at which General Electric was producing the engine.

Many illustrations of comparable experience could be presented. Moreover, the subsequent history of Project SCOOP is of much interest because it shows the tenuous position held by a research and consulting group in a large organization. Project SCOOP reached the height of its acceptance about 1953, five years after its formation, and gradually diminished in importance and effect for the next five years, until it was discontinued.

Project SCOOP: Summation

What are the lessons learned from such an operation?

When we began, in 1948, we had no idea we were in the forefront of a major revolution in the science and art of management. It was fascinating to be involved in the application of electronic computers, but our expectations for this new tool were quite modest. We did not foresee the explosion in computer development and usage that has occurred in the past 35 years.

We realized early that information was a resource, just like other resources with which it could be traded off, and that it had a benefit and a cost. As we manipulated the data with our new techniques

and computers, we developed insights and understanding that did represent a form of power, as shown by our ability to raise the possibility of diverting a billion dollars from aircraft engine spares or to introduce a technique that led to the closure of major defense plants.

We learned a lot about the difficulties of introducing a new system and learned how far people might go to avoid change. We also learned how close the researchers had to be to the implementation process to be sure the technical procedure was being followed. There are many details that can have disastrous effects if they are not handled properly.

We learned how fragile a research group can be, and we came to realize that keeping it productive takes a lot of tender care. A large bureaucracy does not value such groups adequately; they are therefore doomed to have a limited life. Trying to do things differently or trying to have effect inevitably invites attack and criticism. The group can resist such assaults for a time, but eventually its fragility can lead to its decline or demise.

A LOGISTICS DEPARTMENT

The Rand logistics program was initiated at the request of the Air Force in late 1953. It began as part of the Economics Division, which, at the time, included the Economic Analysis Department, the Cost Analysis Department, and the new Logistics Department.

There had been earlier efforts to start a logistics program. I recall spending six weeks at Rand in 1950 as a member of a summer study program in logistics. About ten people had been invited to Rand to undertake brainstorming sessions on useful logistics research and to present their work in seminar fashion. I prepared a two-sided linear programming model, depicting the U.S. military and industrial structure as one side, and the Soviet Union's military and industrial structure as the other side. I used dummy parameters and presented solutions under a variety of assumed conditions.

Merrill M. Flood, who was then a member of the Rand Mathematics Department, acted as a principal coordinator of this summer study work. My office mate was Professor J. W. T. Youngs, a mathematician from Indiana University who, though an abstruse mathematician, had a really down-to-earth approach to logistics problems. We had later opportunities to work together after I joined Rand permanently. I was called back to Washington toward the middle of that summer in 1950; the Korean War was placing heavy demands on the office workload.

Because of the position of the Logistics Department in the Economics Division and because the department head was an economist with a Ph.D. from Harvard, staffing placed strong emphasis on economists. Of course, even at that time, in the middle 1950s, young economists came with good training in mathematics and statistics. Moreover, they were largely trained in micro-economics, with its concentration on the theory of the firm, production economics, and transportation economics. Some engineers were brought in to work in the maintenance area, and some computer specialists to work on data processing problems in logistics.

Cost-Effectiveness

The Department began with a bang, formulating new ways of looking at logistics policy, particularly from a cost-effectiveness

standpoint. Such concepts as risk and uncertainty were introduced in formulating logistics problems, especially in developing new inventory policies and models. To understand the patterns of demand for such key logistics resources as spare parts, maintenance personnel, and ground-based equipment, a great deal of data analysis was undertaken. Efforts were made to explain what generates logistical demands, particularly by correlating flying activity with observed demand.

A particularly fruitful area for applying the concept of cost-effectiveness in logistics turned out to be the flyaway kits used for Strategic Air Command bombers. In the 1950s, the SAC bombers were to be deployed to overseas bases, and kits of spare parts had to be prepackaged and flown overseas in the event of an emergency. The problem was what parts to put into these kits so as to maximize their supply performance, given a specified total kit weight.

The general mathematical approach used was marginal analysis. A computational method was devised such that each unit of a part was added in order of decreasing marginal value per pound of weight. The process was continued until the weight limit was reached. The marginal value was defined as the reduction in stockout probability for that unit. A particularly helpful feature of the technique is that using the Poisson distribution to represent the probability function for spare parts demand makes computing the marginal value of each unit fairly easy.

While this technique was being developed, other work in the department was concerned with analyzing demand data for the B-47 aircraft; the data were then being obtained from special data collection programs. These demand data were unique in that they reflected not only the issuing of parts, but also the fact that a part was demanded but not immediately available. Heretofore, issue data and demand data had been treated as identical, but it is clear that demand data are biased if they report issue of available parts only.

These special data also showed the tail number of the aircraft that created the demand so that demand could be related to individual aircraft and the numbers of hours they flew. Analysis of aircraft demand data has always been a subject of research interest because it ties so closely to spare parts requirements and budgets, a fundamental logistics function.

Later work on spare parts demand dealt with such subjects as common parts, substitute and interchangeable parts, and hierarchies of parts, all of which continue to be active subjects of logistics research today.

This special analysis provided the demand information to use in calculating the flyaway kit. The data on weights of parts were taken from the part numbers and description data in the Supply Catalogue. The criterion against which to measure supply performance was the number of expected unfilled demands, so that minimizing the number of expected unfilled demands for the given total weight was the criterion of merit.

The computations by this method led to flyaway kit compositions quite different from those calculated by the Air Force. The Rand method led to inclusion of a large number of line items, particularly those for which both demand and unit weight were low. It also resulted in a much smaller number of expected unsatisfied demands, compared with the Air Force kit, for the same total weight. The reason is that the Rand kit was deliberately designed to satisfy that criterion; what explicit criteria were met by the Air Force kit, other than experience, was not clear.

The results of the Rand work were so striking that a report on the approach and results was quickly prepared, and briefings were given to the Air Force. The work generated considerable interest, and a conference on flyaway kit techniques of all the major Air Force commands was held at Rand in late 1954. The reason for the great interest in the conference derived not only from the problem area but also from the high repute in which Rand was held within the Air Force; the new Logistics Department benefited from this opinion.

Much of the conference was devoted to explaining the meaning of randomness, demand probability, and the use of a cost-effectiveness model to solve a planning problem. Herman Kahn, an expert on Monte Carlo techniques, gave the major presentation on the meaning of probability in describing demands for aircraft spare parts. The flyaway kit calculations were described in great detail, as were the tests used to demonstrate the superiority of the marginal analysis method.

The conferees reacted positively to the Rand proposals and suggested holding a live field test to evaluate the flyaway kit

technique on B-47 aircraft in SAC. Arrangements were made to brief the Director of Supply at SAC, but he reacted negatively to the idea of a field test. One comment he made was that SAC would never accept anything that was “marginal.” (We had described the approach as “marginal analysis,” the accepted economics terminology for that method of determining the optimum use of limited resources!)

One impression I had from this early contact with SAC was that it tended to be a closed society, emphasizing inner control and accomplishment. Bringing in ideas from the outside was hard. Each group had to strive for high achievement but do it within its own resources and talents. The effort then turned to arranging a similar field test, this time using F-86 aircraft of the Tactical Air Command (TAC). Eventually, both paper and field tests of the technique were run with TAC aircraft — with appreciable success. The technique was then incorporated into an Air Force Logistics Command regulation, where it remained for a number of years. Interestingly, the regulation became less operative over time; as the necessity to deploy strategic bombers vanished, SAC did not require flyaway kits. TAC became much more active in the design of its own War Reserve Kits.

The design of flyaway kits was a comparatively simple problem compared with the much larger and complex problem of determining spare parts requirements for inventory, procurement, and repair. Here, too, marginal analysis techniques were developed, involving tradeoffs between supply performance and logistics cost. In trying to look at logistics efficiency in terms of cost, we inevitably had to deal with the cost of a stockout. Although efforts were made to price a stockout, they were doomed to failure because a great deal of subjectivity was inevitably involved. Consequently, the normal procedure became one of fixing either the performance level or the total budget and optimizing the other. There was then no need to assign a cost to a stockout.

Out of the first efforts to apply marginal analysis came various formulas for setting stock levels of both recoverable and nonrecoverable items. Although these formulations were relatively primitive because they were based on theoretical assumptions, with little empirical study behind them, they did lay the groundwork for future progress in addressing inventory policy. The later methods built around the Multi-Echelon Technique for Recoverable Item Control (METRIC) model can be traced to these earlier efforts.

Centralized Control of Inventory

In addition, insights were being acquired into the role of electronic computers in inventory control. It became clear that, for many purposes, centralized knowledge of inventories had much to offer. One notion was that the supply center would know the status of inventories at every location and could thus place new assets where they would do the most good. A system of this kind also permitted periodic redistribution of assets. Of course, such close management was meant for the more expensive and critical items; data processing was not a cheap operation.

The issue of maintaining centralized inventory knowledge raised a question of feasibility. An opportunity to test the concept opened at the Oklahoma City Air Logistics Center (OCAMA). OCAMA had established a storage site about 80 miles away to store mobility kits that were part of the SAC war plan. The idea was to maintain inventory control over these assets by means of a transaction reporting system, like AUTODIN. The system would move transaction information over telephone lines and store it in a computer. Up-to-date information about the inventory and requisition status of the mobility kits would then be accessible. Rand helped design and conduct the field test. The results were quite satisfactory. They showed that inventory control of physical assets stored in one place could be maintained with data records kept someplace else.

LOGISTICS SYSTEMS LABORATORY (LSL)

It was clear from the first two years' experience of Rand logistics that its proposals had to run the gauntlet of field testing, but such tests were expensive, time-consuming, and somewhat disruptive of field operations. The Air Force was interested in encouraging Rand's innovative activity, but it needed a less expensive, yet realistic, mechanism for evaluating the Rand proposals.

A Simulation Laboratory

Some imaginative people in the Air Force proposed that Rand establish a Logistics Systems Laboratory (LSL) that would serve as a test facility for new logistics concepts and policies. The laboratory would study a given policy proposal by simulating its operation in enough detail to permit observation and measurement of the effects of its policy, organization, and information system characteristics on the Air Force.

The idea of establishing such a simulation laboratory for analyzing and evaluating logistics systems was radical. It was intended that each simulation under study would include both people and computer models of the system. It was therefore described as a man-machine laboratory. The intent was to have the man play the managerial and less structured roles, while the computer simulated the physical and more describable elements, such as flying of aircraft, keeping of inventory records, and performance of maintenance.

The initial plans and actions for the LSL were quite ambitious. Fifteen people from AFLC were sent to Rand for a year's temporary duty to help ensure the realism of the logistics systems simulated in the laboratory. They were middle-grade civilians and military people who were specialists in such logistics functions as supply requirements, distribution, transportation, component maintenance, aircraft depot repair, and procurement. Rand, in turn, assigned a number of staff members to the laboratory; they included economists, psychologists, computer specialists, and clerks.

Rand had some background in this type of research. Its former System Development Division (SDD) had operated a man-machine

laboratory while studying an air defense ground-control center. That Division had recently split off from Rand to become the System Development Corporation because of its success with those simulations. Some former members of SDD, particularly the psychologists, joined LSL. A specially designed area in a rented building that had previously been used by SDD served as LSL's physical laboratory space. It had special observation posts above the floor, enabling the laboratory controllers to observe the exercises without disturbing the players.

Despite similarities between the laboratories of the SDD and LSL, there were also major differences. For example, the SDD lab simulated a short period, usually a day or less, during which there was intense air defense activity. The experiment thus operated on a second-by-second basis, with each second of simulated time corresponding to a second of real time. In addition, an effort was made to reproduce accurately the physical arrangement of the air defense control center. The defense team working in the simulated control center was also identical in number and composition with the team in the real control center.

The needs of the LSL were different. Logistics plans and decisions operate over long periods, often years. In addition, the logistics system is multi-echelon and multi-locational, being dispersed over wide areas. SDD had been interested in observing training; the interest of LSL was in the interactions among the various logistics organizations involved in the management and decision-making of their widespread system. The people in the laboratory, therefore, assumed management roles and compressed time by various devices, including the use of computers to speed the passage of time, and by the assignment of month-to-month decisions to the managers.

It took some time for the senior LSL staff to settle on its first experiment. Although the SDD experience had some relevance, logistics management involves problems and techniques different from those encountered in an air defense control center. We were venturing into virgin territory, and experiments were costly. We therefore had to devote a great deal of time to the planning effort, to make sure of a substantial payoff from our experiments.

Early on, it became clear that specialists in different subjects viewed the laboratory idea differently. No one's point of view was more "right" or "wrong" than another's; they simply had different

expectations of what the lab should do. The psychologists focused on human reactions and behavior. The economists were interested in cost-benefit tradeoffs. The Air Force specialists wanted to build as much realistic detail as possible into the representation of the logistics system.

We were really dealing with an interdisciplinary situation, and all the difficulties that have been attributed to such environments occurred here. People became angry, frustrated, and difficult as they tried to have their own points of view dominate. The situation grew so tense that it became necessary to release some of the most intractable staff members before we could arrive at a mutually acceptable approach and experiment.

Our first simulation efforts, called PROLOGs, were designed to develop the mechanics of logistics system representation and operation in a laboratory setting. For the sake of a more flexible procedure during formulation, we even performed manually some operations that we knew would later be done by computer.

After a couple of months of such preliminary effort, we settled on the first major problem to study. From our research, we had developed new techniques for determining requirements, procurement, and repair of recoverable and nonrecoverable spares and for managing assets in a large logistics system. The research had also yielded new concepts about deriving support from data processing centers for these efforts.

Comparison of Two Logistics Systems

The design concept used in this first official experiment, designated Laboratory Problem-1 (LP-1), was to simulate two logistics systems, one representing the Air Force circa 1958 (called the “current system”), the other reflecting the new Rand policy ideas (the “proposed system”). Each system simulated consisted of five F-86 bases and five B-47 bases, the F-86 bases being under the Air Defense Command, the B-47 bases under the Strategic Air Command. The Air Materiel Command (AMC) comprised a supply depot with a supply manager and a repair depot with a maintenance manager. In addition, there were: a transportation system connecting the bases and depots, a procurement division responsible for buying spare parts, and a factory.

The current system operated under standard Air Force policies and procedures; the policies and methods of the proposed Rand system were consistent with the new theoretical concepts. Each logistics system was given a manual that described how it would work, from both policy and procedural standpoints. The manual described provisioning rules, parts ordering rules, requirements computation methods, repair scheduling routines, shipping rules, etc. Both systems faced the same real world in terms of required flying schedules, reliability of parts, efficiency of maintenance, delays in transportation, and factory production times.

The intent was to subject each of the two simulated systems to the same support requirements and then compare the two as to cost and effectiveness. To permit provisioning, the bases were phased in over time. To stress the system, periodic emergencies were also called, requiring both the air defense and bomber forces to fly accelerated schedules.

Compressed time schedules were used; that is, a real half-day in the laboratory corresponded to a month of the simulated system. This was accomplished by having the computer simulate a month's activity at the bases, depots, etc., and allowing the managers to intervene each morning and afternoon (before and after each "month" was run) in the affairs of their systems. We also treated each year as consisting of ten months, enabling us to simulate a whole year each week. We ran the simulation over a six-week period, the first week being devoted to training the participants, and the remaining five weeks to conducting the experiment itself. We thus simulated a five-year program.

The Air Force assigned personnel from SAC, Air Defense Command (ADC), and AMC to man the simulated organizations of the current system. We had a logistics manager for each base and one for each logistics function within AMC. We had some Air Force people and Rand staff members run the proposed system, because that system had to learn and improvise as experience unfolded. Other members of the LSL operated the experimental controls. All in all, the experiment was a complex undertaking because we had to hold to a difficult and demanding schedule in order to keep the entire staff working continually on the experiment.

An uncertain element in the process was the IBM 702 computer, which had to operate on time and with which we continually ran

into programming errors, as well as computer malfunctions. The computer was in the main building of Rand; the laboratory was in a building several blocks away. The laboratory would produce a set of inputs in the form of punch cards, which then had to be driven to the Rand building, where the computer runs were made and sheets of output were printed. Then they were driven back to the laboratory. Clearly, this kind of routine gave rise to much tension, and even some frustration, whenever one part or another of the tightly linked system broke down.

With much effort, the experiment was brought to a successful conclusion. The system proposed by Rand proved significantly better than the current system over the five-year simulated period of the experiment, costing less and producing fewer stockouts.

There were significant differences in the managements that evolved with the two systems. The current system tended to stock more parts at first, the amount of stock being driven primarily by expected demand rates. The new system had a complicated series of provisioning and procurement rules, one for what were called high-value items, the other for low-value items. The procurement and ordering rules of the new system took price and other supply costs into account in addition to expected demand.

The new system also followed a data processing center concept, so that procurement, repair, and distribution were determined, day by day, by the data and computations at the center. The current system was only periodically and incompletely aware of its data and supply status. The supply manager in that system, lacking up-to-date knowledge of the situation, had to keep calling the bases to check their status.

Many other differences between the two systems helped the research staff understand how the real world would change if the new policies and logistics operating methods were adopted.

When LP-1 ended, several of the Air Force people, including not only the temporary participants in the experiment but also the longer-term technical experts, returned to their home stations. As time passed and the knowledge gained from LP-1 appeared in reports by participants from both Rand and the Air Force, some of the ideas in the new system began to gain acceptance in the real logistics system.

The timing of LP-1 was appropriate because electronic computers were becoming available, and the Air Force was deciding how best to use them in logistics. In addition, the cost of support was increasing as military aircraft became technically more complex, and better methods of determining and allocating logistics resources had to be developed. In effect, the Air Force was finding it necessary to substitute better management for physical resources, such as parts and personnel, to meet the increase in support demands without raising costs drastically.

ICBMs and Logistics

Before the first experiment neared its end, work had already begun in the Logistics Department to plan the second experiment, called — not surprisingly — Laboratory Problem-2 (LP-2). A new team of logistics research people became involved in designing this next experiment with the assistance of the laboratory staff. Combining substantive specialists with laboratory specialists became a characteristic method of operation in every experiment that followed. Both types of expertise were necessary, but, as time passed and the LPs proceeded, each group became knowledgeable about the other's specialty. In effect, the laboratory provided an effective vehicle for promoting interdisciplinary research.

The Air Force was consulted in decisions about the second experiment. With its encouragement, the experiment undertook to study the logistics questions surrounding introduction of intercontinental ballistic missiles into the Air Force. The time was 1957. Both the Atlas and Titan ICBMs were then in development; deployment was planned for about 1960.

The Air Force knew that the support problems posed by ICBMs would be different from the problems associated with aircraft and that advance knowledge about these problems could help in planning, deployment, and operation. These were among the kinds of questions that interested the Air Force:

- One question concerned the operational-support structure for ICBM organizations. It was decided to focus on the missile squadron — which for the Atlas and Titan then comprised 9 missiles — for both operational control and unit support. For reasons of vulnerability, the missiles were physically dispersed into elements of 3, each tied to a control center; the support

center was several miles from each missile silo. The control center could do some maintenance, but major maintenance would be done by the support center. Missile status information was maintained in the control center, and the support center would react to calls from the control center. In addition, the support teams made scheduled visits to the silos for inspection and routine maintenance.

- Another question, especially from a supply standpoint, centered on the size of the missile squadron. There were some indications from all-computer modeling of missile organizational-support structures that a squadron of 9 missiles was too small — even for the Atlas-Titan generation — for a good balance between effectiveness and cost. The point seemed to be that missiles, because of their more static characteristics, make many fewer logistics demands than aircraft and that greater centralization of support for missiles was feasible. Of course, missiles require a high operationally ready rate; so, whenever a missile incurs a failure or needs logistics resources, the system must be able to respond quickly. The question of squadron size was even more important for the next-generation missile, the Minuteman, which was still largely on paper, particularly in its support planning.

The goal of LP-2 generally became one of learning through a man-machine simulation about the support environment associated with ICBMs and the nature of their operations-support tradeoffs. The experimental design simulated two missile squadrons, one consisting of 9 missiles, the other of 36. In contrast to LP-1, which examined a system over five years of simulated time, the focus of LP-2 was on the minute-to-minute changes in the operational support status of the missiles in the squadron. We constructed a “paper missile” that was a hybrid of the Atlas and Titan — and, in addition, a ground support structure of silos, control centers, etc. — because we realized that these facilities would pose problems as severe as those of keeping the missiles themselves on alert.

The 9-missile squadron drew as much as possible upon whatever Air Force plans were available. The 36-missile squadron was designed by the Rand staff, with Air Force assistance. This included settling on supply inventories, maintenance manning, and maintenance policies for keeping the missiles on alert. One difficult technical problem was development of a “failure model” that would cause missiles to fail, either randomly or as a consequence of stresses placed on them by simulated countdowns, training activities, inspections, etc.

The Air Force assigned missile and logistics specialists from Vandenberg Air Force Base and the Oklahoma Air Logistics Center to the LP-2 laboratory to provide technical knowledge about missile operation and logistics and to be exposed to the new missile logistics world, albeit in a simulated setting. Each of the two simulated missile squadrons included a squadron commander, a missile maintenance officer, and a supply officer. Clerical staff members were assigned to help with the paperwork, since the process was so new and undeveloped that programming a computer was impractical. There were no minis or micros in those days. The missile itself, its ground support structure, and the logistics operations resulting from decisions made in the squadron were handled by the laboratory staff, to represent the environment faced by the squadron logistics management.

A great deal was learned in the experiment. For one thing, based on the inputs, the simulation gave the experimenter a picture of the orders of alert rates that could be expected from such missiles. Also, the logistics management information system that evolved differed from that used with aircraft. A significant maintenance policy, called “opportunistic scheduling,” was developed. Because of the concentration on keeping missiles on alert, there was some reluctance to take missiles off alert for scheduled maintenance, a maintenance policy that had long been standard with aircraft. Instead, the strategy that developed was to let missile failures dictate as much as possible when “scheduled” maintenance would actually be performed, that is, while unexpected failures were being dealt with. Such an opportunistic policy set a premium on quick response, on current knowledge of the status and availability of maintenance resources, and on efficient scheduling methods.

Many insights into missile support and its interactions with operations were developed in LP-2. Here again, the knowledge gained from experiment was carried back to the Air Force by the personnel who had participated in both the design and the operation. At the conclusion of LP-2, an evaluation was made by the Air Force Research and Development Command to determine whether an in-house laboratory should be created within that command to help with support planning for Minuteman. Although the evaluation report included a recommendation to that effect, the opportunity was passed up for a variety of reasons, including the preference of the research and development community for relying on its own “systems engineering” approach to weapon system planning.

AMC Management: WSM Versus ICM

In 1959, while LP-2 was still underway, planning had begun on Laboratory Problem-3 (LP-3). The genesis of LP-3 was an active debate whether the Air Materiel Command (AMC), which provided depot-level support to the air bases as well as continuing overall logistics planning and resource acquisition to the entire Air Force, should be organized along weapon system management (WSM) or inventory class management (ICM) lines.

Arguments in favor of WSM were that the resources assigned to a weapon system — say, one of strategic importance — could then be readily protected from diversion to a less important system. In addition, the logistics managers responsible for a given weapon system could readily determine how well it was doing by matching the readiness of their own weapon system with the resources assigned to it. Such an approach might turn out to be more costly, however, because it would tie up resources with one weapon system while another system might have a more immediate need for the same resources. It was recognized that many resources, especially spare parts, are common to more than one weapon system and that they can be shared if policy permits.

The ICM system took advantage of the efficiency afforded by using common parts but found it more difficult to deal with several weapon systems at a time. There seemed to be a tradeoff between supplying the logistics system with more resources for spares to permit the simpler WSM structure, and getting by with fewer resources by substituting the more complex type of ICM management.

There were other ancillary interests in LP-3. For one thing, much research had been done in Rand and elsewhere on spare parts requirements, distribution policy, and depot maintenance management. Plans were already underway within AMC to replace the outmoded management system with a more modern one, in terms of both management techniques and computer support. More integration across requirements, distribution, and repair was desired for the improved system. It was hoped that the LSL would be able to develop the characteristics of such a system in the course of the WSM-versus-ICM evaluation.

Another idea being considered at the time was speeding the logistics process to shorten the pipelines and reduce the investment

in them. Computers were to help in the speed-up. Shorter logistics pipeline times would also reduce the uncertainty of support by shortening the time for which demand would have to be forecast.

The management problem assigned to LP-3 for study in the laboratory was, therefore, evaluation of the relative cost and effectiveness of the WSM and ICM structures in supporting a logistics system consisting of two inventory classes and two weapon systems. Each inventory class comprised 32 high-value items common to both weapon systems. The 64 items reflected the range of characteristics that can affect significantly the cost and effectiveness of support, including demand rates, repair flow times, repair man-hours, procurement lead times, and the accuracy of initial predictions of demand rates. Each weapon system had nine bases: Weapon System-1 (WS-1) had six low-precedence and three high-precedence bases, and Weapon System-2 (WS-2) had six high-precedence and three low-precedence bases.

All 32 line items could be repaired at the specialized repair activity (SRA), and all therefore competed for the limited number of depot man-hours available. In addition, every repair decision involved interaction — through the requirements computation — with decisions made in distribution and procurement.

It was assumed that each experimental run started when the weapon systems had neared the end of their phase-in and that each run represented 8 months of simulated operation. In all, 15 runs were made, based on different assumptions about the conditions prevailing in the support environment. In particular, the runs differed with respect to the amount of available repair capacity and the amount of responsiveness assumed for the management system.

Analysis of the results indicates, first, that the two organizational arrangements did about equally well in adjusting to the conditions and stresses occurring during the runs. Second, policies and procedures used for allocation — assigning available serviceable inventories to the weapon systems and available repair capacity to repair of unserviceable items — worked as desired. Both management structures provided balanced and differential support. Finally, the responsiveness characterizing each management system had a significant effect on its performance in support of the weapon systems. Some quantitative indication was obtained of the amount of responsiveness desired in distribution and repair from a cost-effectiveness standpoint.

The lack of a significant difference in performance between WSM and ICM support was surprising. What seemed to happen in the course of the experiment was that — permitting both management structures to function rationally — no extreme versions of either the WSM or the ICM could be accepted. Instead, as the experiment progressed and each organizational structure had to contend with the stresses placed upon it, such as sudden budget cuts or sudden increases in the flying-hour program, each management system was modified. As a result, the two structures tended toward a median representation. In effect, in terms of more current organizational terminology, a matrix form of management seemed best: that is, either the WSM structure or the ICM structure received more or less emphasis as logistics needs unfolded, and it became the function of the management information system to deal with each structure according to circumstances.

Another interesting insight had to do with information response time. Efforts were made to assess both the cost and the effectiveness of different response times, particularly as represented by the freshness of the inventory data used in the parts repair computations for the SRA and the frequency with which those computations were done.

The parts repair calculation involved a large data organization and computation job for AMC. It also dealt with a critical capability at AMC, that of depot repair. It was felt that laboratory analysis of this major responsibility, with its heavy computational demands, would provide a useful means of sizing and characterizing the kinds of computers AMC should have.

The reception of the LP-3 results by the Air Force and even by the Office of the Secretary of Defense was very positive because 1961-62, when LP-3 was going on, was a period in which high-level study was being done on how to use computers in the Department of Defense logistics systems. The experiment seemed to offer much useful information to help in the design and development of computer-based logistics management systems.

Management of Base-Level Maintenance

After the considerable laboratory effort that had been expended on the logistics management system of AFLC, as well as on spare parts management, the Air Force wanted to use LSL to study a very

different logistics area — management of base-level maintenance. Though management of missile maintenance had been analyzed in LP-2, there was general realization that aircraft, with their more dynamic flying characteristics, posed wholly different problems of maintenance. In addition, the newer aircraft types were becoming technologically more complex and therefore harder to maintain.

In 1962, management of base-level maintenance was still a largely manual process; little use was made of computers. Members of the Rand staff had designed systems for collecting data about aircraft maintenance, had drawn up rules for scheduling maintenance and maintenance data displays, and had developed computer models for studying the relation between maintenance manpower resources and both aircraft readiness and downtime.

Interest now turned to putting all this research together to “design” a modern system of maintenance management control in the laboratory. The operational setting for this work was to be a B-52-wing/KC-135-tanker squadron. The unit aircraft were assigned a series of operational training and crew training flying programs. With these programs came requirements for aircraft maintenance. A key organization for managing maintenance activity is called “maintenance control.” It selects the aircraft that are to satisfy the flying program and assigns the maintenance resources that are to be used to repair the aircraft and prepare them for flight.

Laboratory Problem-4 (LP-4) concentrated on the management activities of maintenance control. It was divided into two phases. The first was devoted to obtaining a benchmark representation in the laboratory that would, we hoped, yield maintenance management results similar to those in the real-world system. The benchmark simulation was run for three weeks in the laboratory and compared with data from real-world B-52/KC-35 bases. The laboratory results agreed with the real-world experience, and the experimenters felt they had a benchmark system into which policy changes could be introduced to determine how such changes might affect the performance and cost of the real-world system. The realism of these results was confirmed by the SAC personnel who visited the laboratory to observe and evaluate the simulation.

Given a good benchmark, the next phase of the experiment, designated B+1, was concerned with devising and evaluating changes in the current maintenance management system, changes

that could be implemented in a fairly short time, perhaps a year. A number of innovative changes — such as dispatching rules for assigning maintenance personnel to aircraft requiring service or maintenance — were tested in B+1. The objective was to increase aircraft availability by minimizing turnaround time in maintenance.

Considerable work was also done on the analysis of base-level maintenance data and of ways to collect and portray the data by means of automated maintenance-information systems. The man-machine laboratory studies were combined with all-computer simulations to convey a better understanding of how to use different planning and management tools in dealing with the complex management problems of maintaining aircraft at a base.

LP-4 proved to be a highly useful experiment in many respects. It used the laboratory in a very different way from previous LPs. They had been based on considerable research, including cost-effectiveness analysis, all-computer models, and field observations. Their experiments had begun with a priori research hypotheses that were to be tested in the “more realistic” laboratory setting. The laboratory results were intended to result in a more reliable estimate of how these proposed policies and techniques would function in the real world. LP-4, by contrast, started with a small amount of prior research on hand because the only method available for studying how humans could use information systems effectively in decision making was in the laboratory itself. The designers of LP-4 had to use the laboratory to understand the maintenance management problem and, with this understanding, to design improved methods of scheduling, analysis, data collection, and processing.

The problem of base-level maintenance management was well suited to this evolutionary approach because in the mid-1960s the real-world system operated almost entirely in a manual mode, with little automation available. Simulating a manual system fitted in with the desires of the LP-4 staff for flexibility and simplicity of operation. Speed of operation was not essential.

Since, moreover, only maintenance control was being simulated, there was no need for a large group of people. However, as specific parts of the maintenance control system — especially job control and some aspects of scheduling and data generation — became well understood, automation was used to help speed the process of examining many alternative scheduling rules and display formats.

At the time (circa 1964), fortunately, independent consoles and terminals, tied to mainframe computers, were becoming available; the analysts could therefore use the computer on line to study rules in the laboratory.

LP-4 continued over a number of years in on-and-off fashion. When there were specific problems, the laboratory was set up to look into them; otherwise, it was kept on the shelf. The physical facilities were kept on standby, and the staff concerned with LP-4 continued with research in maintenance management. The Air Force was interested in the early findings of LP-4 and encouraged further testing and evaluation of the findings at an Air Force base. (One base that was used intensively was Richards-Gabaur, near Kansas City, Mo.) The LP-4 staff had the advantage of working in both the laboratory and the real world.

LP-4 results became even more useful with the growing involvement of the U.S. in Vietnam. The Air Force had suddenly shifted from a peacetime level of operations, calling for less than one sortie per aircraft per day, to a much more active combat role, in which doubling of the one-sortie-per-day rate — and even more — was the object. The Air Force turned to the Rand work on scheduling and control of maintenance operations that had been developed in LP-4. Field tests were run in Thailand to determine how to increase sortie capability without large increases in resources, especially maintenance manning. Rand staff members were assigned to Thai bases to help design and conduct the exercises and to bring to the tests the lessons learned in LP-4.

Working to change the normal habits of a large human organization, such as an aircraft wing in a combat environment, turned out to be far more complicated than had been expected. Human motivations and incentives were deeply involved. Such factors as combat tours, exposure to enemy action, and command prerogatives confounded the relatively straightforward objectives of the field tests. A great deal of useful knowledge, obtained during the late 1960s from the Vietnam experience, has since been used in improving maintenance management.

With the onset of Vietnam and the involvement of the LP-4 staff in that theater, the existence of the LSL became less important. By the late 1960s, it was no longer a viable or identifiable activity within Rand.

The LSL in Summation

The laboratory had enjoyed a life of about 10 years. Its prominence was greatest during the first 5 years, when it drew a great deal of attention in Rand, the Air Force, and academia. It was a unique institution that could function on the scale initially demanded of it, only because a sponsor, the Air Force, was willing to provide the necessary financial resources.

As a recipient of this financial support, however, the LSL was subject to continuing, critical review. It became more applications-oriented. Furthermore, as the American economy slowed and defense priorities shifted in response to the growing demands of the Vietnam War, resources available for research dwindled and the LSL became increasingly vulnerable to termination.

No other organization has tried to create a man-machine laboratory on the scale of the LSL, though there have been laboratories of narrower scope; some of them were devoted largely to training and education at universities, such as Berkeley and the Wharton School.

The basic problem of how to combine men and computers into effective management entities is still with us. Decision support systems are modern-day offshoots of what was attempted in the LSL. Production control systems, with their scheduling rules, resource allocation methods, etc., are another associated modern-day function.

In summary, given its time and place, the LSL fulfilled a highly useful function. It provided a good transition between the logistics researcher and the logistics operator. It helped to accelerate the transfer of sound, feasible findings to the real world. It brought the real world and the research center closer together. And it provided a good setting for studying decision making and information usage on large logistics systems. To conclude, the laboratory was an attention-getting device that helped to promote the importance and challenge of logistics.

INVENTORY AND SUPPLY RESEARCH

This is a classic topic in logistics. When I arrived at Rand in 1954, it seemed most useful to begin by trying to understand the nature of spare parts demand. We were fortunate in that there was a special demand collection system at two Air Force bases — MacDill and March — which had B-47s. Data there were unique in the way they reflected demand. For one thing, the data reported not only issue of parts to aircraft, but also occasions when a demand existed but the part was not immediately available for issue. Heretofore, demand and issue had been treated interchangeably. Given the nature of spare parts demand, errors must result when stockage policy and computing requirements are based on demand data without distinction between satisfied and unsatisfied demand.

Characterization of Demand

Low average demand rates are characteristic of a large proportion of all aircraft parts. In a year, we found no demand at all for as many as a third of the spare parts available at the bases we studied; perhaps this was true of all bases. For three-fourths of the parts, demand was so light as to be unreliable as a basis for forecasting demand.

Demand for most spare parts also tends to be erratic. Even if the demand rate for a part is known for some past period, the demand during a similar period in the future cannot be predicted with accuracy. Many parts, moreover, were low in unit cost. Of all line items in the Worldwide Stock Balance and Consumption Report of the Air Force for 1952-53, in fact, 42 percent were issued fewer than 10 times a year and cost less than \$10 apiece. Slow-moving, low-cost parts accounted for a small fraction of the total dollar value of issues, but, because they were numerous and often essential to the aircraft, they constituted a significant logistics problem. The situation is the same today.

The significance of these demand findings for inventory policy was great because the conventional terminology then used in describing the inventory stockage policy was “days of supply.” We believed the term had originated in situations when consumption or usage was fairly regular over time. This would be the case with

food for humans or animals, with ammunition in sustained operations, or with gasoline in a continuing campaign.

With aircraft spares, however, demands are typically irregular, erratic, and unpredictable. To reduce parts shortages to a reasonably low level, it is not enough to forecast (and apply) average demand rates. The standard, rather, should be the probabilities that various demands will occur.

Based on this concept, efforts were made to describe these probabilities by means of classic probability distributions. To verify the accuracy of such descriptions, statistical distributions were fitted to the actual demand data on individual parts, insofar as the data permitted. Such distributions as the Poisson, compound Poisson, and lognormal were used for these purposes. Eventually, most people settled on the Poisson as the distribution of choice because it fit a large fraction of the items that could be tested and was the simplest to use mathematically.

Because the parameter of the Poisson represents average demand, and it was recognized that an average estimate does not necessarily predict the correct parameter, a further refinement was introduced in the demand estimation process. This involved use of the so-called “prior distribution,” which — again, largely for mathematical convenience, but also with some statistical basis — was the gamma distribution. When the Poisson and the prior gamma distributions are used in combination, the result is the negative binomial probability distribution as the underlying model for representing spare parts demand. This is the conventional probability model used today, but the research that originally proposed using it was done in 1954.

Recognition that demand is governed by a probability distribution led to development of inventory theory that took probabilities explicitly into account. At the beginning, both analytic techniques and computer simulations were used to analyze inventory policy. The first computer simulation at Rand was of a single base with a single part whose characteristics were varied. Costs were applied to the data to treat inventory holding and ordering, as well as costs of stockout. It was learned that cheaper items could be ordered most economically in batches.

The complications involved in stocking low-demand items came to be realized, especially when there were rules setting some minimum number of demands in a specified period as justification

for stocking an item. Matching actual demand data to those rules showed that relatively few items would ever be stocked on the basis of these rules alone.

Relatively complicated analytic formulations for setting optimum stockage and ordering rules were established during this early period, but they were never applied successfully because of the difficult computations required. Later, as the analytic theory became well established, some of the formulations, such as the Wilson Lot Size formula, could be applied practically.

Base-Depot Simulation Model

To understand the relationship between stockage at bases and depots and their respective ordering policies, we also experimented with a base-depot simulation model. At the time, in 1955, there was no multi-echelon theory; simulation was the only quantitative method that was both feasible and available. We could simulate a single depot supporting several individual bases, the depot itself being supplied by a factory. We could also simulate both recoverable (reparable) and nonrecoverable (not reparable) types of items.

Inventory problems and supply have always occupied a central position in the logistics scheme of things at Rand, emphasis varying between empirical studies and theory. Both have been essential to reality in the theory.

Base Stockage Model

The first more modern advance in stockage policy on a systems level occurred about 1965 with the development of the so-called "base stockage model." This model is designed to handle high-value or expensive items. Accordingly, it is built around the (S-1,S) inventory policy. This means that any time an item is issued from supply, an order for a replacement is placed immediately with the next echelon, which supplies it after a time lag. The base itself has some repair capability, which means that it has to order only a fraction of its demands from the depot.

An important aspect of this model is that it deals with base stockage as a systems problem. The objective is to minimize the number of base stockouts for a given investment in inventory over the range of items that can be demanded at the base. Thus, the

optimal policy produces an S-value (stock level) for each item. Since the policy takes the price of each item into account and is trying to use the available budget most effectively, the stockage policy tends to spend relatively less on the more expensive items. This policy was tested with real-world data from several Air Force bases, first in a paper test and later in a live field test in which the base stocks were set to conform to the base stockage policy. In all the tests, the model results proved far superior to those of the Air Force policy then in effect. That policy treated each item separately; it did not take the prices of individual items into account.

At the time, there was no doubt in the minds of the researchers that they had provided the Air Force with a significantly better policy. Yet it was hard to induce the Air Force to commit itself to implementation. It is not easy to explain why this was so, given the obvious gains that could be realized. Some of the explanation could be that we were dealing with a large bureaucracy in which authority was so diffused that locating the right decisionmaker was not readily possible, even if such a person existed. It is not easy to introduce a change in one part of a large system without disturbing other parts, and this effect is hard to foresee and estimate. This uncertainty adds to the resistance to change.

Rand cannot be faulted for the effort it put into trying to gain Air Force acceptance and implementation. We gave many presentations to key managers. We wrote nontechnical reports, explaining the concepts and payoff to the Air Force. We went into great detail about the changes that would be required. We added specific advances to the theory, such as use of the so-called Bayesian technique, to give a better real-world result and make it easier to use judgment in setting demand rates.

Despite all these efforts, implementation of the base stockage model was never widespread, though Air Force managers showed greater understanding of what needed doing, and there was continued support for further Rand work in the area.

Rand realized that the base stockage model took into account only a portion of the total supply system and that this could be an important reason for the Air Force's reluctance to implement only the base stockage part. Optimizing the stocks at bases provides only a modest payoff, since it generally takes the assets within the Air Force as a given.

A more important issue is to determine the minimum investment the Air Force must make in spares to achieve a desired level of supply effectiveness throughout the system. To do this, the model must be a more inclusive representation of the logistics and supply systems. It must be a multi-echelon model, including several bases and a depot.

METRIC

Such a model, known as METRIC, was developed about 1966. It could handle a large number of high-value recoverable items, several bases, and a depot. It could also compute, for a given investment budget level, the number of items to be procured; it then distributed the inventory of each item between the bases and the depot to achieve maximum supply performance for the level of investment budget chosen.

METRIC represents a major step forward in inventory theory in that it describes the real world reasonably well. Even in this respect, however, there are limits. METRIC applies to a single weapon system. It is, moreover, a steady-state model and, for reasons of simplification, considers all bases identical in such characteristics as size, demand rate, and pipeline time.

METRIC was well received in the Air Force. It became a central policy focus for the Advanced Logistics System (ALS), the program instituted by the Air Force to modernize its logistics operations by introducing new procedures, computers, and communications. At the same time, the Air Force introduced its own, simplified version of METRIC into its requirements and procurement system for recoverable-type items.

At the time (about 1970), the F-15 aircraft was under development. A decision was made to apply METRIC to its provisioning process. Obviously, this is a challenging application because there is always much more uncertainty about the demand rates for parts before an aircraft is introduced. METRIC is formulated as a steady-state model, which means that it works best with stabilized demand rates.

Another recognized problem with using METRIC on the F-15 was that the modular system of line-replaceable units (LRUs), which are composed of shop-replaceable units (SRUs), had been introduced into the engineering design of engines and avionics. There was a

need to modify METRIC to reflect this design concept. Under it, an LRU is removed from the aircraft and taken into the base repair shop, where the failed SRUs are replaced. The failed SRUs are then returned to the depot for repair.

MOD-METRIC

A new model, based on METRIC and containing the LRU and SRU concept, was developed at that time; it is called MOD-METRIC. It was used to guide the provisioning of the F-15. Moreover, because an Air Force officer had developed MOD-METRIC, it was much easier to have the Air Force adopt MOD-METRIC as its own. Use of MOD-METRIC for the F-15 provisioning operation did a great deal to earn acceptance of multi-echelon techniques within the military logistics system. All of the Services and several of the aircraft manufacturers developed their own versions of MOD-METRIC. A multi-echelon researchers and users group was formed to advance this research area and to exchange modeling experience. It has met every six months for the past few years.

Despite the early success of the multi-echelon models in the provisioning phase of a single weapon system, they were not used so quickly to help with the broader problem of annual supply budgets (which involve multiple weapon systems) or with determination of follow-on requirements after provisioning is complete. One reason was that the Advanced Logistics System program ran into many problems and was ultimately canceled, setting back general implementation of both METRIC and MOD-METRIC in the Air Force. Some modifications of standard Air Force techniques were made, to better reflect the marginal analysis technique that underlay the METRIC approach to supply modeling. But experts never thought these minor adjustments fully exploited the value represented in the total METRIC approach.

Introduction of Availability

In the early 1970s, LMI, too, began working with multi-echelon models and developed an ingenious way of treating multiple weapon systems, both computationally and conceptually, in a single modeling system. One major advance by LMI was to introduce the concept of availability. Heretofore, the METRIC-type models had applied

the supply criteria of backorders and stockouts, which are explicit supply measures for individual items but do not measure the readiness of aircraft taken as a whole from the supply standpoint. Under the availability concept, one can speak of the proportion of aircraft that are available for flying because they lack no recoverable parts.

In addition, when considering how to allocate a total spares budget most effectively across a total aircraft program consisting of different bomber, fighter, transport, etc., models, one can set availability rates for each aircraft type and model. In such a determination, the manager has an opportunity to exercise judgment in evaluating alternative budget allocations among aircraft models.

The LMI availability technique involves two steps: First, the parts are ordered in terms of the backorder reduction per dollar of spares investment for each additional unit of each part. In this calculation, account is taken of the most efficient distribution of the part between base and depot. The calculation also considers the inventory on hand or on order. Then, on the basis of the budget or availability levels established for each aircraft type and model, the parts to be procured for each aircraft type are determined.

From this information, either a given budget for each type and model produces the optimum availability, or a given availability for each type and model yields the minimum budget. One pass of the parts data produces the budget and associated availability values for so many combinations that only part of the calculation need be repeated to accommodate changing assumptions about budget or availability levels. This flexibility is important for handling the changing assumptions during a budget cycle.

The technique is sophisticated enough to handle parts common to two or more aircraft models, as well as such multi-indentured items as the LRU-SRU and bit-and-piece structure. Because the model computation relies on the data bases used by the AFLC in its own requirements and budget calculations, there is general consistency between the AFLC and LMI computations. For more than five years, the Logistics Program staff of Headquarters, United States Air Force, has relied on the LMI Aircraft Availability Model. The model is one case of a reasonably complete implementation of multi-echelon inventory theory. It has been subjected to considerable review and validation, and its results have stood up well under scrutiny.

Headquarters, Air Force Logistics Command (Hq. AFLC), is now incorporating methods of accounting for availability into its process for determining spares requirements. The LMI work has been carefully developed and produced over a period of about ten years and will soon be tied into the rest of the supply management process in the Air Force.

Many extensions of the LMI model, including distribution and repair scheduling, could improve supply management further. Although AFLC is clearly in need of more computational capacity in its supply management, the systems methods that would go with new computers count as much in producing better management. Full use of LMI's experience should therefore be made in any modernization of the AFLC system.

DYNAMETRIC

As noted earlier, the METRIC computation and its offshoots are built on steady-state assumptions. But there has been a long-term interest in treating the dynamic features of supply policy. For example, it is recognized that an aircraft program goes through a phase-in over several years and that demands for spares from the logistics system vary over time for several reasons, including the effects of experience on reliability and maintainability, the number of aircraft delivered, and the changing ways in which the aircraft are used.

A major dynamic change that should be handled by a model is the progression from peace to war or other contingency. This calls for higher sortie rates, more widely dispersed operations, and different resource demands, with resulting effects on spares demand and supply. Since the major purpose of the aircraft is to be ready for war, preparation of the supply system for such an eventuality is all-important.

A new model, DYNAMETRIC, has been developed by Rand to deal with some of these dynamic aspects of supply. It is a sophisticated model, and the Air Force has found it useful, but it requires complicated computations, and a simplified formulation is required so that the mathematics can work. DYNAMETRIC is now a one-echelon model, although efforts are being made to bring in the depot echelon. It is also a single-weapon-system model, and its present usefulness in budget calculations is therefore limited. But

DYNAMETRIC does face up to the reality of a dynamic logistics system. Such work needs encouragement and support, particularly to produce practical ways of calculating the supply consequences of dynamic programs and demands.

Low-Cost, Low-Demand Items

Although much effort has been invested in high-value, recoverable-type items, they represent only 5 percent of all the items under supply management. Much less research effort has been expended on nonrecoverable items. Single-item economic-order-quantity (EOQ) policies have been the rule. Of course, the reality of following EOQ rules presents many difficulties. Just as with high-value items, the demand for EOQ items tends to be low. Unit prices are also low. Stocking such parts at levels high enough to avoid excessive administrative costs leads to relatively large inventories at the bases and depot. These items do not show much movement. As a result, many remain in the inventory past their useful lives, arousing criticism, particularly by the auditors.

In addition, because of low demand, the rules often forbid stockage of most low-cost items; when a demand for one of them does arise, the item is not in stock. Because there are so many of these low-cost items, analyses of stockout statistics show them to be the primary troublemakers. The result is a dilemma: On the one hand, such items should not be stocked because of their low demand; on the other, when there is a demand, a part is not available. Furthermore, because there are so many low-demand parts, they are usually the culprits as far as stockouts are concerned.

Aside from the dilemma just posed, there is another feature of low-cost-item management that aggravates the problem. It is the use of stock funds. Stock funds are a device that was brought into logistics to emulate commercial business activities. The stock fund manager acts as a wholesaler; the bases are his customers. He buys in quantity to get economy-of-scale cost breaks. He is measured against a criterion of inventory turnover. The more inventory turns he can make during the year, the more highly he is regarded. But this kind of management for rapid turnover does not square with a situation where satisfaction of demand is all-important because grounding an airplane is so costly in terms of diminished readiness. The stock fund manager who seeks rapid turnover of stock tends to

stock items for which demand is high, but these items represent a relatively small fraction of the items for which there *could* be demand.

Although this problem has been noted before, it has not been handled satisfactorily. Statistics are cited to show that stock fund management is effective, but these statistics measure supply performance rather than aircraft readiness; given the characteristics of spare parts demands, applying these two criteria can lead to very different results.

The kinds of inventory research needed by low-value items have just not been pushed. Rand did limited research on an EOQ policy that treated both supply effectiveness and cost, but it was inadequate for two reasons: It was limited to a single base, and it was not tied to the high-value-item theory. Therefore, though it could be used for setting a base's stocks, it was not part of a comprehensive budget-estimating and stock control system.

Low-value items create special difficulties aside from being numerous. For one thing, such items have a multiplicity of applications; they are not usually specific to a single aircraft type and model. Therefore, the factors influencing their demand patterns are hard to identify. Also, they are used not only at base level to support aircraft maintenance, but also at depot level to repair recoverable items. Research done many years ago on the demand characteristics of low-value items found that the bulk of their demand occurs at the depot, but those findings should be reassessed and studied more carefully. Perhaps the better data and more flexible data-retrieval procedures now available will make such research more practical.

The early work on new supply policies went hand in hand with the recognition that electronic data processing was a technology that would become increasingly available and capable.

Centralized Management

The need for greater inventory control as a starting point for improved supply management carried with it the idea that there should be centralized knowledge, if not control, over assets, especially such costly ones as large, complex components. The possibility of frequent inventory updating, based on transaction reporting from the bases, offered the hope of tighter inventory control. For items

of lower cost, it was thought, a policy of larger stocks and less-frequent orders would compensate for the lack of current knowledge of asset conditions.

The more extreme concepts of centralized inventory control proposed at the time called for a “push” system of supply, under which the inventory control center would determine how many assets would be located at each base and would “push” the assets there, either from the depot or from other bases, without any need for that base to act. The idea was that the central location, by knowing the system-wide demands and the system-wide status of assets, could maximize demand protection.

The center would also have all the historical demand information and future program projections, so that it could compute requirements for the entire system. These requirements would serve as the basis for procurement and repair. To create such knowledge centrally called for a dependable communication system and a responsive data-processing system. Special tests in the field and studies in the LSL showed that an extremely centralized system is not administratively feasible. The variability in the system is so great that trying to maintain the close control required would lead to one of two outcomes: Either supply actions would be excessive, with too many assets tied up in the pipeline, or the supporting activities, such as repair and procurement, would not be able to adjust fast enough to changing circumstances.

Unfortunately, these early lessons were not communicated adequately to the designers of the Advanced Logistics System (ALS), who did set ambitious requirements for the new logistics management system planned for the Air Force of the 1970s. This system called for an excess of centralized control through on-line transaction reporting, large data bases, and on-line communications. Given the size and complexity of the Air Force logistics system and the still-limited capabilities (circa 1970) of electronic data processing, failure was inevitable. The unfortunate result was that any major renovation of the Air Force logistics management system has been stymied for the past 10 years because of the bad experience with ALS.

Many abortive efforts by AFLC to produce acceptable long-range plans for its logistics computer systems have come and gone. One serious obstacle is that AFLC has not been able to specify the kind

of logistics management system it wants for the future. Simple conversion of the present system to more modern computers will help a little but will not lay the foundations for dealing with the long-run needs of logistics. Some new computers have been brought in, but these largely emulate the old system that the Air Force has had since the 1950s.

At present, there is a large-scale effort to make AFLC more responsive to wartime needs. One program that is intended to help is to set up "weapon system control" or "support" centers. These centers would try to assure a high level of combat capability for their weapon systems through good logistics management.

We have already discussed the earlier work, done in LP-3, to compare weapon-system management (WSM) with inventory-class management (ICM) for AFLC. We learned that the capability of both systems depends on having the right management tools and that a system of pure WSM may be impossible to achieve. There are just too many resources common to several weapon systems, including spares, repair capacity, and certainly money. Bottling up such resources for one weapon system while another is short and in risk of losing combat capability is not a feasible arrangement. There must be techniques that look across weapon systems and logistics functions so that resources can, in time, be allocated in ways that will do the most good for the logistics system as a whole.

The great need is for a capability to handle such allocation quickly for close-in time horizons; there is, accordingly, a need for rapid communication, quick updating of status information, and effective methods of short-range forecasting. Undoubtedly, being able to confine one's management attention to a single weapon system simplifies things, but at the risk of overall inefficiency and reduction in combat capability.

AFLC is also embarked on a program that includes both use of new technology, especially communications, and development of new systems; the technology seems intended to ease on-base communication at every depot by extensive wiring and cross-wiring of facilities and functions. The system development work is focused on two major AFLC functions: (1) requirements and (2) stock control and distribution.

The requirements effort, which will help in budget and program management, needs to produce a system that ties together the

fundamental data bases used in requirements management and improved computation techniques. If this effort is successful, a long step will have been taken toward a modernized system of logistics management.

The stock control and distribution system also involves a major development program that enables the management system to have current knowledge of requisitions, assets, and issues. Effective interfaces must be built between these two major functions of requirements and stock control and distribution; if not, the capabilities of one or both will be seriously limited.

Both functions — requirements and stock control and distribution — have important uses in peacetime, in addition to the effect that the quality of their functioning then has on readiness for initial combat. It is difficult to visualize a major role for AFLC in a general-war scenario because of the long lead times required for AFLC action relative to the presumably short duration of such a war. It is this incompatibility between a significant wartime role for AFLC (except for its contribution to initial readiness) and the likely pattern of general war that makes it important for AFLC to have a clearer picture of its mission.

Advent of Advanced Computers

The interesting thing about the Air Force and electronic computers is that its logistics system still depends on computers that were produced in the early 1970s (the so-called “two-and-a-half generation”), while industry has been progressing beyond the fourth (375-type) generation of computers. The advent of minis, micros, and personal computers has opened up a whole new set of issues about the future of the computing systems of the Air Force logistics system. The future of massive computers as the workhorses of management seems more limited now than before.

Capabilities for more decentralized management seem to be available. Whether such capabilities fit into an Air Force logistics system — or, if they do, *where* they do — is a current problem that warrants investigation. Clearly, additional remote terminals are called for in the Air Force computing program, but what capability these terminals should have that will make them behave more like micros should be determined.

The Present State of Research

This account has included a great deal on research into supply management, and it is hard to know where matters stand. But I will try to sum up the situation. Considerable progress has been made since the 1950s. A great deal has been learned about the characteristics of demand for spare parts, and this knowledge has served to point research in specific directions.

A breakthrough was achieved with the development of a systems approach to supply management of recoverable items. This helped to get around the difficulty of attaining a desired level of overall support while dealing with many low-demand items individually.

The development of multi-echelon inventory models for recoverable items represented another breakthrough, since it permitted realistic implementation of the systems approach over a significant part of the supply system. Further extension of the theory to treat the concept of availability was also important in tying supply policy and goals to an operational measure of performance.

The extension of multi-echelon theory to deal with multiple levels of indenture and with common items yielded another important practical improvement. The computational methods now available seem quite efficient; there should be no difficulty in satisfying almost any need for data relating supply performance and budget, for both a given aircraft model and a program consisting of many aircraft models. Present procedures are largely tied to providing data for the budget year. Clearly, there is a need for planning data over the entire program-budget period of five or more years, and lack of such a capability creates problems.

The need for dynamic techniques increases as projections are advanced. In addition, the need for sensitivity testing to deal with greater uncertainties becomes more important. Research into these subjects is still at an early stage in relation to a problem as vexing as that faced by the Air Force.

Furthermore, the necessary linkages between budget planning and program execution should be developed. There is now some willingness to rely on computer modeling for budget estimation, but not to the same degree for such decisions as scheduling spares procurement and repair. Yet, without adequate linkage between these

associated processes, there are bound to be inconsistencies and less-than-optimal results for management.

Some of the reluctance of middle-level supply managers (especially at AFLC) to depend on more computerized methods in the programming phase may reflect their concern over adequacy of data and a consequent need to rely more on local knowledge and experience. And there is no doubt that data problems abound in the supply area. Whenever major difficulties are encountered, as in the recent difficulty with Air Force spares budgets that created so much concern in Congress and DoD, investigation reveals many data deficiencies, such as obsolete prices and inaccurate procurement lead times. No technique, however sophisticated or well formulated, can overcome a poor data base.

Much more work should be done with economic-order-quantity (EOQ) items. Their importance to good supply management has not been given enough attention. In particular, there is need to understand how the present stock fund system affects performance and cost at the weapon-system level. Good multi-echelon models for EOQ items have not been developed, and yet this structure is representative of how the system works. Joint management of EOQ items by the Defense Logistics Agency (DLA) and the Services has led to serious organizational problems. Moreover, the intention of the Office of the Secretary of Defense to withdraw these responsibilities from the Services and centralize management of all EOQ items in DLA has added fuel to the fire.

If recoverable-type items suffer from problems of bad data, the problems with EOQ items must be much worse. For one thing, there are many more EOQ items — probably 25 times as many. For another, the inventory data are updated less frequently for computational use. Furthermore, demand data do not reflect base usage, only depot shipments to bases. This gap can cause many errors in requirements and procurement activity.

In short, much has been accomplished in management of EOQ items — and of supply generally — but more has yet to be done.

HISTORICAL REVIEW

The 22-year span of my Rand affiliation was an exciting period to be in logistics research. One might argue that the field came into its own during the period. Before going on, therefore, to other times and places, I should like to place my Rand experience into historical perspective.

Rand made a few unsuccessful efforts to launch a logistics research program about 1950, but its first sustained effort began in late 1953 with the formation of its Logistics Department. As noted earlier, the department was placed within the Economics Division. Early emphasis was therefore placed on applying economic theory, especially theory of the firm, to logistics. This led to emphasis on micro-economics and highly detailed analysis of logistics functions and activities. The Economics Division was the center of cost-effectiveness analysis within Rand, and some of its concepts made their way into the logistics program, which represented a high degree of innovation at the time.

At first, a good deal of emphasis was placed on supply research, combined with interest in data processing and the use of electronic computers in logistics. Attention was also paid to two other logistics functions — maintenance and transportation.

Maintenance

The maintenance effort first focused on trying to understand how information about the relation between flying and maintenance demands could help in the maintenance management process. Use of maintenance resources had to be tied to measures of operational performance. A major research finding led to a recommendation for improving data collection by including the tail number of the aircraft in maintenance man-hour reports so that researchers could analyze the behavior of individual aircraft in determining how to relate resources to operational capability.

Transportation

The transportation research began with work on macro-type problems. These had to do with air fleet assignments to meet a range of transportation tasks at some minimum total cost. The early work

used linear programming as a technique for determining these fleet assignments. The studies were couched in wartime scenarios, where the initial wartime period imposed a strain on the ability of the transportation system to meet deployment requirements. Researchers later calculated the size, weight, and other characteristics of transport aircraft that would meet those requirements.

In addition, a study was made of the possibility of supplementing military airlift aircraft with civilian transports, using the civilian fleet as a backup to the military, especially during the initial surge in airlift demand. It seemed reasonable to have civilian aircraft on standby for military use, with suitable modifications, because the surge was expected to be fairly brief, and building a military transport fleet for the sole purpose of meeting that surge seemed uneconomical. The issue is still moot, with both proponents and antagonists vocal on the subject of the Civilian Reserve Air Fleet (CRAF) program.

Procurement

The next function introduced into the Rand logistics program was procurement. Since procurement of spares was included in the supply research effort, procurement research focused on the acquisition of major systems. Here again, macro approaches were taken. An examination was made of issues related to the type of economic structure that would be most appropriate for military procurement — for instance, whether items should continue to be procured in the private sector or be produced at government-owned and -operated facilities as an armory system.

A study was also made of contract incentives, such as rewarding contractors who reduce costs below negotiated targets. In addition, coproduction — the arrangement under which foreign firms are licensed to produce U.S. aircraft, for instance — was studied as a prototype for second-sourcing, to increase competition in the production of major systems.

Considerable interest in the entire subject was generated throughout the government.

Manpower

Manpower became a subject of research in the mid-1960s. Logistics is a heavy user of manpower, both military and civilian, and

extension of the Logistics Department program into this area seemed natural. Previous research had concentrated on the demand side of manpower, as in use of men and skills for maintenance; new research focused on the supply side of personnel, including the factors that affect reenlistment and the role of pay in obtaining the right kind of manpower.

Other Subjects of Research

About the same time (around 1965), there was also pressure to extend the logistics program into other substantive areas, such as placing greater emphasis on the combat role of logistics and applying logistics skills and techniques to urban and other civilian activities. This pressure was applied not only to the logistics program, but to Rand as a whole. In part, it represented recognition that Rand's professional staff and its training might contribute to solving other problems that were becoming more important in the United States. Also, Rand itself began to need more support as the cost of its operations increased and artificial constraints were placed on its access to financial support by the Air Force and other DoD elements.

As a result, Rand established relations with the Office of the Secretary of Defense — which was increasingly concerned with policy relating to the North Atlantic Treaty Organization (NATO) and other types of alliances throughout the world — and the Third World. In addition, the Vietnam period had begun, and there was interest in having Rand help deal with the resulting problems. Accordingly, Rand logistics researchers conducted studies associated with logistics concerns in deployment of the Army to Europe in the event of a NATO contingency, protection of aircraft on forward bases to avoid bomb damage, and the proper relation between Army combat divisions and their support units. Studies were also done of ground transportation problems in a combat theater, including ways to operate under attack conditions and, conversely, ways to reduce the enemy's capability to operate in such an environment.

Vietnam

In Vietnam, Rand people were assigned for tours of duty to assist U.S. commands, including the U.S. Embassy. Some of the assistance dealt with policymaking in dealing with both South and North

Vietnam; other assignments dealt with the more pragmatic aspects of management, including more effective use of data and computers to evaluate the combat situation.

In addition, Vietnam served as a real-world laboratory for some of the logistics concepts and techniques that Rand had been developing over many years. Rand had been working on techniques for scheduling and employing maintenance manpower and equipment in ways that would yield higher sortie rates for the same resource levels. Since there were operational demands to achieve more effective use of aircraft, an opportunity was presented to test these Rand approaches. Before, we had been confined to a laboratory with limited opportunity to do field testing; now we could take our techniques into the real world. To do so, several Rand people from the Logistics Department were sent to Vietnam and Thailand. They served as technical advisers and analysts during the various field tests and then returned home to do more detailed evaluations of the test results.

Cooperation in these important projects brought the Rand staff and the Air Force closer in their working relationships. Morale was also heightened among staff members who took a direct part in the Vietnam tests because it provided them with a direct opportunity to contribute to the war effort. On the other hand, the work tended to isolate those people somewhat from the rest of the department, because they were working in another part of the world. To help close the gap, efforts were made to involve the whole staff in the Vietnam situation through frequent status reports from correspondence and telecommunications with staff members overseas. Rand was able to patch into the Air Force telephone lines for short periods and thus had daily communication with its people in Vietnam.

But there were disadvantages in working so closely with the Air Force, aside from the effect on the morale of some members of the Rand staff who were not involved in Vietnam. The reason was that not everyone in the Air Force agreed with the Rand proposals for improving combat capability in Vietnam. Sometimes disagreement translated into lack of cooperation in testing.

One interesting conflict between the Rand approach and real-world policy had to do with the one-year tour of duty required of all the military who were assigned to Vietnam. We were proposing a management system that would raise sortie rates for aircraft and

crews. This meant that the crews would have to fly more sorties during their year-long duty tours and would be exposed that much more to the risks of combat. It would have made more sense to create the proper incentives by defining a tour in terms of the numbers of sorties, so that, by flying sorties more often, the crews could go home sooner. But such a change in sortie policy would have conflicted with a higher-level policy of setting the length of a tour at one year. Reducing the time spent in Vietnam by each crew would have made it necessary to send more crews to Vietnam each year, and this would not have gone well with the general public, especially as the unpopularity of the war increased.

Rand prestige probably suffered a great deal from involvement in Vietnam, but there was little that Rand could do about it. It was obvious to those in Rand during the middle 1960s that DoD wanted Rand to change from an organization devoted to long-range and more basic types of research to a program that would be more applications-oriented and more closely linked to the immediate needs of policymakers. This probably explains why demands were made on Rand to become more involved with the policy needs of OSD. The financial device that helped to accomplish it was the ceiling imposed on the Federal Contract Research Centers (FCRCs).

In the early 1960s, Congress became concerned over the growth of the so-called think tanks (or FCRCs, as they were more technically called). Some of this pressure on Congress came from outside consulting organizations that did not like to compete with such organizations as Rand. To reduce the growth of the FCRCs, Congress had DoD impose dollar ceilings on each; as the inflation of the 1960s worsened, Rand could not afford all its staff members and had to seek other contract support. Initially, the additional support came from OSD, which for a few years was exempt from the ceiling effect. But OSD, too, became subject to Congressional ceilings, and Rand had to go elsewhere for support. As noted earlier, one major effect of the OSD relationship was that Rand had to deal with closer-in policy issues, and this tended to affect the total Rand research environment. For instance, Rand was directed by OSD to establish a field office in Paris to give day-to-day support to the U.S. Mission at NATO.

This change in environment was not directly damaging to the logistics people, since we had always been an applications-oriented group, but it did mean that other parts of Rand on whom we relied

for advanced technical support, such as Mathematics and Computer Science, were less useful to the “new” Rand, and the general quality of Rand work suffered. The change in program also affected Rand’s recruiting because we had stressed the excellence of the working environment and staff to attract bright and achieving people.

Civilian Problems

One of the significant new areas to which Rand turned in the late 1960s was urban and social research. The Logistics Department had done research in 1961-65 for the Ford Foundation on the problems and prospects of urban transportation. The country had now begun to pay greater attention to the problems of the cities, and the Ford Foundation decided to support research in that area.

The Ford Foundation made a grant of a million dollars to Rand to do research on urban transportation. The hope at Ford was that Rand would discover some new technology that would produce cheap and effective urban transportation systems. Of course, such a technological goal was not realistic, and undoubtedly Ford was disappointed that Rand did not produce the cure-all. Rand chose to take a systems approach to the problem, which meant that it had to consider the environment that produced the need for urban transportation, as well as the means of satisfying it. This meant understanding such factors as the effect of an urban transportation system on the uses of the land through which it runs. How does a transportation system affect both the values and the uses of such land? This was the period of increasing suburban sprawl, and it was noted that people who lived in the suburbs needed to get to the city centers to do their work, while people of lower income, such as domestics and some repair people, needed to travel from their lower-cost dwellings in the city center to the suburbs to earn their living. This indicated an inefficient relationship between residence and place of work, as far as transportation was concerned.

There was also the issue of transportation modes. Suburban people seemed to favor the automobile (this was before the Middle East crises and the effects of OPEC) and made demands for adequate highways into the city. Construction of roads also affected land use and was resisted by citizens through whose neighborhoods the roads passed. People (usually the poorer ones) were relocated, and a demand arose to place them in public housing. In short, a broad

range of policies and plans of government at all levels had to be taken into account in studies of urban transportation.

In addition, Rand did a great deal of work on the economics of transportation, trying to develop good cost models for the various modes of urban travel: auto, bus, and rail. It also did work on estimating the dollar value of time lost in travel; this was considered an important tradeoff in choosing among travel modes on the basis of overall system cost. An important book was published by the project: "The Urban Transportation Problem," by J.R. Meyer, J.F. Kain, and M. Wohl.

As the Ford funds ran out, Rand spent its own corporate funds to keep intact the Urban Transportation staff (which was located primarily in the Logistics Department). Studies were undertaken on city planning and on the management system such planning requires. In particular, work was done on the possible uses of new data processing systems in state and city management.

Rand's continuing interest in urban problems matched the growing national concern with urban growth and decay and the resulting increases in crime, deterioration of housing in the city centers, and the growth of welfare rolls and juvenile delinquency. About 1965, some key people of the Ford Foundation, who had dealt with Rand on urban transportation, joined the John V. Lindsay administration of New York City. They wanted to apply the systems analysis techniques that Rand had developed for the Air Force and OSD to New York City's burgeoning problems, and they approached Rand with such a proposal.

The Rand-New York City Institute was formed in 1967 and set up in New York. It was a joint undertaking of Rand and the city, with Rand contracting to provide the staff and the city to supply the financial support. Much of the early staff for the Institute came from the Logistics Department — not only people who had been working on urban research, but also others who had been involved in military logistics. This development caused stresses and strains within Rand on how far we could go without short-changing DoD, our source of support for almost 15 years.

This demand for support of the New York City Institute came at a time when there were demands from other parts of the Air Force for the Logistics Department to provide staff for the newly formed Manpower Group. It was an unstable period in the affairs of Rand

as a whole. A new Rand President had just come into office; he insisted on program diversification between defense and non-defense work. Along with many other organizations, Rand was being constrained in its defense funding as a result of the general public disappointment with the Vietnam War. It needed other support to maintain its staff.

Aside from its background in urban transportation and other urban research, the Logistics Department had brought in a number of young people from universities, with degrees in operations research and management science, which were the new quantitative fields that might contribute techniques and tools for achieving the Lindsay administration's goals of greater efficiency. Such goals placed a great deal of emphasis on obtaining greater output from limited resources in the police, fire, and health departments. Operations research techniques, with their emphasis on quantitative analysis and computers, appeared to offer much promise, and, for the first five years of the Institute, applying them yielded significant payoffs in increased efficiency and performance for the City of New York.

Of course, such results did not occur without some pain and suffering by the Rand staff. New York City was highly union-organized. Recommendations by the Institute to alter work rules, staffing rules, and other management policies led to union resistance; the employees demanded increased pay for increased productivity. Moreover, Rand began to undertake studies of more difficult and complex program areas, such as welfare, housing, and program-budgeting for the city. Difficulty in achieving success in these areas supplied the opponents of Mayor Lindsay with political capital, when he ran in 1972 for another term. He was defeated by Comptroller Abe Beame. Beame had always opposed the Rand-New York City Institute and he had fought its establishment from the beginning. He thought it wrong to rely on outside staff for developing city policy. With the advent of the Beame administration in 1973 the Rand-New York City Institute was closed.

In the meantime, the Logistics Department was involved in so varied a program that the Rand management renamed it the Management Science Department (MSD), to identify its work program more accurately. Logistics then became a "program" within the program-discipline structure of matrix management that Rand adopted at the time. However, most of the staff for the Logistics Program came from the MSD, with others provided by the Information Sciences

Department. Later, the name of MSD was changed to the System Sciences Department.

The Rand Logistics Program continued until about 1977, when it ran into difficulty with Congress. Congress had earlier terminated the Air Force's ambitious, highly centralized ALS program for using computers in logistics. The Air Force then started another program, called Project MAX, in which Rand did some consulting. Congress, interpreting Project MAX as a way to circumvent prohibition of ALS, cut off the project and wrote into the annual appropriation that no funds assigned to Rand were to be used for logistics research.

Fortunately, Rand's Air Force projects have enabled it to maintain a logistics research capability by concentrating on the operational implications of logistics.

LOGISTICS CAREER ENVIRONMENT

It is worth commenting on the logistics study environment that has evolved over the past 30 years. The area with which I am familiar is represented by Rand and the universities. Rand has a well established reputation in logistics research. Early on, we sought acceptance and recognition of the technical quality of our work through academic channels. Our staff was largely recruited from universities, primarily the top ones, beginning with Harvard and Berkeley, where our focus was on hiring economists for the Logistics Department. We sought new Ph.Ds or graduate students who were in the thesis stage, offering them a chance to use some staff time for completing their degrees. We also brought in summer consultants, either young graduate students or faculty members who were well regarded in academic circles and at Rand, with the intention of offering them jobs at Rand when they had earned their graduate degrees.

The professional societies of primary interest at the time were the American Economic Association and the Econometric Society. As the Operations Research Society of America (ORSA) and The Institute of Management Science (TIMS) became more prominent and as the academic world began to offer graduate degrees in operations research and systems analysis (mid-1965), Rand Logistics turned increasingly to these two societies for both staffing and professional support. We sent articles to their journals and presented papers at their major meetings, and some of our people were elected to high office.

In addition to the academically oriented logistics staff of Rand, there were many logistics people in the military and industry. In neither the military nor industry, however, was the logistics function considered top-drawer, compared with either operations or R&D.

Originally, entering logistics in the military or industry required no special academic qualifications; people became experts in the field by experience. Dropouts or washouts from operations or R&D were often assigned to logistics, a practice that helped sustain the relatively low esteem in which logistics was held. It was regarded as a paperwork kind of job, with little opportunity for creativity.

Emphasis was on new technology, and little attention was paid to logistics in critical budget decisions. That was left for the time when logistics was really needed, which was usually too late, with

resultant inefficiencies and losses in effectiveness, as occurred during the wars in Korea and Vietnam. The logistics people, however, knew how important their activities were to the military mission.

In the 1970s, industry began to appreciate the role of logistics in its programs. DoD was showing concern about the reliability and maintainability of weapon systems, and, although the issue was generally a matter of engineering, logistics was also involved because the military people who expressed these concerns came from logistics management. Until then, industry could take advantage of lapses in reliability by undertaking design changes or improvements to correct the defects, thereby acquiring additional contracts. But now emphasis was being placed on doing the job correctly from the beginning. Progress with reliability in the space programs showed that this could be done, although at some cost.

As the logistics function within industry became better recognized — sometimes it was called “field engineering” or “support engineering” — the people involved sought professional recognition. One approach was to create a special society recognizing their function — the Society of Logistics Engineers (SOLE). Industry and government personnel joined. They developed standards — including testing and credited experience — for professional recognition as a Logistics Engineer. They held periodic meetings to report on current activities, and they published a journal, *Logistics Spectrum*. Contact was made with the engineering departments of some universities, particularly those looking for new fields in which to develop recognition.

Over time, SOLE has grown to several thousand members. As some members achieved status in their profession, they were called upon more in the accreditation and recognition process. From my personal though limited observations, it seems that SOLE functions more for enhancement of the profession than for technical exchange, although the latter benefit has been receiving more emphasis. Recognition of good research is being promoted.

It is difficult and perhaps controversial to try to contrast the two approaches — the more academic one represented by TIMS/ORSA and the more experiential one represented by SOLE. The former seems much more sharply focused on development and improvement of knowledge; the latter seems more concerned with gaining

recognition and professional status for the logistics function and with fostering the government-industry bond that is virtually essential to military logistics. The time may be drawing close when the two groups — TIMS/ORSA and SOLE — should arrange joint activities in logistics. Perhaps they can learn from each other. They differ so much in emphasis and backgrounds that a stronger capability may emerge from cross-communication.

JOINT LOGISTICS REVIEW BOARD (JLRB)

In early 1969 I was approached by Lieutenant General Lewis Mundell, who asked me to become research director of the Joint Logistics Review Board (JLRB). President Nixon and Defense Secretary Laird had authorized a broad review of logistics as it was functioning during the Vietnam War. The study was to be directed by a board of top military officers from each of the Services. The chairman of the board was General Frank Besson; the other four members were of three-star rank. About 100 other senior officers, mainly of the rank of major or higher, were brought to the Board to help conduct the review. They were divided about equally among the three major Services, in addition to a representation of Marines.

The purpose of the Board was to do an in-depth review of Vietnam logistics from 1965 on. This meant covering all the logistics functions, including planning, management, supply, maintenance, transportation, procurement, communications, manpower, ammunition, petroleum, and construction. A single team of four or five people, representing the different Services, was assigned to each subject. Each of the general officers on the Board supervised several teams. I reported to General Besson and had the assistance of a Civil Service civilian plus a secretary. A contract was also let to Booz, Allen & Hamilton to provide additional technical services; the contract was assigned to me for supervision. Although there was an overall structure to the study and a study organization, there still was a collegial atmosphere, which permitted me to interact with all the groups on a reasonably informal basis.

The study began with a series of general briefings by OSD, the Joint Chiefs of Staff, and the Services, covering the history, organization, planning, accomplishments, problems, etc. of logistics in Vietnam. All members of the Board and staff were invited. In addition, the Board members visited several spots in the Pacific. The trip took about ten days, and I accompanied them. Our itinerary included the headquarters of the various Services in Hawaii, in addition to Clark Air Force Base and the Naval base at Subic Bay, as well as Yokosuka and other points in Japan, Korea, and Okinawa, the base from which B-52 bombers were operating at the time. Entry to Vietnam being restricted, the meetings with senior logistics personnel on the spot were held by senior members of the Board.

The trip was useful because it helped to put into context the geographic and political situation in that part of the world. Later, the senior Board members made a trip to England and Europe to learn about the effect of the Vietnam War on NATO; resources were being moved from Europe to Vietnam to meet the increasing demand for support, especially in ammunition and transport.

The Board was given a year to complete its study. It made periodic reports to Barry J. Shillito, who was then Assistant Secretary of Defense (Installations and Logistics). Each team gathered a great deal of basic information about its functional area, through visits, briefings, and personal experience. A number of the people had served earlier in Vietnam or Thailand.

Periodically, each team made a status report to the senior Board. Since the senior Board members took a personal interest and felt personally responsible for the teams they supervised, the presentations were carefully rehearsed before they reached the Board. My responsibility during this period was to write up the Board notes and comments on each briefing that came before it. In preparation for this assignment and to provide context and guidance for the final report of the Board, my staff prepared a broad outline and structure of what the final report would contain, as far as substantive coverage was concerned. We kept referring to the outline to be sure the teams were being comprehensive enough and responsive to the terms of reference of the directive issued by the Secretary of Defense.

As time passed, it became increasingly clear to me just how the study should proceed, that systematic analysis as such would not emerge from this Board study. Essentially, each team would present historical material about what had happened in its functional area — usually broken down by Service — and then draw a series of conclusions and recommendations. Much of the presentation was descriptive, with little quantitative analysis included to justify the conclusions and recommendations. Perhaps there was not enough time for in-depth analysis, but it was also true that the officers assigned were largely specialists in management and operations — doers rather than analysts.

This characteristic of the staff members made it difficult for me to inject analysis into the Board study. Their concern was largely with the nuts and bolts of the functional operations and with what they called “lessons learned.” Therefore, as time passed, we focused

our efforts on ensuring the internal logic of the presentations, the clarity of discussion, and the consistency of results across the different functional areas. I found that one useful role we could fill was to point out relationships among findings or recommendations in different parts of the study. For instance, a shortage in supply operations could be explained by a delay in transportation delivery. However, this interaction was not easy to achieve because each functional group tended to be parochial about what it considered its turf.

General Besson, as Chairman, took responsibility for arranging all the major briefings given to the Board by outside agencies and for structuring the final study. He also acted as the major point of contact and spokesman for the Board with senior groups, such as OSD and the JCS. He was a thoughtful and quiet man, who was nevertheless effective in getting the work done through his ability to inspire loyalty.

Although the Board was supposed to look at the problems of the Vietnam War through the eyes of the President and the Secretary of Defense, parochial Service interests tended to persist. It was clear, for example, that, from the standpoint of the Office of the Secretary of Defense, there should have been interest in greater support for unified or joint logistics in part or in whole in various logistics functions. At the time — in the late 1960s — major efforts were still underway to unify and integrate such functions as depot maintenance, transportation, and procurement. Though the Defense Supply Agency (DSA) was almost 10 years old, the Services were still fighting its existence. Major efforts to keep the DSA from establishing overseas centers or depots were continuing, even though the General Services Administration had such centers.

The blue ribbon panel, appointed by President Johnson, had recommended greater integration of logistics, but the JLRB showed no interest in supporting something that the Services opposed. My impression was that the senior Board members maintained close links with the senior logistics officers in their Service headquarters and sought guidance — or, at least, reactions — from them on proposed or potential policy recommendations of the Board. The JLRB members also sought to protect their Services from critical findings in the report. There had been major problems with ammunition production and delivery, contracting, and interservicing during

the Vietnam War, but such criticisms were either well camouflaged or omitted entirely.

There was no one on the Board to represent DoD as a whole, and so there was no proponent of a DoD view of logistics in the Vietnam War. The general opinion was that operations and logistics had to be tightly linked. Therefore, if the operations were Service-specific, the same had to be true of logistics, not only in the theater but in the continental United States as well. Consequently, the Board did not support any of the proposals being considered, such as making depot maintenance a DoD function and integrating all the transportation agencies into a single Defense-wide transportation agency. Though the Board did give some support to the idea of a single manager for ammunition, each Service member sought to stipulate exceptions that would exempt his Service from single management control.

The Board finished its study in 15 months. It published more than 20 volumes plus a single executive summary that contained the major findings (lessons learned) and recommendations. Briefings were given all the way up to the President. The study received general approval within DoD, and a monitoring system was established to follow up on OSD, JCS, and Service reactions to the study and their plans to carry out the recommendations. Quarterly reports of progress were to be made to the Secretary of Defense. This effort continued for better than a year, and many of the detailed recommendations were accepted — or, more probably, had already been implemented because they had come from the Services themselves as part of the Board “research.” Therefore, there could be a good feeling within DoD that the study had done some good.

Certainly, the study represented a healthy development. It focused attention within DoD on logistics, which had not always received its just share of attention. It also captured in written form important lessons learned from the Vietnam experience, and it provided a vehicle to make sure that at least some of these lessons had really been learned and benefits thereby derived through constructive changes in the system.

In a large sense, however, the study tended to affirm the current way of doing logistics business and therefore to forgo a major opportunity to examine the area in a fundamental way and lay the groundwork for major improvements. Accordingly, no effort was

made to go out and bring into the Board all the years of research effort that had been expended on better policies and systems. Perhaps I was delinquent in not performing this function for the Board, but it would have meant swimming upstream because I am convinced that the Board members came to this study with the intention of maintaining the status quo insofar as they could. It turns out that this is largely what they did.

LOGISTICS MANAGEMENT INSTITUTE (LMI)

After completing my year (1974-75) as Visiting Professor of Management Science at MIT's Sloan School, I returned to Rand. As is clear from the section, "Historical Review," the organization had, by this time, gone through a number of organizational and substantive changes that made logistics less attractive as a field of study there. Other subjects were being given more emphasis, and I felt it would be more comfortable to continue my logistics work elsewhere.

While I was still at MIT, LMI had invited me to be a part-time consultant. The experiences there during that year convinced me that if I left Rand, LMI would be a good place to go to. Therefore, after 22 years at Rand, I joined LMI in February 1976. I realized that moving from the West Coast to the East Coast would create some personal difficulties, but we had lived in Washington 20 years before, knew the environment, and still had many friends there. Even so, we decided to treat the move as a tentative one, renting out our California home and renting a house in Bethesda for ourselves.

Before venturing into the technical aspects of my LMI career, I should note that from a personal and career standpoint, the move to LMI turned out to be a sound decision. It permitted me to stay in a field that I had been in for more than 25 years, and that made the transition to a new organization a lot easier. From the time I joined LMI, it seemed to keep getting better as a technical organization. Though I am sure the timing is purely coincidental, it nevertheless made me feel satisfied about being at LMI, since I had come from an organization that valued technical skills highly, perhaps overly so.

Assessment of the State of DoD Logistics

My first assignment at LMI was to develop a set of management indicators for the Assistant Secretary of Defense (Installations and Logistics) that would signal the state of health of DoD logistics. He had been receiving a quarterly report of selected logistics measures³

³ Called the Logistics Performance Evaluation and Measurement System.

by the Services, but it did not meet his needs. In our meetings, he referred to what he needed as a “chairman of the board report.”

We began by putting together a general description of the logistics systems of each of the Services, covering such major features as organization, functions, and management reporting systems. We thought this spadework would help us get our arms around the DoD logistics systems while providing the OSD management with more comprehensive information than was available anywhere else at the time. In addition, we picked up all the Service and DoD indicators we could find, describing them briefly in an appendix to the main report.

Once we had completed what became volume 1 of a three-volume study and tried to find what we needed in the management indicators already available, we realized that what we were being asked to find did not exist. We also realized that we had to put the Secretary’s request in a perspective or structure that would guide our future work.

For this purpose, we visualized the Secretary of Defense as chairman or chief executive officer of a corporate conglomerate consisting principally of three operating corporations, the three Military Departments. In this structure, OSD, the JCS, and the Unified and Specified Commands are units in the office of the chairman. We also referred to OSD as the policy level of management and the Departments (and Services) as the operational level. Of course, this is an oversimplified representation of the real-world DoD, but, for study purposes, we thought it gave us a basis for proceeding.

If we do regard OSD as the policy management level in DoD, its primary functions are planning, guidance, resource allocation, and review of DoD performance. The Services, as the operating agencies, execute the plans and programs dictated by the Secretary within the resources allocated to them and report to the Secretary on the progress made.

The two levels of management — policy and operational — are distinctly different in role and function. For our purposes, we had to understand the differences, the relationships between them, and the implications of policy management. We realized that the Secretary must deal with a much more aggregate view of DoD than the Services, that the information provided him has to be put into a form different from that used by the Services. It is not enough to

simply assemble the Service data and combine them into DoD totals. If Service interactions and differences are not accounted for, OSD loses information, not only in the inputs but — even more important — in the broad outputs that the Secretary requires to assess military capability overall.

From our research, we found that most of the published experience and knowledge had been concentrated on operational management, not only in DoD but in civilian activities as well. We had to undertake a pioneering study. This meant producing more structural underpinning for it. To understand the policy level of management, we felt it necessary to study the operational level first, to see what could be accomplished with the approach we were taking. We chose the Air Force for that exploration.

We built a number of broad structures that described the relationship between Air Force outputs, such as readiness and flying activity, and the functions and resources needed by the Air Force to produce those outputs. These structures simply showed graphically how the outputs and inputs were interrelated, using nodes, arcs, and arrows. They are called “graphs” in the systems analysis literature.

These graphs were then used to guide our data search to obtain the reported outputs and inputs. We tried to work with data aggregated as much as possible, as would be appropriate for top-level management, either in the Air Force or in OSD. We were impressed with the ready availability of the data we sought. Using this information and analyzing it in accordance with our structure, we learned a great deal about the Air Force logistics system. We tried to get at least five years’ worth of recent historical data so that we could study the trends in the management indicators that were developed from our structure.

The resulting description and analysis were published as volume 2 of the study, which became known as “A Macro Analysis of DoD Logistics Systems.” The volume comprised analyses of: the operational status and activity rates of weapon systems; gross supply performance in broad aggregates of supply, including engines, exchangeables, and the stock-funded supply; aircraft maintenance; transportation and airlift; and installations and housing.

It was the first time in 30 years of contact with Air Force logistics that I had seen such a comprehensive description and analysis of the system. It was well received within the Air Force (especially at

Headquarters, AFLC, which reviewed the results carefully and reacted positively to the study results). We found that our structure and data analysis produced a useful set of indicators covering much of the Air Force logistics system. Our data pointed up both positive and negative trends in its logistics system that we were sure the Service itself did not realize.

Given the good results with our Air Force work, we moved on to apply the approach to the OSD or policy level. As a preliminary part of this effort, we surveyed all conceivable quantitative techniques that could serve our purpose. We found that the hierarchical analysis approach developed by Professor Thomas Saaty contained the essentials of what we needed. By this means, a complex subject can be decomposed through a series of hierarchical levels and broken down into a series of manageable elements for analysis.

Saaty provides a technique for introducing quantitative analysis into the method through pairwise comparisons at every level of the hierarchy and assignment of priorities by means of eigenvectors. Repetition of the process with priority factors obtained at each level ultimately yields a priority weighting of the entire structure. Although the method necessarily involves a great deal of subjectivity, the hope is that the subjectivity is introduced where it can be used appropriately, and the objective computations that follow reflect the subjective implications accurately.

In our illustrative use of hierarchical logistics analysis, we began with a top hierarchy defining the DoD objectives, followed by a categorization of DoD functions, including logistics, at the next level. From then on, at succeeding levels, we concentrated on the logistics portion of the hierarchy, defining its policy objectives, the logistics operational functions required to achieve those objectives, and then the objectives of the operational functions. Now, by having a series of logistics operational objectives, we could define the operational activities needed to meet these objectives, in terms of both outputs and inputs. These operational logistics outputs and inputs provided the basis for describing or developing an information system that made it possible to measure them and thus be able to evaluate the progress of the system toward the logistics objectives.

Here we could go back to volume 2 and use the experience gained in developing it to establish how well the existing information system

could produce the outputs and inputs, which for our purposes were basically the management indicators sought in our study. Given these management indicators and using the eigenvalue weights given by the hierarchical analysis, we could then trace back through the hierarchy to determine the contributions made by the operational logistics system to fulfill the DoD logistics objectives and thus the overall contribution to the military security system.

We presented this research in volume 3, entitling it “Framework for Policy Level Logistics Management.” By then, we had devoted more than two years to the study. We felt that the work had generally produced what the Assistant Secretary was groping for when he had asked for a “chairman of the board report.” We also knew that we had ventured into virgin territory of management science. As is usual in such long-range efforts, the original proponents of the study were no longer in DoD, and the interests of the new top managers were on other matters.

However, we documented all our work systematically and made many presentations, within both DoD and the research community; if our ideas were worthwhile and useful, therefore, they contributed to the development of this challenging and difficult subject. Our work was given the recognition of publication in a number of important journals and books. We were also able to draw on it in later studies at LMI.

This study in macro analysis represented my first assignment at LMI, and I was deeply impressed with the support we enjoyed, within both DoD and LMI. We were given time, adequate resources, and internal DoD support to proceed with the study. We were able to reach relatively high levels within DoD to present our briefings as we completed major phases of the study. And we made many contacts that served us in good stead in later work.

I believe that LMI benefited from being identified with the work. It indicated that LMI could undertake independent effort of some complexity. This was important at that stage of LMI’s program because there had been some concern, both within and outside LMI, that its program at the time was too often composed of less important tasks that OSD did not have the staff or time to undertake, rather than tasks appropriate to an impartial research and consulting organization.

Review of Support for New Weapon Systems

My second assignment was somewhat related to the first. At least, I could see a thread between the two. It involved the problem of reviewing initial support plans for new weapon systems to determine their adequacy for providing good levels of readiness. I assumed that we were dealing at an early point in weapon system development, when there are only highly aggregate and approximate estimates of such key factors as reliability, maintainability, and activity.

We began our work with a survey of Service models, to find tools that could meet our need. We found nothing useful except for some work that had been done earlier at LMI; it took a highly detailed model and stripped it down to essentials. That model concentrated on supply availability. We wanted one that would treat both maintenance and supply. The report of our survey evoked so much interest, when it was presented at a professional conference, that we were asked to prepare it for journal publication.⁴

At the same time, we continued developing our highly aggregate model, in which we treated the whole aircraft as a single component. We used our earlier work on Air Force indicators to get data for the model and test it for goodness of fit. The results were not bad, and we felt it would be useful to carry the work to the next lower level of indenture, that is, to represent the aircraft as composed of major subsystems. We proceeded to collect the requisite data (which was not easy) and to create a data base management system for manipulating the large amount of data that resulted. However, we could not carry the effort to final solution because the sponsor decided not to support the work any further.

I was disappointed by this decision because I thought there was a real void in this support management area. Others in LMI were carrying on a similar effort but at a much more detailed level, which meant that, in terms of weapon system development, their models and data bases could be used only at a much later stage in the acquisition process. We wanted to be able to use our model to set realistic goals at the subsystem level in terms of performance and cost that would guide the development process and permit monitoring through subsystem testing. I am pleased to report that the process

⁴ Published as "Assessment of Aircraft Logistics Planning Models," by M. A. Geisler and B. L. Murrin, in OMEGA (International Journal of Management Science), 1981.

we visualized is being carried out by Headquarters, AFLC, on the Air Force's Advanced Tactical Fighter, although I do not see a model there that will permit an overall assessment of the factors at the weapon system level.

Assessment of Methods for Measuring Readiness

My next project continued on the same path; that is, OSD needed a management process for assessing Service performance. The area of special concern was readiness. In the belief that DoD tended to divert funds from support of existing weapon systems to pay for new systems whose costs had escalated, Congress directed DoD to submit an annual report on the readiness of major forces and weapon systems.

The Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics) felt that this Congressional requirement imposed an obligation upon him to try to "manage" readiness. He asked LMI to help him devise a way. Here again, we can see a relationship to my earlier LMI work. Our efforts in analyzing the macromanagement needs of OSD had led to OSD's interest in having us extend our approach to readiness.

We recognized that readiness is a complex concept, having both broad-ranging and detailed elements. We also found in our review of past and ongoing efforts with readiness that there was not even agreement on a definition of readiness. We, therefore, began our effort to understand readiness by working on the definition. We found we could take the hierarchical-analysis approach because readiness operates at a series of levels that reflect different aggregations of management and resources. We wanted to decompose readiness in a fashion that would fit it into the management and resource structure of DoD.

Our major conceptual effort, however, focused on producing a "total" readiness management concept, that is, a framework that could be used to structure the knowledge and effort needed for managing readiness so that a "state-of-the-art" system would ultimately be produced for the purpose. We visualized the structure as including a management organization, information flows, and a process that would permit OSD to assess and guide readiness progress quantitatively through goal-setting, resource-allocation, and

monitoring mechanisms. We defined such a general structure in our report and illustrated some of its elements by drawing on the work we had done in DoD macromanagement. We also proposed that some initial administrative steps be taken in the form of a DoD Instruction that would direct the Services to proceed with their own development of readiness management systems toward production of a total-DoD system.

Here again, we were provided with an opportunity to brief senior people within DoD. We hoped for encouragement from our sponsor to continue developing and testing our readiness-management concept, and we did write a few more draft reports on the basis of this follow-up work. But it was clear that what we were proposing did not meet with agreement from the sponsor. We are not sure why he did not approve and encourage us to continue with the work because, to this day, readiness is accorded policy and resource priority in both Congress and OSD. I have not seen as good a structure on which to base a large-scale effort in this area as we proposed back in 1980. My impression is that the present effort on readiness is piecemeal, although some good products are developed from time to time.

Evaluation of LMI's Service to Sponsors

Upon my return from summer vacation in the fall of 1980, I was asked by the LMI Board of Trustees to undertake a survey of DoD sponsors of LMI work to help the Board determine the extent of DoD's satisfaction with the quality of the LMI program. In doing the survey, I met with about 20 deputy assistant secretaries and directors in OSD and in the primary Air Force sponsor.

My overall assessment, based on this survey, was that LMI's work met with general favor by the sponsors. They liked both the staff's performance on work assignments and its cooperative attitude in accepting those assignments in the first place. They found us responsive and knowledgeable. As to successes, LMI's Aircraft Availability Model appeared to be the most solid contribution we had made in the past few years. We were also scoring some successes in the information systems area, particularly in helping to computerize the Defense Energy Information System (DEIS).

At the time, we were also writing guides for both the Services and OSD. These guides, covering such areas as interservice support

agreements, foreign military assistance, and management of weapon system support, were intended to formalize procedures and processes that had developed on an ad hoc basis.

My survey gave LMI a generally clean bill of health, with some indication that we were expanding to other DoD functional areas, including energy, manpower, and foreign military assistance.

Guide to Management of Multinational Programs

Coincidentally, after I completed my survey for the LMI Board, I was asked to help on a guide that LMI had agreed to prepare in collaboration with the Defense Systems Management College (DSMC). This was a Guide for the Management of Multinational Programs.

The original plan was to design a number of chapters, each dealing with a separate subject in the area, and then to enlist authors — mainly professors and consultants — for each chapter. The role of LMI and DSMC was to review and edit the chapters for such qualities as substance and consistency, prepare glossaries, bibliographies, and appendices, and then publish the report as a DoD guide.

Unfortunately, some of the authors were either slow about producing their drafts or not writing them at all. Preparation of the guide dragged on. It finally became necessary for John Fargher of DSMC and me to write some of the chapters. To be sure that the guide would receive DoD approval, a review committee representing the Services and OSD was formed to read and comment on every chapter. Review led to redrafting; eventually, the guide was available in final form.

Although the Director of Defense Research and Engineering had been the chief and active sponsor of the guide, it was decided for administrative reasons — to encourage the Services to accept the guide — to have it issued under the sponsorship of the Joint Logistics Commanders. Several thousand copies of the Multinational Program Guide were published.

The guide evoked excellent reactions. Among other results, it became a text for the DSMC Program Management Course. Although such a guide can quickly get out of date and a recommendation was made that steps be taken to keep it current, no such action has yet been taken. The successful contribution of LMI led to further

work in the multinational area — in particular, codification of the policies and procedures for U.S. representatives to follow in formulating memoranda of agreement for cooperating with other countries in international programs.

Installations Management

My next assignment at LMI was a new study area — installations management. Despite my many years in logistics, the subject was new to me. Installations management is typically related to base operations support (BOS), and BOS, which is considered an overhead area, has not been considered significant for weapon system support. Moreover, installations management has often been treated as a political subject because much of it is concerned with the opening and closing of bases, a subject in which Congress takes an active interest.

But BOS costs had risen dramatically over the past few years because they are driven by manpower costs and manpower costs had experienced severe inflation. Despite the much higher BOS budgets, the bases continued to deteriorate. OSD was looking for drastic action to deal with the problem and asked LMI to help.

One concept being considered by OSD at the time was to create the position of DoD Installations Manager. This officer would act as landlord for all DoD bases and would collect rent from the Services that used them. The idea was to make the cost of using bases explicit, to force the Services to give greater consideration to alternative ways of spending their budgets, choosing between bases and presumably more critical purposes, such as weapon system support.

The proposed management system amounted to setting up an industrial fund for installations, and so I was asked to survey and evaluate past experience with stock funds and industrial funds. In attempts to create buyer-seller relationships like those in civilian commercial activity, such funds had been used for many years in supply, maintenance, and transportation. My assessment of the experience was that such funds did not achieve their purpose because it is impossible to establish within a single general organization — DoD — a real buyer-and-seller relationship. The market is not real, and the price setting process is artificial.

Another issue was BOS productivity. The U.S. Government has had a long-term program to measure and increase productivity. One important area for improvement is overhead accounts, such as BOS. As part of our study, we looked for organizations in the private sector that promote productivity in their overhead activities. We found that IBM has an interesting approach to the problem, and in meetings with members of the IBM staff we obtained descriptions of the technique they followed. We also learned that there were mixed opinions within IBM about the usefulness of the technique, because it included ranking the different plants with similar overhead activities by means of performance data. The effort to compare plants led to internal bickering and challenges to comparability.

In visits to a number of major corporations, we found a variety of systems for handling overhead costs and productivity. No company was fully satisfied with its system, and, in any event, it was not clear to us that the systems were adaptable to the DoD environment. Though it was evident that the overhead charges imposed by top management on operating organizations for such costs as office and plant rent were arbitrary, they could influence a profit-oriented operation to be more rational about its demands for space.

The project produced a number of interesting proposals for consideration of OSD and the Services. However, installations management is necessarily such a politically sensitive area within the Services that obtaining purely objective evaluations of proposals is difficult. Such factors as timing, management prerogatives, and overall budget condition tend to dominate the decision-making process.

Modeling of Information and Support Activity

My last project with LMI began just as I was about to start my vacation in the summer of 1982. The Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics) requested LMI assistance in deciding whether a logistics modeling center would enable his directorates to use mathematical models. Further, he worried about reluctance to use the models, as well as inefficiency and duplication if expert help was not conveniently available.

I undertook the assessment jointly with the Assistant Secretary's Director of ADP and Research. My first job was to interview about

twenty-five other directors in the office. When I found them in general support of creating a modeling center, we laid out its form, staff, and functions. The Director of ADP and Research named it the Modeling Information and Support Activity (MISA). He called upon LMI for a plan for housing and staffing MISA and managing its operations.

We submitted a plan with an estimated annual cost of \$300,000. When only \$100,000 was made available as part of LMI's FY 1984 program, the plan had to be changed. We shelved the MISA concept and agreed to concentrate our modeling support on the readiness project, a high-priority effort under the Deputy Assistant Secretary for Program Integration.

Readiness models were used to analyze and evaluate Military Department programs and budgets. They proved useful and started to attract the interest of staffs in other functions — supply management, for example. But the MISA idea stayed, undisturbed, on the shelf.

HIGHLIGHTS

It seems useful to end this personal history by trying to identify the highlights that I have observed in my logistics career. Of course, such a list is necessarily personal, subjective, and limited by my own experience.

1. I believe the progress made in inventory theory and the implementation of that theory represents one of the most important advances in logistics in the past 35 years. That advance has permitted a reduction in inventory investment, while increasing force readiness.

2. The advances in inventory theory are part of general progress in mathematical and computer modeling in logistics. Such modeling has improved demand forecasting, resource allocation, and other decision making and has led to the formulation and application of criteria for assessing the performance of logistics systems and functions.

3. This progress in theory and modeling has been advanced by improvements in computers, programming languages, and data bases. All of them have benefited from more technically capable logisticians who have been trained to use and interpret scientific advances in management techniques.

4. Technical progress has benefited other functional areas in logistics, improving, for example, the scheduling of maintenance tasks, assignments of maintenance manpower, and use of network models in transportation.

5. Procurement has benefited from the work done in incentive contracting, the rejection of cost-plus contracts except in special circumstances, and the effort to achieve greater competition through dual production and better advertising. Efforts to modernize defense production resources through private investment by means of carefully devised profit incentives represent another rational step forward.

6. Progress in engineering has had fundamental implications for logistics. The advances in electronics through modular design, large integrated circuits, miniaturization, and associated improvements in reliability and maintainability are now reducing support costs and raising readiness.

7. Finally, the overall advances in weapon system planning and management, with increased emphasis on support and cost management, are resulting in sophisticated weapon systems that do not have the cost overruns of years past.

My intent in presenting these highlights in staccato form is not to gloss over the many problems, difficulties, and even frustrations that continue in each logistics function and program. They exist and they do limit progress, but they do not stop it. It is comforting to me to see, in the end, the greater recognition and emphasis that logistics has achieved in defense management.

BIOGRAPHICAL NOTES

Murray A. Geisler

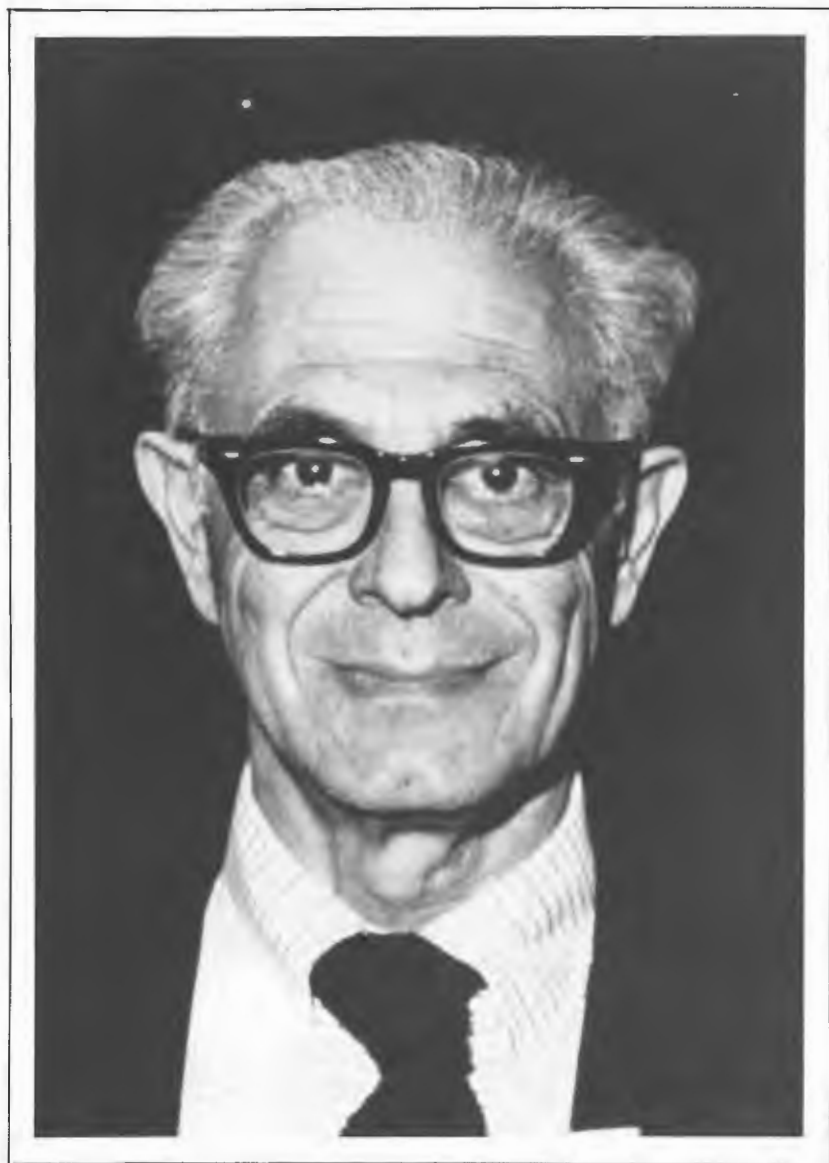
When Murray A. Geisler died of leukemia at the age of 68, he left behind an outstanding reputation as a pioneer in logistics research.

Dr. Geisler's distinguished career included operations analysis and logistics research for the Air Force, supervision of logistics research for the Rand Corporation, and service as senior logistician of the Logistics Management Institute. He was active in professional societies and publications, as president of The Institute of Management Sciences (TIMS), editor of logistics papers for *Management Science*, the journal of TIMS, and member of the editorial Board of the *Naval Research Logistics Quarterly*. He also served as visiting professor of operations management at MIT's Sloan School of Management.

He received an undergraduate degree in mathematics for the College of the City of New York, a master's degree in economics and statistics from Columbia University, and a doctorate in statistics from Stanford University.

Dr. Geisler retired as a colonel in the U.S. Air Force Reserve.

He is survived by his wife, Margaret; a son, Gary Evan; and a daughter, Lauren Sonia.



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