PROJECT RAND

LABORATORY EVALUATION OF SUPPLY AND PROCUREMENT POLICIES

The First Experiment of the
Logistics Systems Laboratory

(Unclassified Version)

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SUMMARY

The first large-scale logistics simulation, Laboratory Problem 1 (LP-1), performed in RAND's Logistics Systems Laboratory was an experiment to evaluate a set of proposed supply policies and procedures. These policies and procedures were put to work in a simulated Air Force environment and were compared with another set of policies based on Air Force logistics practices that were more or less current in mid-1956.

Traditional Air Force policies were represented by Logistics System 1 (LS-1), which formed the standard for comparison. The proposed policies were embodied in Logistics System 2 (LS-2) and consisted of (1) deferred procurement of Cost Category I (Hi-Valu) airframe spare parts with interim support from contractor buffer stocks during the phase-in of the weapon system; (2) procurement, stockage, and distribution of medium-value (Cost Category II) and low-value (Cost Category III) items according to so-called economical formulas that sought to minimize supply costs on the basis of such factors as estimated demand rates, stockout costs, reorder costs, holding costs, and prices of the items; and (3) automatic distribution and resupply of Category II and III items by a data-processing center that kept centralized records and computed order levels and order quantities according to the economical formulas.

To put the proposed policies to a reasonable test, a substantial slice of logistics reality was simulated in the Laboratory. Each system consisted of an Air Materiel Area (AMA) with its associated depot supply and repair activities, ten Air Defense Command (ADC) bases operating simulated aircraft of fighter-interceptor type, a factory, a transportation system, and a communications network. The systems were embedded in a framework comprising Headquarters USAF, Headquarters ADC, and Headquarters AMC. Both systems employed the weapon-system-manager technique in providing airframe spares support.

The usual events that trigger or constrain logistics activity were simulated. Each system had to deal with these events within its prescribed set

second simulated year; the other, a year later. These wars were designed to test the ability of each system to operate without central supply or maintenance support under the stress of enemy attacks. Because of its wider distribution of assets, LS-2 lost less of its inventory in the simulated destruction of the storage site and other depot facilities. In both wars, LS-2 obtained a better combat-ready rate; and in both wars, the LS-2 Category II and III policies performed better than the LS-1 policies. The LS-2 Hi-Valu policies, on the other hand, gave a poorer performance than the LS-1 policies. In the first war, which occurred relatively early in the weapon phase-in, thorough-going deferral of procurement was responsible for the poorer performance; in the second, poor distribution of Hi-Valu stocks and inadequate provisioning of one particular part were the contributing factors.

Other results of the experiment appeared in the form of object lessons; i.e., gaps and errors were discovered and corrected, both in the experimental design and in the several new policies being tested in LS-2. In general, the simulation of logistics activity in the Laboratory proved useful and successful as an adjunct to logistics research.

of logistics policies and procedures. At the appropriate times, provisioning conferences were held, spares purchased, bases activated, flying-hour programs laid down, and sorties flown. The characteristic logistics facts ensued: parts failures were experienced, scheduled and unscheduled maintenance was called for, Technical Order compliances appeared, programs were changed, and bases were phased out. The systems first operated in a peacetime situation and were then exposed to the stress of war. The simulated time span of the whole experiment was approximately $3\frac{1}{2}$ years of weapon-system life, but the real time that elapsed was about 3 months. Data were collected and analyzed to determine which system met the common flight program more effectively and with the smaller dollar expenditure. Wherever possible, the effects of the proposed policies under test were isolated for analysis.

The LS-2 Cost Category II and III policies produced about twice the effectiveness for approximately the same spares expenditures. The LS-2 Hi-Valu policies suffered initially from unrealistically high demand rates that had crept undetected into the simulation. When more realistic demands were used, LS-2 gave almost the same Hi-Valu performance as LS-1, at roughly half the spares costs. Finally, centralized data processing was of obvious assistance to LS-2 in obtaining greater effectiveness, although the benefits could not be isolated quantitatively from those of the proposed supply policies. In the last analysis, the potentialities of the LS-2 policies seemed clearly superior to the traditional practices.

The impact of the LS-2 policies and procedures in certain areas was also assessed. In general, LS-2 made fewer shipments of materiel than LS-1, indicating that its stock was better distributed and controlled, but LS-2 burdened the factory-procurement complex more heavily than LS-1. LS-2 also made greater use of premium modes of transportation. Its policies shifted warehousing costs away from the storage site and to the base level. Initial base stockage was substantially less for LS-2 in all cost categories except Category III, where the proposed policy called for liberal stockage of the cheaper items. No clear conclusion could be drawn about the impact of the proposed policies on maintenance activities because the maintenance simulation was not sufficiently realistic.

Two wars were simulated in the experiment. One occurred early in the

FOREWORD

The Logistics Systems Laboratory is a collective research venture of the RAND Logistics Department. Many Air Force and RAND people cooperated in the design, plan, and execution of its first major experiment. Appendix IX, page 95, lists all the personnel who were associated with the experiment. The Air Materiel Command sent 24 people to the Laboratory, 12 of them for 1 year's extended duty. Some of the AMC people served as technical consultants; others, along with 31 enlisted men and civilians from the Air Defense Command and Air Training Command, were participants in the experiment.

This final report has been prepared by Dr. R. M. Rauner. Among the other members of the Laboratory staff who played leading parts in the final exercise were Mr. H. A. Blanchard, who was in charge of the mechanics of the simulation; Dr. W. W. Haythorn, who designed and supervised the day-to-day floor operation; Dr. R. S. Lincoln, who handled the observation activities; Dr. H. M. Markowitz, who was responsible for the final modeling of simulated activities; and Dr. R. W. Winestone, who directed the analysis of results.

In addition to the present comprehensive report, several RAND research memoranda will be published to provide detailed information and data on the experiment. The manuals used by the participants will also be available; they contain procedures that can be adapted to the Air Force logistics system. In addition, in order to provide further insight into the method and purpose of a large-scale logistics simulation, the Air Force has produced a movie about the experiment called *Project SIMULOG*.

The first Laboratory venture produced many lessons and results that are now being applied to new Laboratory studies.

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GLOSSARY

ADC—Air Defense Command
AFB—Air Force Base
AMA—Air Materiel Area
AMC—Air Materiel Command
ANFE—Aircraft Not Fully Equipped
AOCM—Aircraft Out of Commission for Maintenance
AOCP—Aircraft Out of Commission for Parts
ARDC—Air Research and Development Command
ASI—Amended shipping instruction
ATC—Air Training Command
DM—Distribution Manager
DPC—Data-processing center
ERC—Expendability-Repair-Cost (code)
GOR—General Operational Requirement
HVO—Hi-Valu Control Officer
IAM—Inventory Accounting, Monetary (Report)
IRAN—Inspect and Repair As Necessary
LEWS—Logistics Early Warning System
LP-1—Laboratory Problem 1
LSL—Logistics Systems Laboratory
LS-1—Logistics System 1
LS-2—Logistics System 2
MCO—Material Control Officer
MDAP—Mutual Defense Assistance Program
MRS—Master Repair Schedule
ORI—Operation Readiness Inspection
PPB—Provisioning Parts Breakdown
PRD—Parts Repair Depot
SAC—Strategic Air Command
SRL—Systems Research Laboratory
TOC—Technical Order compliance
WSM—Weapon System Manager
WSSM—Weapon System Supply Manager

CHAPTER 1

INTRODUCTION

The Air Force has to live with limited resources. Its responsibilities for the nation's defense and safety are virtually unlimited. Limited resources and unlimited responsibilities stand little chance of ever being completely reconciled, but improvements in the use of resources may reduce the gap and increase the Air Force's capabilities. The "General Operational Requirement for a Materiel Data-handling Support System"¹ called for such improvements. It announced the Air Force's intention to supplant the present materiel data-handling system by a faster, more efficient, and more economical system based on the use of modern high-speed data-processing equipment.

While a better materiel data-handling system was obviously desirable, GOR No. 144 recognized that Air Force combat readiness and effectiveness implied uninterrupted logistics support. This, in turn, made it necessary to retain the conventional materiel data-handling system until the capabilities of the proposed system were fully proved. As one possible means of obtaining this proof, the Project RAND Logistics Systems Laboratory (LSL) was established on October 1, 1956, on the initiative of Headquarters USAF, Headquarters ARDC, and Headquarters AMC. The objectives of the Laboratory, as stated in its enabling special Air Force Regulation No. 20-8, were as follows:

- a. To study the organizational and functional interactions of the logistics system.
- b. To test and evaluate alternative data flow systems, logistics policies, and organizational and management structures, and to explore required equipment characteristics in order to facilitate selection of the most efficient, complete, and integrated systems.

¹GOR No. 144, Department of the Air Force, Headquarters, United States Air Force Directorate of Requirements, February 3, 1956.

- c. To compare and evaluate partial and entire logistics system changes in a laboratory environment representing realistic peace and war situations prior to service testing.
- d. To provide an opportunity for Air Force personnel to broaden their logistics perspectives by participating in logistics research work.
- e. To explore the man-machine relationships in data processing.
- f. To develop the steps necessary to accomplish a transition to an advanced system utilizing modern automatic data-processing equipment with minimum disruption to operations.

Prior to 1956, The RAND Corporation had acquired some experience with laboratory studies. The Systems Research Laboratory (SRL), set up in 1952 to consider air-defense problems, had developed techniques and applications that subsequently became part of the regular training program for Air Defense Direction Centers. Some of the personnel, methodology, and physical facilities of the earlier SRL were available for use in the Logistics Systems Laboratory.

The first major experiment of LSL was entitled "Laboratory Problem 1." To prepare for it, two preliminary exercises, PROLOG I² and PROLOG II,³ were run in October–November, 1956, and January–February, 1957. Their purpose was to develop Laboratory simulation techniques, to train Laboratory personnel in the use of such techniques, to discover gaps and errors in the original Laboratory design and methodology, and, more generally, to prepare for LP-1. On August 5, 1957, the major experiment began. Its complement consisted of some 16 Laboratory staff members, 14 Air Force long-term consultants, about 40 ADC, AMC, and ATC (Air Training Command) short-term personnel to staff the simulated organizations during the run, and about 20 clerks. Nine RAND Numerical Analysis Department programmers were on hand for preparation of the computer codes.

²*First Tooling-up Exercise for Logistics Systems Laboratory (October–November, 1956)*, Logistics Systems Laboratory, The RAND Corporation, Research Memorandum RM-1924 (ASTIA No. AD 133010), July 1, 1957.

³*Second Tooling-up Exercise of Logistics Systems Laboratory (January–February, 1957)*, Logistics Systems Laboratory, The RAND Corporation, Research Memorandum RM-1961 (ASTIA No. AD 133036), August 19, 1957.

CHAPTER 2

PURPOSE AND DESIGN OF LP-1

PURPOSE OF LP-1

The main purpose of LP-1 was to observe within a laboratory environment the operation of two sets of logistics policies. In collaboration with the Air Force, the RAND Logistics Department had produced several policies and procedures that promised gains in logistics efficiency, but the level of abstraction required to carry out these studies left open the question of their feasibility in the real world. It was only natural, therefore, to look to the Logistics Systems Laboratory as a means of providing RAND and the Air Force with greater insight into the practicability of the proposed policies and procedures. In such a Laboratory the facilities and techniques could be developed to compare, under controlled conditions, the experience of two logistics systems designed to reflect the Air Force's current, and RAND's proposed, policies.

Three of the Logistics Department's proposals were drawn upon to provide the foundation for a proposed logistics system, or LS-2 as it was called in the experiment. This system contained, first, automatic resupply of Cost Category II and III items to bases by means of a data-processing center (DPC) modeled after the RAND ELECTRO LOGS concept.¹ This DPC, equipped with an IBM 704 computer plus various ancillary punch-card and sorting machines, automatically computed stock-level objectives and reorder points for all supply-using activities. It also automatically ordered routine resupply when required, and maintained up-to-date records of spares, issues, and serviceable balances for the various activities. This information was available both currently and on demand by the activity managers.

¹M. A. Geisler and J. A. Postley, *Research and Development of a New Data-processing System for Air Force Logistics*, The RAND Corporation, Research Memorandum RM-1639-1 (ASTIA No. AD 96903), June 13, 1956.

The second feature of LS-2 was a deferred initial provisioning scheme for all Hi-Valu items.² Activated squadrons were supported for the first year or so from buffer stocks established at the contractor's facility. Some time toward the middle of the phase-in period the major Hi-Valu buys were made for the purpose of base and depot stockage. A special set of procedures was devised to manage the distribution of the Hi-Valu materiel.

The third feature of LS-2 was the procurement and distribution of all Cost Category II and III items by means of certain economical formulas developed at RAND.³ These formulas generally led to decisions to make larger initial buys and provide larger base resupply quantities of the cheaper items than was current Air Force practice.

In devising the contrasting "1956" Logistics System, or LS-1, the intention was to try, insofar as possible, to construct a reasonable approximation to the logistics system used by the Air Force in 1956. This meant that LS-1 employed so-called decentralized data processing. Supply-using organizations maintained independent records within the system, computed their own reorder points and stock levels, issued their own requisitions, and provided reports both periodically and as required by higher echelons. Air Force practices more or less current in 1956 were used for the provisioning, procurement, and distribution of spare parts.

If any light was to be shed on the effectiveness of the proposed policies, it was necessary that each logistics system be subjected to the same requirements of the representative weapon-system cycle. For this purpose the following framework was constructed. It was assumed that each system would have ten operating bases. These were activated at the rate of one every 3 months. Two series of aircraft—the so-called F-1-C and F-1-D—were planned. They were phased in over a period of approximately 2½ years; the F-1-C's were assigned to the first five bases in each system while the F-1-D's went to the remaining five bases. Early in the fourth year the bases began phasing out in the order of their original activation. Their

²J. W. Petersen, *Savings from Procurement Deferral with Interim Contractor Support: The Case of Hi-Valu Airframe Spares*, The RAND Corporation, Research Memorandum RM-2085 (ASTIA No. AD 144297), January 10, 1958.

³Allen R. Ferguson and Lawrence G. Fisher, *Stockage Policies for Medium- and Low-cost Parts*, The RAND Corporation, Research Memorandum RM-1962 (ASTIA No. AD 156001), April 18, 1958.

respective series of aircraft were disposed of and were no longer available to the system at large. During this over-all cycle, the two systems were faced with the same operational requirements.⁴ They used the same basic-parts sample and experienced the same Technical Orders affecting the application, substitution, and addition or deletion of parts from the sample inventory.⁵ They suffered the same demands for spare parts because of failures and scheduled or unscheduled maintenance.⁶

In order that the performance of the two systems under these common inputs could be assessed, it was planned to record their procurement expenditures, their operating and spare-parts costs, and their maintenance and transportation costs. Their records of Aircraft Out of Commission for Parts (AOCP's), Aircraft Out of Commission for Maintenance (AOCM's), and Aircraft Not Fully Equipped (ANFE's) were tabulated, and so were their peacetime combat-ready aircraft, their flying hours accomplished, and their performance during alerts, maneuvers, and under wartime conditions. On the basis of such data it was believed that the suspected virtues of the proposed policies would be demonstrated. It was also thought that some suggestions would appear as to how the components of LS-2 could be improved to afford greater efficiency, economy, and responsiveness of logistics support.

One important thing should be noted about LS-2. This system, in its entirety, was not designed to serve as a model for Air Force logistics procedures. Rather, it was intended as merely a framework for the three proposed policies, because it would have been prohibitively expensive to test each policy separately.

DESIGN OF LP-1

Simulation Methodology

It was a major task to combine in one experimental play both the realism and the abstraction needed to make a meaningful—and also

⁴See Appendix I, p. 71, for a description of the program model.

⁵See Appendix II, p. 75, for a description of the parts sample.

⁶See Appendix III, p. 77, for a description of the failure model.

manageable—comparison of complex logistics systems. Indeed, it was necessary to develop an entirely new simulation technique within the Laboratory.

To simulate ordinarily means to reproduce the main features of some phenomenon or arrangement without duplicating every detail. The aircraft cockpit simulator is a familiar example. Pilots or crews are provided with the customary controls and are subjected, during the course of an assumed flight, to certain controlled variations of weather, traffic, malfunctions, etc. In such a simulation there is a one-to-one correspondence between operations in the simulator and operations in the real world. The cockpit positions and instruments are the same, and it takes the same time for things to happen in the simulator as in the real world. Participants and controller-observers tend to have little, if any, trouble adjusting to the simulated environment, since it is virtually identical with that of the real world. Input or controlled data can be gathered from the real world and applied directly to the simulator so that the participants ordinarily are unable to distinguish the simulated from the real-world problems and experience. In the same way, outputs from such a simulator do not require extensive interpolation in order to gain real-world significance.

Logistics simulation, however, is a different proposition and requires different techniques in dealing with space and time. First, it is impossible to duplicate the magnitude and complexity of the Air Force logistics system, with its systems within systems. The real-world logistics organizations have to be scaled down in respect to their materiel, personnel, functions, and geographic extension. Second, to reproduce the cycle of a logistics system, or even of an item within the system, might involve 5 years or more. Obviously, the costs of such a project would be tremendous, and the data gathered would be obsolete before they could be used. Some compression of the time span of logistics experience is therefore mandatory. These two major differences from a one-to-one simulation gave LP-1 the following profile.

Organizations Simulated

Each of the two logistics systems was divided into two levels termed

"top deck"⁷ and "floor"⁸ organizations. As shown in Fig. 1, the top-deck activities consisted of Headquarters USAF, with two major commands, Headquarters ADC, and Headquarters AMC. For the purposes of the

Fig. 1—Organizations simulated in LP-1

simulation it was obviously desirable to have these staff and command relations. At the same time, it was possible only to scratch the surface of the Pentagon complex and the real-world network of some fifteen major Air Force commands. The Headquarters USAF simulated in LP-1 was

⁷The expression was derived from the physical nature of the Laboratory top deck, which was a balcony or upper room that overlooked the main-floor activities.

⁸This expression also evolved from the physical makeup of the Laboratory, since most of the activity managers were located on the Laboratory main floor.

responsible for establishing the Air Force operational programs and policies, and for providing the materiel and services required to support them. The simulated ADC was required only to maintain a fighter-interceptor force capable of defending the North American continent, as compared with ADC's real-world responsibility for the entire national air-defense system. The reduction of ADC operations to this simulation level permitted a similar scaling down of AMC. In the real world, of course, AMC is responsible for supporting all of the major Air Force Commands, the Mutual Defense Assistance Program (MDAP) nations, and other agencies, for providing technical guidance and control of logistics support for weapon systems, and for training specialized units for overseas logistics duties. But the AMC simulated in the Laboratory was only responsible for providing materiel and maintenance support for the simulated Air Force activities. It therefore merely operated and controlled the depot, which was assumed to procure, receive, store, repair, and issue materiel to the simulated using organizations.

The extent of the compression achieved in these top-deck simulations is more fully shown by the fact that USAF, ADC, and AMC were represented in the experiment by any one of three persons, who composed a so-called Control Group. In their top-deck roles they provided inputs to the two logistics systems in the form of the aircraft production and delivery schedules, base activations, and programs, such as flying hours, alerts, and inspections. They considered requests for maintenance overtime and for additional manpower allocations, and permission for trips and conferences by the activity managers. They also provided information and interpretation of strictly USAF, ADC, and AMC policies and procedures.

Another top-deck organization was the factory, which produced the assumed aircraft.⁹ In contrast with its real-world magnitude, it was scaled down to a single factory manager and several clerks. In the experiment they received orders, computed contract costs, scheduled factory work, and prepared delivery schedules. The transportation office was also of a top-deck nature and was responsible for furnishing transportation data and information to the using activities.¹⁰

⁹See Appendix IV, p. 83, for a more detailed description of the factory model.

¹⁰See Appendix V, p. 85, for a more detailed description of the transportation model.

The top-deck organizations were common to both logistics systems. In the simulated practice, however, they served whichever system required their attention at a given moment.

The floor organizations simulated in the experiment were an AMA, through which AMC exercised its operating authority, and a network of ten bases operated or tenanted by ADC. These basic outlines were duplicated in each logistics system, although within the systems certain differences existed, which will be noted later.

For LP-1 purposes the simulated AMA was assumed to be the Sacramento Air Materiel Area. Once again, the need to compress space and personnel resulted in a Laboratory organization considerably scaled down from its real-world counterpart. Thus, real-world commodity class management was expressly excluded from the simulated AMA's duties, as were production surveillance, contract awarding on the basis of competitive bidding, mobilization planning, quality control, etc.

Within the AMA a Weapon System Manager (WSM) was given responsibility for complete logistics support of the simulated weapon system. (See Fig. 2 on page 10.) This meant that he was responsible for procurement, supply, and maintenance. The LS-1 WSM was also made responsible for Hi-Valu control within his system.

Subordinate and directly accountable to the WSM were the depot maintenance and supply activities. The depot maintenance functions were divided between the Weapon System Maintenance Manager, who managed the simulated IRAN (Inspect and Repair As Necessary) facility, and the Parts Repair Depot Manager, who controlled the Parts Repair Depot (PRD).¹¹ Supply management responsibilities were slightly different in the two logistics systems. In LS-1, a Weapon System Supply Manager (WSSM) handled the provisioning, requirements computations, procurement initiation, and distribution of the weapon-system inventory. In these tasks he was assisted by a Distribution Manager (DM) located at the Weapon System Storage Site. In LS-2, on the other hand, the Hi-Valu Control Officer (HVO) was given complete Hi-Valu control, including procurement, provisioning, requirements computations, and distribution.

¹¹ See Appendix VI, p. 87, describes the IRAN-PRD model in greater detail.

SUPPLY AND PROCUREMENT POLICIES

Fig. 2—Simulated Weapon System Managers' organizations

(See Fig. 2.) A Material Control Officer (MCO) in LS-2 performed parallel duties for the Category II and III items. One or two clerks within each simulated AMA were available for routine chores as needed.

In the Laboratory, it was obviously desirable to approximate, in so far as possible, the time and distance problems that confront real-world weapon-system managers. The ten ADC bases of each logistics system were therefore selected so as to give a balanced geographic coverage in relation to Sacramento. (See Fig. 3.) Transportation and communication

Fig. 3—Simulated geography of LP-1

delay times and costs appropriate to these geographic relations were devised.

Each of the ten bases in each system was represented by one person responsible for both base-supply and base-maintenance functions.

Real-world-Laboratory Differences

The main differences between the real world and the activities simulated in LP-1 now become apparent. Most striking, of course, is the fact

that each of the simulated logistics systems was staffed by approximately 15 to 20 people, whereas their counterparts in the real world would be staffed by many thousands. In the same light, the organizations simulated in the Laboratory were housed in three or four rooms, while in the real world they would be spread over the entire United States. Some of the compression of space and personnel was achieved by leaving out certain functions and by combining other functions in a single individual's simulated duties. Additional compression was obtained by having the IBM 704 perform a great deal of the routine requisitioning, computing, and record-keeping work. (Incidentally, some 25,000 separate instructions were finally written for the "machine.")¹² Punch cards and computer records (print-outs) were used to represent procurement, shipment, storage, repair, and installation of both new and repaired spare parts on aircraft. A so-called Laboratory Control Point guided the simulation of some of these transactions by receiving shipments of aircraft and materiel from relevant activities, determining how long it took to transport the item or items by the mode specified, and, after the appropriate delays, delivering the proper card or report to the designated activity to signify receipt of the item or materiel. Delays to simulate the passage of maintenance or repair time were calculated automatically, and completed jobs were shown either by computer records or by punch cards. Materiel ordered from the factory was shipped, received, and recorded in a similar manner after the proper lead time and transportation delay time had elapsed.

Personnel and space were further compressed by using a parts sample. The activities in each logistics system dealt with only 700-odd different airframe parts, as compared with the many thousands of items handled in any real-world system.

In all these ways it proved possible to capture the essential organizational and functional features of a complex logistics system.

The second major difference between conditions in the Laboratory and in the real world was the time scale employed. Time compression was

¹²To prevent confusion, whenever the IBM 704 was used to perform routine or clerical tasks for both systems (mainly in order to facilitate the time and space compression), it will be described as the "704" or the "machine." Whenever it was utilized in a manner uniquely and originally designed to carry out the data-processing policies of LS-2, it will be referred to as the "DPC."

necessary to gain several years of simulated logistics experience in a brief span of real time. The high-speed computer was a great convenience in this respect. For example, requirements computations, which ordinarily take several months in the real world, were performed in a few minutes. By reducing the sheer physical magnitude of the logistics system as described above, it was possible to assume that daily routines in the simulation would require less working time than in the real world. Ultimately, therefore, the simulated work day consisted of about 60 minutes of real time. The simulated month was shortened to 10 simulated days, the quarter to 30 simulated days, and the simulated year to 120 simulated days. This time compression permitted the Laboratory to complete approximately a full year's logistics operation in about 20 days of real time.

Simulation Control

An experiment of these dimensions required stringent simulation control. Since people were a part of the experimental design, it was necessary to prescribe the lines of action open to them.¹³ For example, the comparisons between the two systems would not have been very meaningful if the manager of Westover AFB in LS-1 always mailed his Stock Balance and Consumption Reports to the AMA, while the Westover manager in LS-2 reported his status by a loud shout across the room. In addition to its USAF, ADC, and AMC roles, then, the Control Group attempted to discover and correct all violations of simulation ground rules, checked reports and records in an effort to eliminate errors or misunderstandings in Laboratory procedures, and offered interpretations of policies as needed. The group's objective was to prevent either system from acquiring other than the originally built-in characteristics.

The Control Group was assisted by an Observation Group. These people sought to obtain information on the systems' performances beyond the simple tabulated results. They had facilities for monitoring and recording

¹³The rejected alternative course was merely to give the people a general logistics problem to solve in their own trial-and-error ways. This approach would have involved a one-to-one correspondence in time and persons and would have required techniques of observation and analysis too elaborate for the present state of logistics-simulation art.

both in-person and telephone conversations among the participants. In this way a running account of daily events was produced that covered the manner in which floor problems were handled and revealed situations that might require Control Group action. At selected times the Observation Group administered standardized questionnaires and interviews in order to obtain data on the attitudes and roles of the participants in the experiment.

Obtaining Meaningful Results

The very high cost of running the Laboratory made it imperative to ensure that the outputs of the experiment would have some useful degree of real-world applicability. At first glance this may seem to be a simple matter, but in practice it is not always easy.

Suppose, for the sake of argument, that deferring procurement of Hi-Valu items is expected to produce dollar savings. To test this hypothesis does not appear unduly difficult. One might set up two systems, one using deferred and one using regular procurement practices. Both systems could be subjected to the same operational tasks and, at the end of an appropriate interval, dollar expenditures could be compared. This comparison would presumably favor one or the other policy.

But would it? If both systems attained the same combat-ready rate, the situation would be clear. But what conclusion could be drawn from the result, say, that one system spent more money on Hi-Valu stocks and got more combat-ready aircraft, while the other spent less and got fewer combat-ready aircraft? Again, what would be the value of such a seemingly simple test of procurement policy, if nothing were said about the way that maintenance reacted to the policies, or about the stresses and strains placed on the factory and transportation system? According to what rules would the Hi-Valu goods be distributed within the systems? And what burdens would this distribution place on maintenance and transportation facilities? One very quickly discovers that it is impossible to keep logistics experimentation simple and still obtain results that have much significance in the real world.

Several other points about the experimental design warrant notice. It

was decided to make the comparison between the systems on the basis of the dollar expenditures for spares and maintenance, transportation costs, and the AOCP, AOCM, and ANFE rates. Since both systems were to have the same inputs (numbers of assigned aircraft, attrition rates, parts characteristics, parts failures, flying-hour programs, Technical Order compliances (TOC's), unit costs, etc.), the differences in the expenditures required to satisfy these programs would reflect the policy and procedural differences built into the two systems.¹⁴

The decision to compare expenditures and performances of two systems faced with the same basic inputs also produced the decision to run both systems simultaneously.¹⁵ On the same day each system was given the same simulated task. As part of the failure model a "failure tape" was prepared for the 704 in order to accomplish this. Thus, for example, on the fifty-eighth day of the first year, the Larson AFB in each system was expected to experience its thousandth flight. On the thousandth flight at that base, however, stock number 298 was scheduled to fail. This information was relayed by the 704 to the system managers, whereupon they undertook to solve the problem in their respective ways. It was foreseen that running the two systems side by side might cause occasional trouble if one system began "limping" because of some policy or procedural mistake or error. Should the systems then go out of phase, inputs from the failure tape would appear at the wrong time and, if cumulative, could distort the final comparisons. Therefore, to ensure that the two systems were always more or less in step, a method was devised for controlling the base flying activity.¹⁶ This control over the flight operations of both systems simply reduced the number of variables and gave more meaning to those that remained.

¹⁴ An alternative approach would have been to give each system identical budgets and let them strive for the maximum combat-ready rate. The better system would presumably show a higher rate for the same dollar outlay. This course was ruled out because of the complexities involved in modeling a single budgetary cycle to fit the policies of two different logistics systems.

¹⁵ The alternative to this would have been to run the systems consecutively. Such a procedure would have doubled the time required to complete the experiment and would have added considerably to the costs.

¹⁶ See Appendix I, p. 71.

CONTRASTING SYSTEM POLICIES

Put simply, the two weapon systems, LS-1 and LS-2, were designed to reflect 1956 and proposed procedures for data processing, provisioning, and the distribution of airframe spare parts. The manner in which these contrasts were detailed in the Laboratory is of considerable importance to the practical logistician and will be discussed in the balance of this chapter.

LS-1 Stock-control and Requirements Computations Policies

First on the list of contrasts between the two systems were the stock-control and requirements computations policies. In LS-1, stock control at the storage site was effected through a defined hierarchy of stock levels abstracted from the 1956 version of Air Force Manual 67-1. The basic definitions were as follows: *operating level of supply*—the level of supply required to sustain system operations between procurements or between arrivals of successive shipments; *procurement lead time*—the time elapsing between the initiation of procurement action and the receipt of materiel in the system; *warning point level*—the level of supply at which procurement action was indicated; and *minimum reserve level*—that systemwide stock position at which further issues were rationed and distributed in accordance with indicated priority of need. The warning point level was taken to be the sum of the operating level and the procurement lead time, while the minimum reserve level was expressed as a fraction of the warning point level. These levels were specified for the three cost categories¹⁷ according to the 1956 Air Force Manual 67-1 and were then incorporated into the Laboratory time scale. Each level was expressed in days of supply and was subject to quarterly review and amendment as con-

¹⁷The Weapon System Managers in both logistics systems were directed to use the same categorization program. In the customary way they were to take Category I items as those selected and designated for special (Hi-Valu) control. These were generally items in the parts sample with high unit costs, although some items with large total costs were also included. Category II was to cover those items with a unit cost greater than \$10.00, not designated as being in Category I. Category III covered all items with a unit cost of less than \$10.00. Each stock item was assigned an Expendability-Repair-Cost (ERC) code describing its cost category, the level to which it was to be processed for maintenance, and the limit at which it was to be condemned.

sumption data were accumulated. Charts were available to help in establishing or adjusting levels.

The 704 handled a great deal of the routine processing of requisitions in LS-1. This was necessary for the sake of time compression and was not intended to give LS-1 the benefits of a data-processing center. Available storage-site materiel was automatically sent to the requesting activity. Any time the quantity of stock on hand or due in was reduced to the warning point level, a machine print-out marked "Warning Point" was forwarded to the Weapon System Supply Manager. This print-out showed the warning point level, the minimum reserve level, and the quantities due in under the various procurement contracts. A similar print-out marked "Minimum Reserve Level" was made whenever stocks on hand or due in reached the storage-site minimum reserve level. All Priority 1 requisitions¹⁸ on the storage site were satisfied down to a zero balance for the item, at which point a print-out marked "Trouble" was prepared for the Weapon System Supply Manager. This contained the same information as the other print-outs. Any Priority 1 requisition unfilled was automatically back-ordered. Priority 2 and 3 requests were supplied only down to the minimum reserve level, after which the Weapon System Supply Manager or the Distribution Manager personally handled their distribution. Quantities not available were back-ordered as in the case of Priority 1 requests. Depending on the asset level present (including due-ins), the Weapon System Supply Manager or the Distribution Manager issued amended shipping instructions to the factory, changed quantities on order under existing contracts, expedited quantities on existing contracts, expedited materiel from repair, or waited for a scheduled review of the buying program. The depot-issue concept was expressly employed for items with a Category III classification, and once such materiel was distributed to the bases it was considered lost to the control of the Weapon System Supply Manager or the Distribution Manager.

¹⁸The base managers in both logistics systems were required to use the same system of priorities. Priority 1 involved parts for aircraft that were AOCP or ANFE. Priority 2 covered work stoppages and positive need for parts within 6 (Laboratory) days. Priority 3 applied to routine stock-level replenishment. Communication and transportation modes appropriate to each priority level were also specified.

At the LS-1 bases, stock was controlled through a scale of stock levels similar to those established for the storage site. These levels, like the depot levels, were expressed in days of supply and were as follows: *stockage objective*—the quantity of materiel authorized to be on hand or due in at a base distribution point in order to meet replenishable demands; *base stock control level*—the stockage objective plus the average pipeline time for the item; *base reorder point*—the number of days' supply of stock at which requisitions were to be submitted for the purpose of raising base stocks to the stockage objective; and *safety level*—the minimum number of days' supply of stock required to ensure uninterrupted support of base operations from within base stocks. The original distribution of stocks to bases was derived from Air Force Supply Table II,¹⁹ but thereafter the base managers were required to requisition from the storage site in order to raise their stocks to the authorized levels. The base managers were permitted and encouraged to adjust their stock levels on the basis of the experience and issues during 60 (Laboratory) days. If these data were not available, the managers used prepared supply tables as guides until sufficient issue experience had accumulated. Analyses for stock-level adjustments were made quarterly or whenever an AOCP requisition was submitted to the storage site. In this way trends were detected and off-setting action was taken as quickly as possible. A procedure was established by which the base managers could interrogate the 704 for data bearing on their stock levels. Changes in levels were permitted at any time, and a means was provided for instructing the 704 of such changes.

The Weapon System Supply Manager in LS-1 was responsible for computing requirements whenever system assets reached the warning point level. This was in addition to any stated cyclical computations and was, therefore, an attempt to simulate the Logistics Early Warning System (LEWS). In conformity with the 1956 Air Force Manual 67-1, the operating level and procurement lead time requirements for all recoverable-type items were computed at the wearout rate. The gross issue rate was

¹⁹ Air Force Supply Table II, "Airframe," gives "the recommended spare parts and supplies based on available consumption data that is considered adequate for organizational and field maintenance for a specific quantity of a particular type, model, series" of aircraft. See Air Force Manual 67-1, Vol. 2, June, 1958, p. 13-3.

used in computing stock-level and repair-cycle requirements for such recoverable-type items. All requirements for nonrecoverable-type items were made on the basis of the gross issue rate. Category III stocks were treated as nonrecoverable unless facts indicated the contrary. The 704 was used to simplify these computations as much as possible, although manual calculations were recommended for Hi-Valu items. The Weapon System Manager, or his representative, however, was encouraged to adopt the results of requirements computations only in the light of his experience and judgment.

LS-2 Stock-control and Requirements Computations Policies

The stock-control and requirements computations policies used in LS-2 were different from those just outlined, both in over-all conception and in the separate treatment of Hi-Valu and Category II and III materiel. In the first place, stock control of Hi-Valu items was carried out without recourse to supply levels as such. This distribution policy provided both for the pre-positioning and the apportioning of Hi-Valu stocks in such a manner that they were available to the needy organizations with a minimum of transshipping. The initial and subsequent distribution of the system's Hi-Valu commodities was made by the Hi-Valu Control Officer in terms of so-called expected base stock shortages. These expected base stock shortages were calculated monthly by the DPC on the basis of a formula built up from the production lead time of the item, factory production responsiveness, factory buffer stock, the month in which the serviceable life of the item was expected to end, and the projected requirements for, and expected assets held by, the base in question. This information was distilled by the DPC and was then printed out for the Hi-Valu Control Officer, along with a compilation of systemwide data covering the item's failures, condemnations, and overhauls. The Hi-Valu Control Officer then sought to utilize his assets and due-ins to meet the indicated needs. Since the Hi-Valu program in LS-2 implied that numerous small orders were to be placed against the factory production line during the deferral period, the distribution problem in the Hi-Valu area was essentially one of directing expedited shipments from the factory, or in some

cases from activities with excess stocks within the system, to those places where shortages were present or anticipated.

The requirements computations for Hi-Valu items were also made by the DPC. These calculations depended on the service-life estimate for operating-type items (i.e., those items not subject to periodic replacement), the estimated failure rates for individual aircraft, the anticipated wearout rates, and the average repair-cycle times for the item. Each month, the DPC computed the time-phased requirements for all the Hi-Valu stock, showing expected monthly gross and net system needs for 1 year. Whenever the available stock, including the quantity held in the factory buffer, exceeded the cumulative net requirements for a period of one procurement lead time ahead of the current month, procurement action was deferred. If the expected net requirements for a similar period exceeded the available stocks, a procurement was made. At that time sufficient materiel was purchased to cover 4 months' cumulative net requirements plus 2 months' requirements (to be considered war reserve) computed at the gross base failure rate. Each month, a procurement review was made and orders were adjusted accordingly. This sequence continued up to 1 month plus one raw material expedite lead time from the end of the production program for the item. Then, a decision was made to defer procurement or to make a final in-production buy to cover system stockage. Specially prepared tables, based on the length of the remaining program, the out-of-production set-up costs, the demand rates, and the interest charges, were used to facilitate this buy decision.

The Category II and III stock-control and requirements computations procedures for LS-2 were designed for centralized and virtually automatic procurement, replenishment, and distribution of the system's assets. The objective, of course, was to provide better control over those items which, although low in dollar value, contributed to roughly 78 per cent of the AOCP's. To effect this, the prerogative of setting and adjusting stock levels for Category II and III items was taken from the bases, IRAN, PRD, and the storage site, and was vested, instead, in the DPC. The policy was laid down in terms of four basic definitions: *reorder level*—the quantity of stock at which it was necessary to undertake stock replenishment; *warning level*—the quantity of stock indicating that the reorder level

would soon be reached; *reorder quantity*—the amount of stock to be replenished when the reorder level was reached; and *stock control level*—the sum of the reorder level and the reorder quantity. As demands brought the stock of activities down through these successive levels, replenishments in the required amounts were made automatically by the DPC.²⁰ The DPC reached these decisions on the basis of certain economical formulas, which responded to stockout costs, reorder costs, holding costs, interest charges, and the probabilities of demand for an item during a resupply period. By applying these formulas to the complete and continuous demand history for all the Category II and III commodities, the stock levels for all supply-using activities were obtained, set, and adjusted as necessary. In practice, the formulas automatically produced orders for quantities sufficient to last anywhere from 1 year or more to 1 month or more. These orders could be on the factory from the storage site or on the storage site from other activities. In contrast to LS-1, however, no attempt was made to establish stock levels to support a given number of days or months of operation.

Since the range of data involved was vast and the results were required quickly, these computations had to be performed by the DPC. In addition, central and speedy access to all the relevant information was mandatory if the DPC was to make initial and subsequent distributions of stock, maintain current balances of assets for all activities, and automatically requisition or procure appropriate amounts whenever reorder levels were reached—all in time to be useful.

Although the routine procurement and resupply activity was entirely automatic and required no direct managerial intervention, the LS-2 policy still provided for manual control under certain exceptional conditions. Thus, whenever the supply of an item became short throughout the system, the item was placed under the personal direction of the LS-2 Material Control Officer who distributed or redistributed it to achieve the most effective supply support. On any given day, if the storage site had insufficient stock to meet all the demands placed against it, the DPC

²⁰ A program difficulty prevented the stock-level control from functioning automatically for the LS-2 IRAN and PRD. Therefore, during the run these managers had to adopt manual procedures for supply support.

printed out a Critical Item Report. This report indicated the current asset position for the item at all activities within the system. When an item appeared in the Critical Item Report, the DPC automatically refused to satisfy any request for it, even though some serviceables were available at the storage site. Instead, the Material Control Officer sought to use his limited stock in such a way that the most critical needs were satisfied first.

Ordinarily, the Material Control Officer attempted to alleviate AOCP's as soon as possible. From his knowledge of the extent and location of systemwide assets he either ordered shipments from other activities to the requesting activity, used substitute items, expedited repair from the PRD, or made a superexpedite procurement order on the factory. The objective, in any case, was to satisfy AOCP requests immediately, regardless of cost. If an item was in the Critical Item Report, the Material Control Officer usually expedited procurement or speeded up the repair of depot reparable. It can be seen that in contrast with the LS-1 procedure, the LS-2 Material Control Officer possessed instantaneous knowledge of the distribution, condition, and quantity of his Category III stocks. This enabled him to provide significantly better supply support.

It will be observed that the base managers in LS-2 were virtually ignorant of the state of their own base stock levels at any given time, since the calculations by which these levels were reached or adjusted were carried out elsewhere. The base managers were able to interrogate the DPC, of course, but they possessed no means of controlling or changing their own stock levels. This denial of local prerogative was designed to ensure centralized control of system assets and, in that way, to avoid the distortions that usually result when single organizations act without regard for their effect on others.

All the stock levels calculated by the DPC were automatically adjusted to allow for changed programs, changed production costs and lead times when aircraft or spares were out of production, Technical Order compliances, changes in repair-cycle times, applicability of items to specific aircraft series, and war-reserve requirements established by higher authorities. At the beginning of each year, the DPC also prepared a listing of procurements judged to be necessary for the ensuing year.

LS-1 Provisioning Policies

The provisioning policies for the two logistics systems varied greatly from each other. In LS-1, initial provisioning²¹ had to support the first year's operational requirements plus any established stock levels. Thus, the familiar 16½, 17½, and 18½ months of supply for Categories I, II, and III, respectively, were provisioned. These requirements were computed with the help of simulated test data or of estimates of the issue rate made by the Weapon System Manager on the basis of his general commodity knowledge. As experience unfolded, the initial provisioning could be revised; but no revision was permitted later than 30 days before delivery of the final aircraft on the production contract. The follow-on procurement contract served items common to both the F-1-C and the F-1-D and was open to amendment in the light of on-hand inventories, life-of-type and terminal requirements, and whatever data had become available.

LS-2 Provisioning Policies

In LS-2, the initial provisioning²² of Category I items was made independently of any notion of required levels; instead, the amounts of these items were kept to an absolute minimum until more accurate usage data would appear. The objective of this policy was to diminish the uncertainty associated with buying expensive spares for aircraft several years before any worthwhile demand experience is obtainable. The uncertainty is due to unpredictable variations in the early operating program, to the difficulty of forecasting the demand for individual items, and to the engineering and design changes frequently encountered during the phase-in period. By living "hand to mouth" and sharing some of the burden of uncertainty with the contractor, the Hi-Valu Control Officer in LS-2 gained time in which demand experience could unfold. To satisfy base demands during this deferral period he placed numerous small orders against the contractor-maintained buffer stock. As more demand data became available he used them in the follow-on procurements. The initially provisioned

²¹ See Chapter 3, p. 27, for a description of the LS-1 provisioning procedures.

²² See Chapter 3, p. 29, for a description of the LS-2 provisioning procedures.

quantities were determined by the DPC on the basis of certain prescribed formulas and factors. Quantities specified for the initial provisioning of activities phased in at later times were obtained by the same procedure, but on the basis of the experience accumulated by activities already in operation. At the appropriate time the DPC indicated when and in what amounts the major procurement for the Hi-Valu stock was to be made.

The Category II and III items in LS-2 were also initially provisioned in amounts calculated by the DPC. The factors used in these calculations included such things as the service life of the item, its unit price in and out of production, the costs associated with unsatisfied demands, the average repair, the procurement lead time, the initial consumption estimates, flying programs, reorder costs, and holding costs. Before later bases phased in, the DPC calculated their initial stockages on the basis of the usage experience gathered up to that time.

EXPECTED OUTPUTS

Given the form, shape, and structure of the two simulated systems, the outputs were expected to give some insight into these problems:

1. The consequences of the proposed procurement and distribution policies for Hi-Valu goods appearing in the relations between support effectiveness (i.e., AOCP's, AOCM's, and ANFE's) and (a) demands on the factory for priority production, (b) demands for high-speed transportation, (c) spares support costs, (d) demands for priority requisitions, and (e) ability of the system to meet contingencies such as program changes, war readiness, or even war itself.
2. The effects of the proposed Category II and III provisioning and distribution policies on supply effectiveness and cost similar to those enumerated above.
3. The use made by the Weapon System Manager of the data-processing system in implementing the Hi-Valu and Category II and III policies.²³

²³The DPC in LS-2 was merely modeled after the ELECTRO LOGS concept and was not intended to test or develop detailed specifications for data-processing hardware or procedures.

The emphasis in LP-1 on the provisioning and distribution of airframe parts was not meant to imply that other supply problems were uninteresting or that maintenance problems, for example, were unimportant. But research into procurement, distribution, and data processing in the RAND Logistics Department had reached a point where some firming up of results was needed. The Laboratory was the obvious place to do it.

CHAPTER 3

LOGISTICS MANAGEMENT IN LP-1

LP-1 was more than an arrangement of a few formulas on a computer. It encompassed people and a continual process of decisionmaking. To convey a picture of the activities, the present chapter will consider the major work cycles. While this description cannot cover every event that occurred during the run, it will give a good idea of the simulation of logistics management in LP-1.

PROVISIONING

The provisioning of spare parts was the first step in the experiment. Responsibility had been delegated to the two Weapon System Managers for calling conferences to select items and quantities necessary for the initial and subsequent support of the simulated aircraft. The Provisioning Conferences of both logistics systems proceeded on the assumption that the production contract or letter of intent for the aircraft had already been issued. The actual provisioning procedures were somewhat different for the two systems.

LS-1

In very broad outline, the provisioning sequence in LS-1 was as follows. Some time prior to the formally scheduled Provisioning Conference the contractor prepared a production list that contained the long-lead-time items recommended for procurement to cover initial support requirements. This production list included part numbers, descriptions of parts, technical data, costs, and lead times. Against this original production list the contractor then placed the flying-hour programs, utilization rates, and overhaul programs given him by AMC. Ten days after receiving this information the contractor released to production all items on the original

production list. A copy of this list was then forwarded to the Weapon System Supply Manager, who, meanwhile, had established a Hi-Valu Review Board and a Provisioning Committee for handling the Category II and III items. These two groups reviewed the contractor's production list in the light of available program data, the current asset position (if any), usage data, and any undelivered on-order quantities of materiel. Within 10 days of receiving the contractor's production list the Weapon System Supply Manager returned a revised copy to him. The contractor then increased or decreased the in-production quantities as required.

Forty days after the contractor had released this revised production list, he presented a Provisioning Parts Breakdown (PPB) to the Weapon System Supply Manager. The PPB contained all items applicable to the aircraft and, therefore, included the long-lead-time items covered by the previously submitted production list. The Weapon System Supply Manager was required to have the PPB in his possession at least 9 months prior to delivery of the first aircraft. Upon receipt of the PPB he convened a Provisioning Conference consisting of the Hi-Valu Review Board, the Provisioning Committee, representatives from the using command, and various specialists from the Weapon System Manager's and contractor's offices. This conference was held at least 6 months before delivery of the first aircraft. The Weapon System Manager chaired the meeting of the Hi-Valu Review Board, which chose the Hi-Valu quantities required to fill the Table II's, to support the aircraft for the programmed period, and to stock the IRAN and PRD facilities. The Weapon System Supply Manager chaired the meeting of the Provisioning Committee when the non-Hi-Valu quantities required for the over-all program were selected.

No later than 20 days after receipt of the PPB by the Weapon System Supply Manager, a copy, as amended at the Provisioning Conference, was forwarded to the contractor. This became his official authorization to place additional items and quantities in production.

Delivery of spares was concurrent with acceptance of complete aircraft according to a schedule stipulating that (1) at least 25 per cent of the initially provisioned quantity of each item had to be delivered before or concurrent with delivery of the first aircraft; (2) at least 50 per cent of each item before or with delivery of 50 per cent of the aircraft; and (3)

100 per cent of each item ordered before delivery of 95 per cent of the aircraft. The Weapon System Supply Manager was permitted to authorize pre concurrent delivery of spare parts up to 90 days before receipt of the aircraft, if such an arrangement seemed advantageous. At any rate, no later than 10 days after the contractor had received the amended PPB, the Weapon System Supply Manager was required to provide him with shipping instructions based on the delivery schedules agreed on for each item on contract. These instructions were to specify destinations, quantities for Table II, and the dates of arrival.

The outlined time sequences applied to the spares provisioning for both the F-1-C and F-1-D.

The Weapon System Supply Manager could increase the production contracts any time up to 30 days before the scheduled acceptance of the last aircraft without incurring out-of-production set-up costs. Decreases to production contracts were, of course, subject to cancellation charges. Delivery of any such changed items or quantities was to be on schedules arranged between the Weapon System Supply Manager and the contractor. The contractor was allowed a period of 15 days after receipt of such change orders before submitting the delivery schedule to the Weapon System Supply Manager for approval.

LS-2

At some time in the design and test phase of the aircraft program the contractor submitted to the Weapon System Manager a preliminary list of long-lead-time items needed for initial support and insurance requirements. This preliminary list was screened by the Hi-Valu Control Officer and the Hi-Valu Review Board in order to estimate, tentatively, the quantities to be procured and to be placed in the contractor's buffer stocks. This original screening permitted the members of the Hi-Valu Review Board to familiarize themselves with the characteristics of the long-lead-time items and the AMC program factors. In the meantime, the contractor had prepared a production list, containing the long-lead-time items recommended for initial procurement and buffer stocks on the basis of program information provided by AMC. This production list went to

the Weapon System Manager. He thereupon convened the Hi-Valu Review Board for the purpose of revising the production list in the light of factors and information generated in the review of the preliminary list. The revised and marked-up production list was then returned to the contractor so that he could make revisions in the scheduling of items already released to production.

After receiving the revised production list, the contractor prepared a Provisioning Parts Breakdown with descriptions of all the detailed parts, including the long-lead-time items from the production list. This PPB was forwarded to the Weapon System Manager at least 9 months before the first aircraft was scheduled for delivery.

As soon as possible after receiving the PPB, and no later than 6 months prior to the first aircraft delivery, the Hi-Valu Control Officer called an *informal* Provisioning Conference. This was attended by the Hi-Valu Review Board and the Provisioning Committee. These two groups worked on the Hi-Valu items and the Category II and III items, respectively, to establish failure predictions, cost data, reparability of items by Air Force maintenance facilities, revisions of initial usage estimates, and changes in program information. When all these data had been reviewed and analyzed, forms were prepared by which the data were committed to the DPC. The DPC thereupon calculated the initial procurement quantities for all the cost categories on the latest PPB.

Once the results became available from the DPC, the Weapon System Manager called a *formal* Provisioning Conference to review the Hi-Valu quantities. The Hi-Valu Review Board made this review as comprehensive as possible and eventually produced a final selection of quantities required for initial support. In keeping with the prescribed policies, the amounts of the Hi-Valu items specified for initial provisioning were kept to a minimum. The Provisioning Committee simultaneously reviewed the DPC-computed quantities of Category II and III items. When both reviews had been completed, a copy of the finally amended PPB for all cost categories was given to the contractor. Parts were fabricated and suitable delivery schedules based on the operational programs were developed. In no case, however, was spares delivery permitted to be more than 1 month prior to the first aircraft delivery.

Two months before an activity became operational, its initial stock on order and scheduled in were reviewed on the basis of the usage data accumulated up to that time. Whenever DPC computations or other sources indicated that changes to the initial production contract were necessary, these changes were submitted to the contractor. As in LS-1, such changes were permitted any time up to 30 days before scheduled acceptance of the last aircraft without incurring out-of-production set-up costs. Termination charges were also established.

ANNUAL ROUTINE

As might be expected, the annual cycles of each logistics system were primarily a matter of preparing or reviewing reports for the year. Headquarters USAF annually published a Base Utilization Program for both systems showing the scheduled activations and deactivations. In the same connection, Headquarters USAF annually released the aircraft production and delivery schedules and the future flying-hour programs to be used to derive the several program factors. These programs were distributed to the floor activities by Headquarters ADC and Headquarters AMC.

LS-1

In LS-1 an annual requirements computation was made to cover requirements by quarter for 12 quarters into the future. Except for the Weapon System Supply Manager's plugging in of the factors based on the annually released programs, most of this computation was accomplished by the 704. The results appeared in a print-out called the Supportability-Cost-Analysis Report. For each stock number, data were presented showing the lead time and repair-cycle time in months, the projected quarterly issue requirements, the serviceable inventory, the repair requirements, reparable generations, total items repaired, maintenance man-hours required, gross procurement requirements, due-ins, additional procurement requirements, and total assets in the system. The cost of the last quarterly entry for each of these categories was also included. As requirements were computed for each Hi-Valu item, the system assets (including due-ins and reparable) of that

item were divided into segments. These segments showed the operating program, minimum stockage objective, lead time, recommended termination quantity, economic reserve, procurement requirements, excess serviceables, and excess reparable.

A Segmentation Report was also prepared annually. It contained dollar-value summaries of the three cost categories related to the segments mentioned above. This report, like the Supportability-Cost-Analysis Report, was designed to help the LS-1 Weapon System Manager in deciding on revisions of delivery schedules, termination of procurement, or disposal of excess.

The Weapon System Supply Manager in LS-1 was required to prepare annually the Master Repair Schedule (MRS) containing a list of items and quantities to be repaired in the quarters of the coming year. He also coordinated with the IRAN Manager in the preparation of the yearly IRAN schedule.

LS-2

By and large, the annual time period was much less significant for LS-2 than for LS-1 because, except for the weapon-system cycle, the policies by which LS-2 were governed were independent of any fixed time interval that procurement or distribution was to support. Only two strictly annual routines were evident in LS-2. An annual requirements estimate was prepared by the DPC for Category II and III items. This list contained only items for which procurement action was estimated to be necessary during the forthcoming year. The Material Control Officer used the list for general information only, since, as has been seen, Category II and III procurement was ordinarily automatic.

As in LS-1, the IRAN schedule was compiled on a yearly basis.

QUARTERLY ROUTINE

LS-1 AMA

For both logistics systems the quarterly cycle involved a great amount

of managerial activity. In LS-1 the requirements computations were reviewed each quarter by the 704. If this review disclosed that the recommended procurement quantities were substantially greater than those shown on the annual computation (Supportability-Cost-Analysis Report), a print-out of such divergent items was provided for the Weapon System Supply Manager. After reviewing this print-out he could revise delivery schedules for the relevant items.

At least once per quarter, but more often if required, the Distribution Manager in LS-1 reviewed his storage site warning point and minimum reserve levels on the basis of the Quarterly Stock Balance and Consumption Report. This report came from the 704 and reflected the systemwide balances, issues, condemnations, and reparable generations for Category I and II items, in addition to providing the same information for Category III items at the storage site, IRAN, and PRD. Each quarter, the 704 also prepared a balance listing for each of the activities in the system. This listing varied somewhat among the activities, but generally it indicated the serviceable and reparable balances on hand, due-in quantities, in-transit material, reparable generations, condemnations, items repaired, and issues for the current, and the current plus the previous, quarter.

An Inventory Accounting, Monetary Report (IAM)¹ was also prepared quarterly for the Weapon System Supply Manager and showed by cost category the dollar values of issues, and the total value of serviceable, reparable, and TOC balances. In the ordinary accounting manner these values were given for the beginning and end of the quarter, the increase or decrease transactions through the quarter, and the total increases and decreases for the period.

The IRAN and PRD managers in LS-1 were required to develop and maintain material standards on which their 30- and 60-day workload projections were based. Once this information was transmitted to the Weapon System Supply Manager, he effected the transfer of parts and material into the respective "Q" accounts from which the quarterly schedules were supported. Throughout the quarter, the IRAN and PRD managers sought to refine their material standards on the basis of past

¹See Appendix VII, p. 89, for a discussion of the IAM system modeled in the Laboratory.

usage experience. Any changes were then incorporated in the report made at the end of the quarter.

The LS-1 IRAN Manager was required to prepare a Quarterly Aircraft Status Report showing the IRAN schedule for the current quarter, the number of aircraft received at IRAN, the aircraft IRAN's completed, IRAN AOC days for the current quarter, aircraft in work at the end of the quarter, overtime days expended, and the average aircraft flowtime through IRAN during the quarter.

The LS-1 PRD Manager submitted to the Weapon System Supply Manager Quarterly MRS Status Reports showing for each stock number the annual requirements from repair and the quantities repaired and condemned at the PRD to that date and during the current quarter. Information was also included in this report about the PRD man-hour utilization.

LS-2 AMA

LS-2 had no quarterly requirements computation similar to that of LS-1. The Hi-Valu Control Officer and the Material Control Officer did receive a Quarterly Stock Balance and Consumption Report and a Quarterly IAM Report containing the same information as those for LS-1. But in practice these reports were of minor interest since the LS-2 officers could interrogate the DPC at any time for a statement on the system assets.

Each quarter the DPC automatically computed the MRS for the Category II and III items in LS-2. This covered the number of reparable carcasses expected to appear in the next 4 quarters. In the print-out, economical batch repair sizes were recommended. The Hi-Valu MRS was on a monthly schedule, as will be explained below.

The LS-2 IRAN and PRD managers completed Quarterly Aircraft Status Reports and Quarterly MRS Status Reports identical with those described above for LS-1.

Bases

With one exception, the quarterly routines at base level were the same for both logistics systems. Each quarter the base managers received Stock

Balance and Consumption Reports and Quarterly Balance Listings. These listings gave information on serviceable, reparable, and TOC balances; due-in balances; issues for the current, and the current plus the previous, quarter; base-reparable generations; depot-reparable generations; and condemnations. Quarterly IAM Reports were also provided to the base managers. They showed, by cost category, the dollar value of base-level transactions and base-level balances.

Although base managers were permitted to use 25 per cent of their quarterly assigned manpower for field maintenance overtime without recourse to higher authority, changes in the assigned manpower allocations required authorization. Consideration of the adequacy of the assigned manpower was, therefore, part of the quarterly cycle for the base managers. Requests for additional manpower had to be submitted to Headquarters ADC at least 10 (Laboratory) days prior to the end of the quarter in order for the increase to become effective on the first day of the following quarter.

The only difference between the two systems in the quarterly routine was in respect to stock-level adjustments. In conformity with the policies established, LS-1 base managers were required to review all stock levels at least quarterly and they were encouraged to review them more frequently if necessary. Any changes indicated by these reviews were made immediately, of course. The LS-2 base managers, on the other hand, had no power to set or change stock levels, so this problem was not included in their quarterly tasks.

Factory

Each quarter, the factory had to make a report on the funds necessary to complete the orders received. In this report, Hi-Valu items were identified, while other items were grouped in their respective cost categories. A second quarterly report covered the funds expended to date. Like the first, this was divided into Hi-Valu line items, and the amounts spent in Categories II and III. A third quarterly report from the factory contained the number of routine, expedite, and superexpedite orders received. All these reports were submitted to the two Weapon System managers.

MONTHLY ROUTINE

LS-2 Hi-Valu Control

The bases in both systems, and the Weapon System Manager's organization in LS-1, had no strictly monthly routines. In LS-2, however, the monthly interval carried greater significance. For purposes of Hi-Valu control the DPC made a monthly print-out of the demand listing of each Hi-Valu item and projected future demands. These print-outs were the Hi-Valu Control Officer's main guides to procurement and supply action. By comparing the available stock of parts with the cumulative net system requirements shown in the monthly print-out, he could make procurement or deferment decisions. Similarly, by relating the projected requirements of an individual activity to its assets, he could discover the need for resupply actions. As the system's experience unfolded, the Hi-Valu Control Officer adjusted the original data on which the DPC computations were based. Whenever necessary, he altered the class of the item, lead time, percentage of repair done at base level, base and depot repair-cycle times, accident factor, wear-and-tear factor, base and depot wearout rates, new base aircraft status, phase-in schedules, applicability of item to aircraft series, and item's service-life estimate. Changes in one or several of these elements were worked into the DPC computations and appeared in the monthly Hi-Valu print-out. In this way, the Hi-Valu Control Officer kept a very close watch on his requirements and assets.

The DPC also calculated a Master Repair Schedule for Hi-Valu items. This MRS appeared in the monthly print-out, although it applied by quarter to the next 8 quarters of the operating program. Once this MRS was made, it was forwarded to the PRD Manager, who effected the day-to-day scheduling of repairs. In contrast with the Category II and III items, which were generally put through the PRD in economical repair batches, the Hi-Valu items were usually repaired immediately.

DAILY ROUTINE

LS-1 Weapon System Supply Manager and the Distribution Manager

The daily sequence of most activities in the experiment was generally

oriented around the receipt of daily reports or print-outs from the 704 or DPC. For both systems the arrival of these print-outs 10 minutes after the start of each simulated day signalled the beginning of managerial activity. In LS-1 the Distribution Manager at the storage site received a Daily Status Report and an Input-Output Listing. These reports contained most of the information necessary for the daily management of the storage site. For example, if the quantity of stock on hand or due-in happened to be zero, and if a Priority 1 demand was placed against the storage site, the Daily Status Report would contain a listing marked "Trouble." Under this heading the report would show the stock number, the warning point level and the minimum reserve level, and the serviceable balance and due-in quantity on the various contracts. The Distribution Manager would usually confer with the Weapon System Supply Manager about this condition and resolve the problem by expediting procurement, attempting to obtain repair of the item, or issuing a shipping order on some activity within the system. Daily Status Report print-outs similar to the one just described were also made for the LS-1 storage site whenever an item's warning point level or minimum reserve level was reached. If action was to be taken on the same day, instructions to the 704 had to be ready for pick-up and processing within 5 minutes of the original delivery of the Daily Status Report. Any machine instructions not collected at that time were picked up and processed the next day.

The Input-Output Listings provided the LS-1 Distribution Manager with information on all the orders received and the actions accomplished by the 704 in its relation to the storage site. In this way the Distribution Manager was able to follow through on any back orders, stock distributions, or disposals that he might have made. He could also check on any storage-site stock levels that he might have altered or on any procurements or amended shipping instructions (ASI's) that the Weapon System Supply Manager might have made.

Fulfilling TOC's was often a part of the Weapon System Supply Manager's daily routine. To make the required spares modifications he had to procure a sufficient quantity of TOC kits. He also had to see to it that the parts subject to TOC, and the kits required, were present at the right place at the right time. Once the TOC's were completed he had to calculate the

stock levels for the new items created by the change, revise the relevant stock numbers, and dispose of obsolete spares.

In the course of an ordinary day the Distribution Manager was generally concerned with shifting assets around within the system in order to get the most effective supply support, while the Weapon System Supply Manager was usually busy with problems arising between the system and the factory. Naturally there was a considerable amount of discussion between these two managers concerning ways of handling pressing or anticipated problems.

LS-2 Hi-Valu Control Officer and the Material Control Officer

The different logistics policies for LS-2 called for different daily routines. In LS-1 the Distribution Manager handled all categories of stock, while the Weapon System Supply Manager procured all categories. In LS-2, however, the Hi-Valu Control Officer had the task of distributing the Hi-Valu goods within the system, in addition to procuring them from the contractor. The Hi-Valu distribution and procurement policies have already been explained.² On the basis of the monthly print-outs the Hi-Valu Control Officer made his daily decisions to distribute, redistribute, expedite, or procure the necessary material.

Category II and III items were both distributed and procured by the Material Control Officer within the framework of the prescribed policies. Daily managerial action was required of him whenever a Critical Item Report was produced, signifying that some Category II or III item was in short supply in the system at large.³

Each day the Weapon System Manager received activity reports from the bases and IRAN. Relevant bits of this information were then channeled to the Hi-Valu Control Officer, the Material Control Officer, and the DPC for their respective daily uses.

The LS-2 TOC procedure was basically like that in LS-1, except for the division of responsibility and the stockage policy. In LS-2, the Hi-Valu Control Officer handled Hi-Valu TOC's, while the Material Control

²See Chap. 2, pp. 19-20, above.

³See Chap. 2, pp. 21-22, above.

Officer dealt with TOC's in the Category II and III area. In the case of stockage, both officers relied on the computations made by the DPC along the lines already described.

LS-1 IRAN

The LS-1 IRAN Manager's Daily Status Reports contained information, by flight number, on the time remaining to accomplish the maintenance, on the flight numbers awaiting parts, and on the time required to repair AOCP aircraft after parts became available. This report also showed when balances in the "Q" account reached zero. In this way the IRAN Manager could see whether or not material would be available to support his workloads. If no material was projected, or if aircraft became AOCP, he manually requisitioned stock from the storage site. Observed changes in his "Q" account balances tended to prepare him for revisions to projected material standards. The IRAN Manager was able to relieve serious AOCP conditions by cannibalization if other means were unavailable and if the Weapon System Supply Manager approved. He had to inform the 704 of aircraft starting through IRAN and of aircraft to be returned to their assigned bases after completion of IRAN.

The IRAN Manager in LS-1 also received a Daily Input-Output Listing reporting all actions taken by the 704 in his behalf. This was, virtually, a running account of his activity.

LS-2 IRAN

The IRAN Manager in LS-2 followed a daily routine similar to his LS-1 counterpart. Hi-Valu items required at IRAN were handled by the Hi-Valu Control Officer in accordance with prescribed distribution policies.

LS-1 PRD

In LS-1, the PRD Manager's Daily Status Report contained a variety of information on items scheduled for repair. It showed the number of items to be repaired, condemned, and not repaired because of unavailable

material; the labor standards for reparable items; accumulated repairs; accumulated condemnations; total of items scheduled; and status of items subject to TOC. As in the IRAN Daily Status Report, notice was given when items reached a zero balance in the "Q" account. The Manager reviewed this report daily to ascertain the passage of parts through the repair facility and to make requisitions on the storage site if necessary. He scheduled items for repair up to the full amount of his available man-hours and serviceable parts. He also coordinated with the Weapon System Supply Manager to schedule work on TOC's at the PRD.

The Daily Input-Output Listing received by the PRD Manager was identical with the ones described above.

LS-2 PRD

In function, the LS-2 and LS-1 PRD's were identical.

Bases

In contrast with the Weapon System Manager's office, where activities tended to be complex and varied, the base daily routines were simple and straightforward. They revolved around the receipt of daily reports. A Daily Base Status Report and a Daily Base Input-Output Listing were delivered at the same time as the AMA reports. The Daily Base Status Report showed a listing by flight number of the aircraft awaiting parts, the stock numbers and item identification numbers (IIN's) of the failed parts, the criticality of failures, the time required to repair failures, a listing of the aircraft awaiting time (in man-hours) to fix failures, the field-maintenance man-hour shortages for AOCP and nonstocked items, any extractions on the base, and any local manufactures accomplished. Also included was a summary of aircraft on alert, the accumulated flights, combat-ready aircraft, numbers of AOCP, AOCM, and ANFE aircraft, total assigned aircraft, and aircraft in IRAN. In addition to this, the Daily Base Status Report provided a statement of the flights required and scheduled by the Base Operations Officer, as well as the flights actually accomplished by the base. The Base Daily Input-Output Listing recorded

all action pertinent to the base that had been placed in, or accomplished by, the 704 or DPC on the preceding day. The base managers used these reports to follow by stock numbers and flight numbers the course of requisitions, shipping orders, receipts of materiel, back orders, TOC's, maintenance, IRAN's, etc.

Immediately after reviewing these reports, each base manager sent a daily status report of his own base to the Weapon System Manager's office. He also prepared any simple machine or DPC instructions or interrogations. The reports and forms prepared by the base managers were picked up approximately 5 minutes after the Daily Base Status Report and the Daily Base Input-Output Listing had been delivered. They were then screened and processed for use by the 704 or DPC.

The base managers ordinarily devoted the remainder of the day to considering means of handling actual or potential problems. They studied the possibilities of trade-off between expected supply time (perhaps including procurement time) and increased maintenance manpower expenditure, or a faster field-maintenance repair cycle, or cannibalizing, or using next-higher assemblies. They also changed stock levels where permitted, handled TOC's directed by the Weapon System Manager's office, and prepared the stated monthly, quarterly, and annual reports.

Though the base managers covered both the supply and maintenance areas, their maintenance tasks were not very demanding. Two levels—organizational and field maintenance—were established for base maintenance activity. Organizational maintenance consisted mainly of periodic inspections and removing and replacing failed parts. These activities were performed automatically by the 704, and no intervention by the base managers was required. Field maintenance was given responsibility for repair of base-reparable carcasses. Although the 704 automatically effected the repairs, the base managers in both logistics systems were responsible for determining and changing the priority of repair classes of base-reparable and base TOC items. Each stock item could be placed in one of 10 classes reflecting roughly its dollar importance. Priorities from 1 to 13 were then assigned to the classes. Depending on the prevailing stock level of its class, an item would be "repaired" in the 704 according to priority. A base manager exerted some control over the speed with which his base-

reparable or TOC items became serviceable by changing repair priorities or item classes. In this way he could assist his own base supply activity.

Some time during the Laboratory day, mail was delivered and collected. The mail usually consisted of higher-echelon orders or directives, correspondence with higher authorities, and memoranda about procedures or problems.

These routines were pretty much the same for the bases in both logistics systems. They differed only when the prescribed policies were different.

NOTE ON PAPER WORK

This description of logistics management in the Laboratory may give the impression that LP-1 was a virtual mountain of papers, reports, IBM cards, and calculations. It was. A complex logistics process cannot be managed without a vast amount of paper work. But the crux of the matter is that "paper pushing" must be controlled by a logical design so that it will serve, not swamp, the thinking of the managers. One of the principal efforts of LP-1 was to accomplish just that.

CHAPTER 4

RESULTS AND IMPLICATIONS

RESULTS

The original design of LP-1 provided for the two logistics systems to operate during 5 simulated years. Because of some difficulties described below, it proved impossible to reach that objective and only 14 quarters of weapon-system life were completed. In that time, however, all ten bases in each system were activated and both systems were run at a peak rate for $2\frac{2}{3}$ quarters. During the final 2 quarters, two bases in each system were phased out. While some of the phase-out problems had to remain unexplored, most of the important logistics questions could be dealt with in the first 14 quarters of the experiment. Furthermore, knowledge of the failures contained on the failure tape, combined with the pattern of operations through $3\frac{1}{2}$ years, permitted some estimates of performance through the remainder of the weapon-system cycle.

It will be remembered that LS-2 consisted of three proposed logistics policies: automatic resupply of Category II and III items to bases by means of a data-processing center, procurement and distribution of Category II and III items according to economical formulas, and deferred procurement of Category I (Hi-Valu) parts. Although these proposed policies were aggregated into a logistics system (LS-2) for purposes of the experiment, the accomplishments of this system were actually of less interest than the performance of the individual policies. For that reason, the policies will be analyzed separately, even though they undoubtedly interacted during the run.

Interpretation of Category II and III Results

The Category II and III policies incorporated in LS-2 proved highly successful. As shown in Table 1 and Fig. 4, LS-2 had only half as many

Table 1
PERFORMANCE SUMMARY FOR COST CATEGORIES II AND III
(14 quarters)

Performance Factor	LS-1	LS-2
Stockout days	7,936	3,513
AOCp days	4,886	1,853
ANFE days	1,502	1,275
Supply actions		
Priority 1	6,559	1,333
Priority 2	3,789	1,113
Priority 3	18,589	10,689
TOTAL	28,937	13,135
Man-hours accomplished		
PRD	36,000	30,000
Field maintenance	47,228	38,344
Spares expenditures (\$) ^a	2,191,811	2,227,472

^a Spares are reckoned at factory cost, which includes administrative costs, expedite charges, and production set-up costs wherever applicable.

stockout days¹ as LS-1. A similar relationship held with respect to AOCp days, since every stockout day implied at least one AOCp day. LS-2's advantage regarding ANFE days was not so great because of an error in the design of the factory.²

¹ A stockout day was tallied whenever an aircraft had no remaining maintenance time due and a part was missing from it. One aircraft would have more than one stockout day associated with it if more than one part was missing and the maintenance time due was zero.

² ANFE items were not given the same factory expedite treatment as AOCp items. This was an invalid discrimination, since ANFE items were just as effective as AOCp items in preventing aircraft from being combat ready. Because the policies generally indicated smaller procurements of the high-valued Category II items, LS-2 had to depend on a very responsive treatment by the factory. The factory records show that LS-2 made six times as many Category II expedite orders as LS-1. Since the expedite order was the fastest factory response allowed for ANFE items, LS-2 was in greater trouble as far as such items were concerned. Had the factory been more responsive, the LS-2 ANFE's in Category II would have been fewer.

Fig. 4—Cost Category II and III performance for 14 quarters

The LS-2 Category II and III policies employed automatic resupply. Some idea of their success, apart from the smaller number of stockout days, is conveyed by the noticeably fewer Priority 1 and 2 supply actions required in LS-2.³ It is also indicated by the fact that the LS-2 base managers made less than half as many "interrogations" of the machine for stock balances as the LS-1 managers.

The man-hours of repair accomplished were approximately the same for both systems.

Since each system spent about the same amount of money for medium- and low-value spares, it is clear that the LS-2 Category II and III policies were significantly superior to their LS-1 counterparts. On the basis of the

³Supply actions are receipts at an activity of shipments from the factory, the storage site, or other bases. Supply actions are a more accurate measure than the familiar requisitions because (1) in LS-2 some supply was effected automatically and without a requisition properly so-called, and (2) if only requisitions were tallied, the factory, which was really an integral part of the LS-2 supply system during the phase-in period, would have been discounted.

Laboratory experience, then, they seem to be worth considering for implementation. Automatic resupply, of course, has already been planned for or introduced in certain operations at Oklahoma City AMA, San Antonio AMA, and Warner Robins AMA, and some steps have been taken by the Air Force along the lines of the LS-2 policies by a "deeper" stockage of Category III items at real-world Air Force bases. But the LS-2 policies combined these features with new requirements computation techniques and a new form of support of maintenance facilities, and these were the truly novel aspects of the Category II and III experience in LP-1. A few examples will suffice.

First, systemwide demand data were combined with an individual activity's flying-hour program and its demand experience (if any) in order to derive a demand prediction for that individual activity. This contrasted with the 1956 method of predicting demand for an activity on the basis of *its* previous 6 months' experience. Second, IRAN and PRD were stocked like bases, so that the stock-control-level and reorder-level principle was applicable. This meant taking into account the prescribed demand and cost factors and not merely attempting to support those activities for a given period of time. Third, program factors were employed in the requirements calculations for Category III items, not only for bases but also for the IRAN and PRD as well. Thus, phase-in and phase-out requirements were explicitly accounted for whenever a Category III procurement was indicated. This, too, contrasted with LS-1's once-a-year Category III requirements computation. Fourth, the Category II and III policies were expressly designed to take advantage of the dynamics of the phase-in. As an integral part of the continuing requirements computations, any excess procurements for earlier aircraft series could be applied to later series, and deficiencies on earlier procurements could be made up on later contracts.

The comparative performance figures show that these and other departures from real-world (i.e., 1956 system) techniques were generally improvements. This certainly suggests that the Air Force might well consider moving even further along the LS-2 Category II and III lines than it already has. Of course, the details would depend on the particular environment. LP-1 showed that the basic concepts were sound.

Interpretation of Hi-Valu Results

Table 2 provides a summary of what happened in the Category I area during the peacetime phase of the experiment. Both systems had about the same number of stockout and AOCF days. LS-2 had almost three times

Table 2
PERFORMANCE SUMMARY FOR COST CATEGORY I
(14 quarters)

Performance Factor	LS-1	LS-2
Stockout days	2,003	2,154
AOCF days	1,524	1,571
ANFE days	161	436
Supply actions		
Priority 1	1,100	1,464
Priority 2	474	803
Priority 3	<u>1,505</u>	<u>1,517</u>
TOTAL	3,079	3,784
Man-hours accomplished		
PRD	108,206	119,305
Field maintenance	24,277	33,531
Spares expenditures (\$) ^a	904,572	517,127

^aSpares are reckoned at factory cost, which includes administrative costs, expedite charges, and production set-up costs wherever applicable.

as many ANFE days, largely because of a peculiarity in the factory design.⁴ The number of supply actions was practically the same and the man-hours of accomplished repairs were similar. For this same performance, however, the deferral policies of LS-2 used only about half as much money for

⁴The trouble here was the same as that encountered by the high-valued Category II items. (See footnote 2, p. 44.) The factory records show that LS-2 made many more Category I expedite orders than LS-1. A more responsive ANFE treatment would have reduced the number of Category I ANFE days in LS-2.

spares expenditures as the traditional policies. Moreover, this result was obtained under an extreme form of deferral that deferred procurement on *every* Hi-Valu part except one. With a selective policy, items with obvious operating-type characteristics would not be deferred initially and an even better record of performance versus spares costs could be expected.

Since the figures for spares expenditures were not taken directly from the Laboratory floor, but were obtained only after subsequent analysis, they deserve some comment. About half way through the run, it was discovered that the demand data supplied to RAND by the Air Force for the purpose of constructing the failure model did not reflect *actual* demand rates that had occurred in the real world, but were merely *estimates* for procurement. These estimates of demand rates proved as much as ten times higher than actual demands. Because the error could not be removed during the run, it was necessary to wait until the experiment was over before it could be corrected.⁵ This correction took the form of weighting the original spares expenditures figures—\$1,810,764 in LS-1 and \$1,974,984 in LS-2—to bring them into line with realistic, real-world demand rates. The rationale and technique used in the weighting procedure are presented in Appendix VIII.⁶

Although it was not possible to complete the entire phase-out portion of the experiment, it appeared that LS-2 would probably have ended the 20 quarters originally planned with fewer Category I spares excesses than LS-1. By applying the pre-established condemnation rate to the failures contained on the failure tape for the remaining 6 quarters, it was possible to estimate the drainage on the assets held at the end of the 14th quarter. It was discovered that of its ending serviceable and reparable inventory of \$1,472,633, LS-1 would have had approximately \$995,884 of Category I excess spares, with \$68,646 of procurements necessary. LS-2 had an ending inventory (serviceable and reparable) of \$1,185,380 and would have had about \$461,224 of Category I excess spares, with about \$13,955 of additional procurement needed. Although this calculation was made on the basis of inventories derived from the high demand rates, it showed

⁵The trouble was confined to Category I items and did not affect the performance of LS-1, relative to LS-2, in the medium- and low-cost-spares area.

⁶See p. 91, below.

that LS-2 was in much closer touch with the anticipated demands than LS-1; its Category I excess was only half that of LS-1.

Quite apart from the quantitative results, the Laboratory proved helpful to those responsible for designing and developing the LS-2 Hi-Valu policies. LP-1 offered the first occasion to reduce the general procurement deferral concept to a specific, detailed program. In spelling out this program, many problems were highlighted or solved. Three examples are worth mentioning here. First, for purposes of the experiment, it had been arbitrarily assumed that a straight, across-the-board buffer policy was feasible for all Hi-Valu items. During the run it became evident that discriminating policies were desirable. Such policies could presumably relate the size and makeup of the buffer stock to the service-life characteristics of the item and to the deployment of assets in the course of the base phase-in. These policies are now under development. Second, shortly after the experiment began, it became apparent that once a procurement had been made, it was unsatisfactory to rely on routine supply; some portion of the buy required faster treatment. A technique was therefore evolved for determining what amount of the projected ordered quantity should be expedited. Conversion of insurance- to operating-type items was a third case in which the Laboratory forced the LS-2 designers to innovate. At the outset of the run, the "class knowledge" of the Hi-Valu Control Officer was expected to provide him with sufficient criteria to determine whether or not an item should be designated as being insurance or operating type. During the run, however, more specific rules were needed. They were developed and, in practice, removed all uncertainty as to whether and when a conversion should be made. Clearly the Laboratory test developed experience of practical importance to the deferred procurement of Hi-Valu parts.

ESTIMATED IMPACT OF THE LS-2 POLICIES

As measured by performance against spares expenditures, the proposed policies demonstrated real superiority over the traditional policies. This judgment of success cannot be complete, however, without some assessment of the way in which other parts of the system were affected by these

proposed policies. The impact of these policies in the major areas of supply, maintenance, factory and procurement, and transportation will now be described.

Supply

In the supply area, several observations are possible regarding the effect of the proposed policies. For one thing, LS-2 tended to bypass its storage site by shipping factory procurements directly to other activities. As shown in Fig. 5 and Table 3, LS-2 sent roughly 89 per cent of its procurement

Fig. 5—Factory shipment by destination (all cost categories)

directly to using organizations, while LS-1 sent only about 2 per cent. This relation held for both the Category I and the Category II and III items. So far as factory shipments were concerned, then, the LS-2 policies obviously implied lower storage-site workloads. Factory shipments, however, did not constitute the entire storage-site activity. Shipments to other activities were also involved. (See Table 4.) In shipping from the storage site, there was much less LS-2 activity for Category II and III items. For Category I items, however, the number of shipments from the storage site was almost the same for both systems.

Some of the base-level supply burdens are indicated in the shipping and

Table 3
SHIPMENTS FROM FACTORY BY DESTINATION, COST CATEGORY,
AND PRIORITY
 (14 quarters)

Cost Category	Number of Shipments					
	LS-1			LS-2		
	Storage Site	Other Destination	Total	Storage Site	Other Destination	Total
Category I						
Priority 1	0	0	0	0	540	540
Priority 2	1	0	1	0	183	183
Priority 3	<u>573</u>	<u>8</u>	<u>581</u>	<u>33</u>	<u>189</u>	<u>222</u>
TOTAL	574	8	582	33	912	945
Category II						
Priority 1	9	12	21	6	247	253
Priority 2	33	0	33	157	441	598
Priority 3	<u>4579</u>	<u>71</u>	<u>4650</u>	<u>524</u>	<u>3044</u>	<u>3568</u>
TOTAL	4621	83	4704	687	3732	4419
Category III						
Priority 1	2	20	22	0	17	17
Priority 2	43	2	45	16	55	71
Priority 3	<u>2764</u>	<u>51</u>	<u>2815</u>	<u>293</u>	<u>3488</u>	<u>3781</u>
TOTAL	2809	73	2882	309	3560	3869
GRAND TOTAL	8004	164	8168	1029	8204	9233

receiving activity shown in Table 5. Shipments from bases were more numerous in LS-2, since the bulk of the LS-2 assets were held there; this larger number of shipments held uniformly for all three cost categories. But compared with off-base shipments, receipts of materiel form an important part, and a much larger part, of the base supply burden. In this respect LS-2 had more receipts in Category I, but far fewer in

Table 4
SHIPMENTS^a FROM STORAGE SITE BY COST CATEGORY
AND PRIORITY
(14 quarters)

Cost Category	Number of Shipments	
	LS-1	LS-2
Category I		
Priority 1	1,060	715
Priority 2	471	619
Priority 3	<u>883</u>	<u>1,106</u>
TOTAL	2,414	2,440
Category II		
Priority 1	3,044	524
Priority 2	1,610	321
Priority 3	<u>3,742</u>	<u>1,947</u>
TOTAL	8,396	2,792
Category III		
Priority 1	3,451	180
Priority 2	2,124	96
Priority 3	<u>7,147</u>	<u>538</u>
TOTAL	12,722	814
GRAND TOTAL	23,532	6,046

^aSince the automatic resupply feature in LS-2 precluded tallying requisitions, shipments are a better common measure of supply activity at the storage site for the two systems. Shipments in LS-1, incidentally, were about 65 per cent of the total number of requisitions submitted to the storage site.

Table 5
BASE SHIPMENTS AND RECEIPTS
 (14 quarters)

Cost Category	Number of Shipments		Number of Receipts	
	LS-1	LS-2	LS-1	LS-2
Category I				
Priority 1	40	209	1,060	1,255
Priority 2	2	1	471	802
Priority 3	41	189	891	1,295
TOTAL	83	399	2,422	3,352
Category II				
Priority 1	55	286	3,056	771
Priority 2	7	17	1,610	762
Priority 3	142	298	3,813	4,991
TOTAL	204	601	8,479	6,524
Category III				
Priority 1	13	76	3,471	197
Priority 2	0	10	2,126	151
Priority 3	93	557	7,198	4,026
TOTAL	106	643	12,795	4,374
GRAND TOTAL	393	1,643	23,696	14,250

Categories II and III. Figure 6 summarizes these materiel movements. The base-level receipts of Category I materiel must be seen in the light of the excessive demand rates, however.

Base-level issues were practically the same for both systems: 69,022 for LS-1 and 68,383 for LS-2. Since issues are almost directly related to flight operations, and since each system's flights were deliberately controlled, there was no possibility for a large difference in the number of issues. Incidentally, LS-1 made 145,942 flights during the peacetime phase of the run; LS-2 made 146,130.

Fig. 6—Materiel movements (all cost categories)

As a direct consequence of the proposed policies, fewer attempts were made by LS-2 to cannibalize parts or use next-higher assemblies in the Category II and III area. In Category I, the reverse was true and LS-2 resorted to more cannibalizations and use of next-higher assemblies than did LS-1. (See Table 6.) These differences seem to be a clear reflection

Table 6
ATTEMPTS TO CANNIBALIZE OR USE NEXT-HIGHER ASSEMBLY^a

Cost Category	Attempts To Cannibalize		Attempts To Use Next-higher Assembly	
	LS-1	LS-2	LS-1	LS-2
Category I	402	873	1	18
Categories II and III	1820	533	306	76
TOTAL	2222	1406	307	94

^aThese data cover only the first 11 quarters of the experiment.

of the proposed policies, although some moderation of the Category I figures might be expected with more realistic demand rates.

Table 7 indicates that at the base level the total warehousing costs did

not differ significantly between the two systems. Nor were the variable warehousing costs very different for Category II and III items. In Category I, however, LS-2 incurred variable warehousing costs not quite twice as large as LS-1. At the depot level, the total warehousing costs were almost two and a half times greater in LS-1 than in LS-2. LS-1 spent almost four times as much as LS-2 in warehousing its Category II and III items at the storage site; it spent twice as much in warehousing its Category I stock. These comparisons suggest slightly lower total warehousing expenditures under the proposed policies, but with a shift in emphasis toward the bases and away from the storage site.

Table 7
WAREHOUSING COSTS
(In dollars)

Type of Cost	LS-1	LS-2
Base Level		
Variable warehousing costs ^a		
Cost Category I	73,176	114,100
Cost Categories II and III	169,640	187,689
Issue charge ^b	69,022	68,383
Fixed charge	158,575	158,575
TOTAL	470,413	528,747
Storage Site		
Variable warehousing costs ^a		
Cost Category I	86,470	40,900
Cost Categories II and III	178,751	47,313
Fixed charge	56,000	56,000
TOTAL	321,221	144,213

^aIncludes charges for the value of inventory warehoused, charges for cubage space rented, charges for receipts, and charges for shipments.

^bAssumed to be \$1.00 per issue from base warehouses.

The LS-2 policies imply some change in the present Table II concept of initial base stockage. It was discovered, for example, that the average initial base stockage of Category I items was, in dollar terms, one third as much in LS-2 as in LS-1. In Category II, the average initial base stockage in LS-2 was a little more than half as much as in LS-1. In Category III, on the other hand, the average initial base stockage in LS-2 was 13 times greater than in LS-1. Table 8 and Fig. 7 portray the relevant figures and indicate the directions in which the LS-2 Hi-Valu or Category II and III policies would tend to change initial base-stockage volumes.

Table 8
AVERAGE INITIAL BASE STOCKAGE^a
(In dollars)

Cost Category	LS-1	LS-2
Category I	35,800	12,000
Category II	89,000	50,800
Category III	1,300	17,000
TOTAL	126,100	79,800

^aCovers materiel originally deposited at bases or delivered within the first 5 days of base activation.

Fig. 7—Average initial base stockage

Maintenance

As Table 9 indicates, the maintenance activity at base level was practically the same for both systems. At the depot level, however, LS-2 returned a somewhat greater value of items repaired, and incurred slightly higher costs.

Table 9
MAINTENANCE ACTIVITY: BASE AND DEPOT LEVEL
(14 quarters)

Maintenance Activity	LS-1	LS-2
Base level (field maintenance)		
Value of items repaired (\$)	1,502,176	1,424,857
Maintenance costs ^a (\$)	1,264,189	1,317,355
Value of bits and pieces used in repair (\$)	30,044	28,497
Man-hours of accomplished repairs	71,505	71,875
AOCM days ^b	36,214	35,384
IRAN days ^c	5,142	5,592
Depot level (PRD)		
Value of items repaired (\$)	2,637,363	3,247,263
Maintenance costs ^d (\$)	1,152,132	1,235,115
Value of bits and pieces used in repair (\$)	59,185	66,419
Man-hours of accomplished repairs	144,206	149,305

^aIncludes a per man-hour charge and a fixed charge.

^bRepresents the number of days that aircraft were grounded to perform base maintenance activity.

^cRepresents the number of days that aircraft were off base for depot overhaul.

^dIncludes a per man-hour charge, a fixed charge, and a charge for repairing nonbatch quantities.

The base-level relations were generally as expected, since most base maintenance resulted from flight activity that was, in turn, deliberately equalized for both systems. Beyond that, however, the base-level maintenance models were fairly loosely drawn; both systems were given the ability to repair almost all reparable immediately and with virtually no man-hour constraints.

At the depot level, the maintenance figures were more surprising, since it had been thought that some of the LS-2 policies would produce greater comparative maintenance burdens than the figures indicated. This did not happen because both systems were given a very short (1 month) repair cycle at the PRD. While this was in keeping with LS-2 policies, it provided LS-1 with a much more responsive maintenance network than was true for the real world. Thus, the comparative maintenance figures of Table 9 do not unequivocally reveal the impact of the LS-2 policies at the depot level. On the other hand, it can be said that without the high maintenance performance assumed, LS-2 would probably not have been able to live as "close to the vest" as it did with respect to Category I and high-valued Category II parts.

Factory and Procurement

In the factory and procurement area the impact of the LS-2 policies was expected to be considerable, since procurement was put on a generally continuous basis. The total number of shipments from the factory was indeed somewhat larger in LS-2 (see Table 3 on page 51), but most of the burden imposed by the proposed policies fell on the administrative and production-scheduling activity in the factory. As shown in Table 10, the number of Category I hi-priority and expedite orders was much larger for LS-2. Some of this difference was caused by the excessive Category I demand rates and some was due to the fact that the LS-1 managers adopted the policy of making very few hi-priority or expedite orders because they judged the costs to be too high in relation to the service. Keeping these two points in mind, however, the Category I hi-priority and expedite orders implied about 11.3 assembly-line disruptions per

Table 10
ACTIVITIES AFFECTING THE FACTORY

Activity	Number of Orders	
	LS-1	LS-2
Cost Category I orders		
Hi-priority	0	103
Expedite	1	55
Routine	<u>101</u>	<u>124</u>
TOTAL	102	282
Amended shipping instructions	0	52
Contract revision	28	140
Cost Category II orders		
Hi-priority	3	165
Expedite	46	241
Routine	<u>639</u>	<u>1297</u>
TOTAL	688	1703
Amended shipping instructions	1	617
Contract revision	92	441
Cost Category III orders		
Hi-priority	10	14
Expedite	4	45
Routine	<u>758</u>	<u>1295</u>
TOTAL	772	1354
Amended shipping instructions	17	422
Contract revision	152	105

quarter for LS-2, compared with almost no disruptions for LS-1. LS-2 also made many more Category I amended shipping instructions (ASI's) and contract revisions than did LS-1.

In Categories II and III, the relations were similar. LS-2 disrupted the assembly line on an average of 33.2 times per quarter compared with 4.5

disruptions for LS-1. As with Category I, LS-2 made considerably more ASI's and contract revisions. Figure 8 summarizes the total burden of factory orders by cost category.

Fig. 8—Factory orders (all priorities)

Communications to and from the factory were three times more numerous in LS-2 than in LS-1.

These data and observations suggest that the proposed policies used in LS-2 added something to the administrative burdens in the factory and procurement area.

Transportation

As had been anticipated, LS-2 depended on premium transportation much more than LS-1; its over-all transportation costs were about double those of LS-1. (See Table 11.) The largest part of this difference resulted from the use of the superpriority method by LS-2.

Table 11
TRANSPORTATION COSTS
(In dollars)

Priority Rating	LS-1	LS-2
Superpriority	21,200	84,100
Priority 1	42,354	27,738
Priority 2	4,475	11,776
Priority 3	<u>13,947</u>	<u>22,095</u>
TOTAL	81,976	145,709

LIMITATIONS AND CONCLUSION

In order to minimize the chances of misinterpreting the LP-1 results, it is necessary to note some of the limitations under which they were obtained.

In the first place, it was clear right from the start that the results obtained in the experiment would not have unqualified real-world significance. It was known in advance that certain features would limit direct extrapolation. Among these features were a parts sample composed only of airframe items; the deliberate "fixing" of the parts sample so that it did not contain the same cost-category proportions that exist in the real world; the conscious exclusion of a budgetary constraint on the managers; the specific form of the logistics-systems geography; the specification of the weapon-system life cycle; the more or less automatic nature of the maintenance models; and the provision of communication and DPC services without cost to the systems.

In the second place, because of time and money limitations, the experiment could be run only once. One may be strongly confident that the large factors of difference obtained in such a single run were significant; but a high level of confidence in less dramatic comparative results could develop only after a large number of runs.

Third, the standard of comparison—LS-1—was, and had to be, partly synthetic. Yet, even if it had been a perfect duplicate of the 1956 Air

Force system, any comparative results obtained in the experiment were automatically bound by that date. If the LS-2 policies proved conclusively superior to the 1956 policies in the Laboratory, they might not be equally superior to real-world policies operating, say, in 1958.

While these limitations had been foreseen, the actual conduct of the experiment revealed some unpredicted difficulties. The major trouble, which primarily affected the performance of the proposed Hi-Valu policies in LS-2, has already been discussed. Among the minor troubles encountered were some instances of erroneous experimental design, as, for example, when routine requisitions on the storage site were given priority over shipping orders from the Weapon System Manager's office; or when the transaction load exceeded the programmed machine capacity, causing some items to be omitted from reports or some requests to be ignored. Several essential reports and computations were not available in suitable form until some time after the run had begun, and these omissions caused trouble. In a few cases, managers used wrong procedures that resulted in program stoppages. And, of course, there were outright "machine" breakdowns.

Some of these problems were solved during the run;⁷ but others could only have been remedied in a repetition of the experiment.

Even with these reservations, however, the results obtained during the experiment have much bearing on the proposed policies. In addition, some of the mistakes made along the way were invaluable in producing a more finely developed end-product. The Laboratory offered an exceptional opportunity for isolating sources of trouble and, in this way, for understanding better the nature of the final results. Had LP-1 been a "Logistics Field Test 1" instead, isolation would probably have been much more difficult.

In conclusion, the Laboratory simulation showed that the LS-2 Category II and III policies gave about twice the performance as did the traditional

⁷This is not as easy as it sounds. Tracing down something as simple as a wrong input card might take only about a day of real time, but during that interval a Laboratory *month* might have elapsed. Since halting the run involved very high costs, there were few opportunities to wait for on-the-job repairs. On the other hand, not waiting resulted in additional problems.

policies for approximately the same spares costs. In the Hi-Valu area an unrealistic demand environment taxed both systems, but particularly LS-2. When the demand environment was adjusted, the LS-2 Hi-Valu deferred-procurement policy provided the same performance at about half the spares costs incurred by LS-1.

The benefits to LS-2 of centralized data processing and recordkeeping could not be isolated. But the provision of virtually instantaneous knowledge of systemwide assets contributed substantially to LS-2's achievements. The LS-2 policies reduced over-all supply burdens, increased factory-procurement activity, and posed greater transportation requirements. They also shifted warehousing costs away from the depot and toward the bases. No conclusion was possible regarding their impact on maintenance activities.

CHAPTER 5

SIMULATED WARS

Since the final test of Air Force logistics is combat capability, an evaluation of logistics policies should cover their wartime effectiveness. The two simulated logistics systems in LP-1 were, therefore, exposed to the stress conditions of simulated wars. The interest, however, was less in the actual simulation of war than in determining how well the bases of each system operated with only their own resources once the war began.

To bring wartime experience into the Laboratory without stopping the experiment, a flashback technique was used. After most of the peacetime run had been completed, the two systems were reset to conditions prevailing on some earlier day. The war then "broke out," and the systems operated according to the commands and alternatives given to them. This approach avoided disrupting the peacetime weapon-system cycle and breaking the important part of the regular run into disconnected parts.

Two wars occurred during the experiment. Each lasted for 10 (Laboratory) days. One took place without warning at the beginning of the second year; the other occurred early in the third year and was preceded by a brief time of international tension and alert status for the activities of the systems. The details of these simulated wars are classified.¹ Nevertheless, their general outlines can be described here, along with the way in which the various logistics policies reacted to the assumed stresses.

WAR 1

Assumed War Conditions

The first war occurred fairly early in the weapon-system phase-in. The

¹See R. M. Rauner, *Laboratory Evaluation of Supply and Procurement Policies: The First Experiment of the Logistics Systems Laboratory* (U), The RAND Corporation, Report R-320, July, 1958 (Confidential), pp. 63-81.

AMA, the factory, the transportation system, and one base in each logistics system were assumed to have been destroyed by an enemy force using high-yield weapons. Local airlift was available to effect interbase shipments; the surviving communications network (radio and courier) was simulated by telephone lines.

With the outbreak of war the failure model was adjusted to reflect wartime demand rates, a wartime aircraft attrition rate was applied, and the maximum possible sortie rate was scheduled by the Base Operations Officer.

Results

The only limitation on flights made by each system was combat-ready aircraft. LS-2 had a higher combat-ready rate than LS-1 for the 10 days of war and therefore accomplished more flights. It was able to do this because of the smaller number of AOCP days associated with Category II and III items. This result was a clear reflection of the superiority of the proposed Category II and III policies. AOCP days caused by Category I items were, in LS-2, almost double the number experienced by LS-1, however. This also reflected the proposed deferred procurement policy and indicated that without depot support, severe operational stress during the early stages of the weapon phase-in could cause trouble. The shipping activity between bases, incidentally, was slightly higher in LS-2 than in LS-1.

The field-maintenance activity was practically the same for both systems. LS-2 had substantially fewer cannibalizations, however, because of the better supply support given the maintenance operations in Categories II and III.

Because its policies prescribed heavier base stockage, LS-2 lost less Category II and III inventory when the depot was destroyed. Therefore its bases had more of such inventory on hand when the war broke out. As has already been noted, this was the main cause of LS-2's lower AOCP rate. In Category I, LS-2 also lost less inventory at the depot, but because of deferment its bases had less Category I inventory on hand at the start of the war.

WAR 2

Assumed War Conditions

The second war was designed to differ from War 1 in two major respects. First, it was to occur a year later in the weapon-system cycle, meaning that the systems would have a chance to phase in more bases and to grow in logistics experience. Second, it was to be preceded by a short period of warning, meaning that the systems would have some time to take preparatory measures for war. In other respects the two wars were practically the same: the AMA, the factory, the transportation system, and several bases were assumed to have been destroyed; local airlift was available for interbase shipping; courier and radio communications were simulated by telephone lines.

Results

In War 2, LS-2 had a slightly higher combat-ready rate than LS-1 and also made more flights, although its advantage in both respects was not as great as it had been in the first war. LS-1 apparently was able to derive more than LS-2 from the year's logistics experience between the two wars. This enabled LS-1 to provide notably improved supply support and, thereby, to draw closer to LS-2's combat-ready rate than it had in the first war. As in War 1, the LS-2 Category II and III policies were the major factor that kept its combat-ready rate above the LS-1 rate. Although deferred procurement had practically ceased by the time of War 2, the LS-2 Hi-Valu policies still were not as effective as the LS-1 policies. Their poorer performance was due mainly to inadequate provisioning of one particular part and to a peculiar distribution policy adopted for the Laboratory but not inherent in the concept of deferred procurement itself. The interbase shipping activity reversed in War 2, with LS-1 making more shipments than LS-2.

The field-maintenance activity again was almost the same for both systems. LS-2 still had fewer cannibalizations than LS-1, but the difference was not as great as it had been in War 1. This came primarily from LS-1's improved Category II and III support in the maintenance area.

The inventory losses were smaller in LS-2 than in LS-1, but the difference was much less than in the first war because during the interwar and warning periods LS-1 had distributed its depot materiel more widely than it had in the year prior to War 1. The LS-2 policies, of course, had already effected a generally broad distribution of stock.

With the portrayal of both the peacetime and wartime portions of LP-1 now complete, it is possible to summarize their results. This will form the subject of the next chapter.

CHAPTER 6

CONCLUSION

This report has described the way in which several proposed logistics policies operated within a simulated logistics environment of peace and war. The time has now come to draw together the various conclusions that emerged from the experiment.

In comparison with the traditional (1956) Air Force practices, the proposed Cost Category II and III policies (including automatic resupply) were demonstrably superior during the peacetime phase of the experiment. For approximately the same spares expenditures, they produced less than half as many stockout days, AOCP days, and supply actions as the contrasting system, and slightly fewer ANFE days. The burdens on the storage site and base-level supply activities were also smaller under the proposed policies, although the factory was taxed somewhat more. The warehousing costs were slightly higher at base level, but substantially less at the storage site.

In the Hi-Valu spares supply area, once allowance was made in analysis for an unrealistic demand environment, the proposed deferred procurement policy gave just about the same figures for stockout days, AOCP days, and ANFE days as the 1956 policies, but at roughly half the spares costs. The impact of the proposed policies appeared in a somewhat greater stress on the factory than under the traditional policies, while the base- and depot-level supply activity was about the same. Warehousing costs were higher at base level, but lower at the storage site. Some moderation of these impacts could be expected with a more realistic demand environment, however. Because they had not been modeled with sufficient realism, no final conclusion was possible about the effect of the proposed policies in the maintenance area. It was clear, however, that deferral of procurement implied a very short repair cycle.

After the simulated raids of the two wars, the proposed Category II

and III policies preserved much more inventory intact and performed much better than the traditional policies. Their degree of superiority was less in the second war, however, largely because LS-1 gained relatively more from the operational experience of the interwar period.

The proposed Category I policies did not obtain the same performance level as the LS-1 policies in either of the two wars. In the first war, procurement deferral was still in process and much less inventory on hand in LS-2 led to more Category I AOC days for LS-2 than for LS-1. This poorer performance, of course, was one of the admitted risks implicit in the basic deferral concept used in the Laboratory. In the second war, deferral had practically ceased and the performance degradation should have been minimal. The LS-2 Hi-Valu policies still produced more AOC days than the LS-1 policies, however. The reasons were a poor provisioning of one part and a peculiar distribution policy adopted for the experiment but not inherent in the concept of deferred procurement.

These, of course, are only the principal conclusions with regard to the tested policies. The Laboratory made it possible to arrive at a tentative evaluation of the proposed policies quickly and cheaply compared with an actual service test. Justification of the policies, however, was not the sole purpose of the experiment. LP-1 provided those who designed the policies with an opportunity to specify, improve, and develop their designs; it gave those who observed the simulation valuable insights into the Air Force logistics process. While these developmental and educational effects are much harder to document than quantitative results, they are no less important. It is safe to say that the Laboratory experiment increased and sharpened logistics knowledge.

APPENDIX I

PROGRAM MODEL

The basic operational and logistical programs of LP-1 were the aircraft production and delivery schedules, base activations and utilization, flying hours, aircraft attrition, alerts, and inspections. They were applicable to both logistics systems.

As noted in the text, the aircraft was assumed to be a fighter-interceptor type in two series, F-1-C and F-1-D. The production and delivery schedules were set so as to equal the amount of aircraft required to satisfy base activations plus attrition during the production period. An average of 17 to 18 aircraft per month was produced and/or delivered during the 15-month production period. This satisfied the cumulative requirements for 261 F-1-C's.

The first five bases of each logistics system were equipped with the F-1-C exclusively. These bases phased in at the rate of one per quarter, and they received their aircraft in two monthly deliveries of sufficient quantity to establish the total base complement of 50 aircraft (25 aircraft per squadron), plus any attrition that might have occurred. The last five bases of each system were activated at the rate of one per quarter starting in the second quarter of the second year of the experiment. These bases received F-1-D's in quantities and according to delivery schedules identical with the earlier series.

The flying-hour program was critical to the over-all design of LP-1. In the first place, such a program was required for planning in the provisioning, supply, and maintenance functions of the floor organizations. In addition, the program afforded means for controlling the experiment, since it could be managed in such a way as to ensure that both systems would achieve approximately the same operational objective.

The first step in the construction of the flying-hour model was to determine the monthly flying-hour program. On the basis of studies previously

made for real-world aircraft roughly similar to the F-1-C and F-1-D, it was decided that 18 flying hours per month per aircraft for the first year of operation (of an aircraft series) was a representative program figure. For the second and later years, 20 flying hours per month per aircraft was established. The total monthly flying-hour program was obtained by multiplying the number of aircraft in the system's inventory by the relevant flying-hours-per-month figure. This program was then automatically apportioned to the operating bases in terms of their assigned aircraft. Two aircraft per squadron were required to be on 5-minute alert at all times and were, therefore, not available for ordinary training flights. Theoretically, a base with 50 assigned aircraft in its first year of activation would have a monthly flying-hour program of $(50 - 4) \times 18 = 748$ flying hours.

The next step involved the reduction of the flying-hour program to individual base daily sorties. In real life, the number of hours actually flown are ordinarily fewer than the number stipulated in the original flying-hour program. This slippage is due to causes ranging all the way from poor supply and maintenance support to strikes and bad weather. It is particularly acute during the phase-in of a new aircraft, when engineering changes are frequent. For obvious reasons it was desirable that the flying-hour model reflect this real-world discrepancy between programmed and accomplished flying hours. But it would have been extraordinarily difficult to model *all* of the causes that keep bases from meeting their flying-hour programs. Therefore, the scheduling of base daily sorties was made a top-deck, instead of a base-level, function. A so-called Base Operations Officer of the simulated ADC controlled the daily sortie schedule as a means of reaching the base flying hours that were to be accomplished. The extent of the discrepancy between the flying-hour program and the flying hours scheduled was determined in advance and was derived from a study of operations at Air Force bases. Thus, a simulated base with a monthly program of 748 flying hours might have been scheduled to fly only 540 hours in a month, even though an average of 40 aircraft were combat ready, which should have permitted 720 flying hours (40×18 hours per aircraft per month). If necessary, the Base Operations Officer rationalized this discrepancy to the base managers in such terms as

"inclement weather," "lack of pilots," "strike of tower personnel," "shortage of fuel," etc. If a particular base seemed to be falling behind in its flying-hour program by more than the predetermined discrepancy, the Base Operations Officer would call this fact to the attention of the base manager. He, in turn, would presumably undertake supply or maintenance action to try to increase the number of combat-ready aircraft on his base. Such action, of course, would show up as either depot requisitions or utilization of maintenance manpower.

Every flying day of the experiment was divided into four 2-hour periods. Available aircraft were limited to a maximum of four training flights per day. The duration of all sorties was set at $1\frac{1}{2}$ hours, with the remaining $\frac{1}{2}$ hour of each 2-hour period allotted to preflight and postflight inspections, fueling, etc. The range of sorties scheduled per base per day lay between 7 and 70. The Base Operations Officer scheduled the number of sorties for each 2-hour period at each base by submitting cards to the 704. If the aircraft were available, the 704 printed out a statement of the number of sorties actually made during the day and thus served notice to the Base Operations Officer that his scheduled flights had been accomplished. If sufficient aircraft were not available at a particular base, even taking into account the previously calculated difference between the flying-hour program and scheduled flights, the shortage was due to poor supply or maintenance action. The 704 then informed the Base Operations Officer of such an aircraft deficiency. If this deficiency caused the number of sorties to fall short by more than 25 of the number of sorties scheduled for that base, then the Base Operations Officer instructed the delinquent base (by means of the 704) to fly the maximum number of sorties with its available aircraft. This arrangement continued until the scheduled and accomplished flights were once more equivalent. As before, the effort to achieve the flying-hour program showed up in the supply and/or maintenance area. At the same time, by his power to control the number of flights made by each base in each logistics system, the Base Operations Officer ensured that each system had roughly the same operational experience by the end of the run. This expedient was designed to facilitate analysis of the experiment.

Two other fixed elements of the flying-hour program were "cocked

pistol" alerts and Operation Readiness Inspections (ORI's). Cocked-pistol alerts were of 1 day's duration and were scheduled twice a year at each base. During such alerts all combat-ready aircraft were grounded except those used for interceptions. The number of interception flights scheduled by the Base Operations Officer ranged between 0 and 8, and these were credited to the basic flying-hour program. The number of hours lost from normal training flights because of cocked-pistol alerts was made up as soon as practicable after the termination of each alert.

Operation Readiness Inspections were of 2 days' duration and were scheduled one per year for each base. The base managers had no fewer than 2 or more than 5 days' advance notice of such ORI's. They were empowered to add either 2 or 4 hours of organizational maintenance overtime at the end of the last day before the scheduled exercise. This overtime continued through the second day of the exercise, after which normal hours returned. During the ORI's a maximum effort in terms of hours flown was required. Usually, between 68 and 80 daily base sorties were scheduled.

The last of the program inputs was the attrition of aircraft. A rate of 1 aircraft lost per 3000 flying hours was in force for the first year's operation of each aircraft series. During the second and later years the rate was set at 1 aircraft per 4000 flying hours to reflect the presumed improvement in the pilots' abilities and familiarity with the aircraft.

In summary, the program inputs of the experiment were designed to subject each logistics system to approximately the same operational requirements. The costs of achieving this objective would measure effectiveness.

APPENDIX II

PARTS SAMPLE

If anything like the real number of line items in a current weapon system had been brought into the experiment, the four or five people who made up the LP-1 Weapon System managers' offices would have been overwhelmed with work. Therefore, it was necessary to build a parts sample that afforded representative coverage of a real-world weapon system, but was still small enough to fit the capacities of the simulated organizations.

The parts sample was limited to airframe spares. Data on airframe parts were taken from the North American F-100D. About 50 line items having individual demands of at least 10 or more during the period from April 1, 1955, to June 30, 1956, were chosen from the *Worldwide Stock Balance and Consumption Report* for this aircraft. With the aid of the F-100D Illustrated Parts Breakdown, the next-highest assemblies that contained the original 50 items were selected. Then, all the F-100D peculiar line items contained within these assemblies were drawn; vendor-manufactured parts and nonprocurable parts were omitted. The final collection numbered about 731 items and constituted what was called in the experiment the F-1-D aircraft. One series change was incorporated. This was made by taking from the North American F-100C Illustrated Parts Breakdown the comparable F-100D figures used for the initial (F-1-D) sample. After some necessary adjustments and substitutions, a second sample was derived covering what became the first series of aircraft, the F-1-C. This sample consisted of 707 items. Six hundred and nineteen of these were common to the F-1-D as well. Ultimately, the two series of aircraft each contained 49 major assemblies, of which 33 were common and 16 were unique.

The final list of sampled parts was not chosen at random. Studies have shown that about 90 per cent of airframe line items have 0 or 1 demand

per 1000 aircraft months.¹ Application of this demand pattern to the sampled parts would have produced relatively little demand experience in the Laboratory. Therefore, items with a higher demand rate than normal were oversampled. This oversampling resulted in a total demand for the sampled parts that was greater than would have been true for a representative sample of airframe parts chosen at random. Similarly, it is known that approximately 3 per cent of all airframe line items fall in the Cost Category I (Hi-Valu) region.² If this distribution had been used, the managers' Hi-Valu experience would have been meager. In order to enrich that experience, the Hi-Valu items were deliberately oversampled and constituted about 7 per cent of all the sampled parts. Cost Category II items formed about 46.5 per cent and Category III items, about 46.5 per cent.

The Technical Order compliances used in the experiment were drawn from a review of published Air Force Technical Orders on the F-100. Unfortunately, the published Technical Orders and the LP-1 sampled parts did not correspond in every case. Therefore, available Technical Orders were applied to similar sample parts whenever possible, but in some instances they were fabricated from a general knowledge of previous modifications. Fifteen of the 25 TOC's were scheduled for the F-1-C; the remainder applied to the F-1-D.

A catalog was printed for the use of the participants. This was the official identification list of all spare parts, and it provided information for classifying material, requisitioning parts, and establishing, maintaining, and reporting stock record data. It was the official source of information for organizational, field, and depot levels of maintenance and gave the various managers a method for determining the maintenance hierarchy for any failure that might occur. It also contained information necessary for the establishment and utilization of maintenance record data.

¹M. A. Geisler and J. W. T. Youngs, *Predictability of Demand for B-47 Airframe Spare Items*, The RAND Corporation, Research Memorandum RM-1300 (ASTIA No. AD 85488), August 14, 1954.

²*The Selective Management of Air Force Materiel*, Report No. 6 of the Spares Study Group, HqAMC, November 27, 1956, p. 41.

APPENDIX III

FAILURE MODEL

The purpose of the LP-1 failure model was to create a realistic demand environment for the two logistics systems. The model was required to provide a history of flying-hour activity, along with the dates, quantities, and part numbers of items failing throughout the entire life of the weapon system. It was not easy to meet this objective, since the data needed were not readily accessible in Air Force statistics. Only for higher-priced items were detailed and current consumption figures available. For Cost Category III, consumption data are compiled only at the end of a 1-year period, and few, if any, systemwide totals of these data exist for the life of a real-world weapon system. For these reasons it was necessary to piece together from isolated special studies, covering relatively brief periods of time, the demand data on which the complete failure model was built. While this introduced some distortions, it made the model more realistic and relevant than one based on purely hypothetical parameters.

Three criteria were established for the failure model: (1) The total quantity of spare parts and maintenance man-hours consumed at both base and system levels were to be primarily a function of the number of hours flown.¹ (2) Consumption or issue rates for individual items were to reflect insofar as possible the real-world experience over time of the items included in the parts sample. (3) Variability of issue rates for individual items was to be a function of (a) flying-hour programs; (b) predictable elements, such as time-change requirements and IRAN schedules; and (c) empirical measures of such unpredictable events as changes in types of mission, altered experience of flight and maintenance crews, and waves of inspections and replacements that follow the occurrence or detection of one or two failures.

¹B. B. Brown, *Characteristics of Demand for Aircraft Spare Parts*, The RAND Corporation, Report R-292 (ASTIA No. AD 107426), July, 1956.

The first step in the construction of the failure model was to specify the number of "discrepancies" occurring by quarter in each of the 65 different major assemblies included in the parts sample. A discrepancy was defined as the failure of one or more sampled parts within a major assembly. A discrepancy rate for each major assembly per 100 flying hours was derived from four factors: (1) the current consumption rates on F-100 parts used for requirements computations at Sacramento Air Materiel Area as of December, 1956; (2) additional discrepancies due to time-change requirements for items within major assemblies; (3) average service-life estimates reflecting the increased consumption rates of aging parts within major assemblies; and (4) simulated TOC's affecting worldwide consumption. The total number of discrepancies expected for each major assembly, by quarter, through the life of the weapon system was obtained by multiplying the discrepancy rate by the number of hours scheduled to be flown. Since the discrepancies derived by this calculation were related to flying hours and predictable causes, it was necessary to adjust them to reflect nonflying hours and unpredictable causes. This adjustment factor was obtained from a study of the quarterly fluctuations in demand for 50 major assemblies in the C-47 aircraft. For example, the expected discrepancies in, say, the twenty-first major assembly for the second quarter of the Laboratory run might be 2 on the basis of predictable causes, such as flying hours, time-change requirements, and TOC's. The C-47 data, however, might show a sudden increase in demands for parts in the equivalent of the second quarter of operation and indicate that these parts were contained within the C-47 equivalent of the simulated twenty-first assembly. If 5 discrepancies were recorded in the real-world data and if this number were substantially different from the mean quarterly demand for the relevant C-47 major assembly, the extent of the deviation could be determined and then applied to the Laboratory discrepancies. As adjusted, the discrepancies modeled for the twenty-first simulated assembly in the second quarter might be 4 instead of 2. In this way, the Laboratory discrepancies were the result of both predictable and unpredictable demand fluctuations.

The next step was to distribute the discrepancies among the ten bases of each logistics system. The purpose here was to simulate realistic quarter-

to-quarter variability of demands for particular assemblies within bases, and to simulate interbase demand differences for individual assemblies throughout the weapon-system life. The latter was deemed especially important for taxing the distribution capabilities of each logistics system. The C-47 data, which covered demands from twelve bases for 50 major assemblies during 12 quarters, were used as the basis for this distribution. Ten of the real-world C-47 bases were matched with the ten LP-1 bases, and the systemwide quarterly discrepancies were allocated to the LP-1 bases accordingly. Thus, to use the previous example, if 4 actual discrepancies were to occur in the twenty-first assembly in the second quarter, and if the distribution between C-47 bases matched with two of the LP-1 bases showed the proportions 0.300 and 0.700, 1 of the 4 discrepancies would occur at one base and 3 at the other. Whenever necessary, this discrepancy distribution was modified to account for assemblies peculiar to either one of the aircraft series.

Since quarterly demands for assemblies at a base are not randomly distributed among the working days of a quarter, it was necessary to employ patterns of daily demand drawn from real-world experience. The only data of suitable detail for this purpose were obtainable from a study of the daily demands for B-52 airframe parts at Castle AFB. After reducing the Castle data to the Laboratory time scale and after selecting some 200 of the higher-demand line items, distributions were made of the quantity of B-52 items demanded for a period corresponding to 30 Laboratory days. These distributions were then applied by a random-sampling technique to the LP-1 assemblies to give the actual base daily discrepancies through Laboratory quarters.

The next step was to assign the base daily discrepancies to flights. This was accomplished by drawing at random from the flights scheduled for a particular day and base those flights on which discrepancies were to occur. No more than 1 discrepancy in the same assembly was permitted, although a given flight might have discrepancies in several assemblies. A study of F-100 bases had disclosed that approximately 25 per cent of airframe discrepancies required immediate maintenance, while the remaining 75 per cent were deferred until the 50-hour periodic inspection. A similar distinction was made in the failure model. For each discrepancy

scheduled to occur on a flight, a draw was made from a 25-75 dichotomy; those falling in the 75 per cent portion were set aside until the first periodic inspection occurring after the draw.

Component-part failures were assigned to major assembly discrepancies on the basis of a conditional probability of failure. Conditional probability of failure was taken as that proportion contributed by an item to the sum of the demand rates for all the parts in the assembly. Each time that an assembly discrepancy occurred, its entire list of component parts was sampled until at least one was shown to have failed. For example, the twenty-first major assembly might contain five parts with respective demand rates of 5, 3, 2, and 0 per 100 flying hours. If this twenty-first assembly was drawn for a discrepancy on a given base, day, and flight, its five parts would be sampled with the probabilities of drawing the first part 5, the second 3, the third 2, and the last two 0 out of 10 times. The level of repair of failed items was previously determined in the construction of the parts sample. Therefore, in the event that the first sampling revealed the failure of a depot-reparable item, or of an item that could not be removed from the assembly at base level, that item, or the removable next-higher assembly in which it was contained, was "shipped" to the PRD. These parts or assemblies were compiled in a list according to the probabilities of failure known to exist at a PRD, and this list was then sampled to determine additional failures at the depot level. This second sampling was designed to reflect the higher consumption rates experienced when a more complete inspection and overhaul was made. After collecting all the failures determined by the first and second samplings, a third sampling was made to determine whether the failed items were to be condemned or whether they were to be repaired at the appropriate level.

A relatively simple model was constructed to generate the failures when an aircraft underwent IRAN. This was possible because the real-world IRAN demand for parts is closely related to the number of aircraft being processed. The failure probabilities were obtained from a study of available F-100 material standards and estimates made by a representative from the Sacramento Air Materiel Area. When an aircraft entered IRAN its entire list of parts was sampled and failures were determined according

to their Sacramento IRAN failure probabilities. The list of parts failing at IRAN was then sampled to determine their condemnation-reparability status.

The entire failure-model outputs were contained in the IBM 704 tapes. The results appeared in the information given to the respective base, PRD, and IRAN managers during the experiment.

APPENDIX IV

FACTORY MODEL

The factory that was simulated in LP-1 consisted of a factory manager, several clerks, and a person to represent the Air Force Procurement Division. Its purpose was to "manufacture," control, and cost the materiel ordered for the bases and storage sites in each logistics system. Tables, files, and other records showing the times and costs required to manufacture and deliver items included in the parts sample were built up from information provided by North American Aviation, Inc. In addition to providing lead times and cost information to the Weapon System managers, the factory model ordinarily simulated the manufacture and deliveries of originally contracted items and quantities. On direction, it also amended contracts to increase or decrease the quantities of provisioned spares, amended contracts to change the urgency of orders, and changed delivery schedules on any change orders.

Three levels of responsiveness were stipulated: (1) Routine orders were scheduled for production and delivered to the shipping dock after the normal materiel procurement and production lead times had elapsed. (2) Expedite orders were available in approximately 40 per cent less time than routine materiel procurement lead time and in 60 per cent less time than routine production lead time. These expedite schedules applied to both lot-produced and continuously produced items. (3) Hi-priority orders, which were limited to the satisfaction of AOCP conditions, were met on schedules specified for continuous or lot production. After a hi-priority order was received, one continuously produced item was taken from the factory buffer and was made available for delivery at the beginning of the third (Laboratory) day after the order was received. Thereafter, continuously produced items were expedited in steps of 25 per cent of normal daily production rates for the first month, 50 per cent for the second month, 100 per cent for the third month, and 200 per cent for the fourth

and later months. A specified number of lot-produced items were available for shipment from the factory buffer at the beginning of the third day after receipt of the hi-priority order. If more than these amounts were required, the items were produced out of cycle and required the full hi-priority materiel procurement and production lead times.

In order that the Weapon System managers might be aware of the increase of factory costs and prices once the aircraft went out of production, a "day of decision" was determined as not less than 30 days prior to the scheduled acceptance of the last aircraft on the production contract. The managers were required to place orders for materiel before this day of decision or suffer the higher costs for future orders. A schedule of charges covering the three cost categories was provided to show the difference between in-production and out-of-production costs.

The factory published a schedule of costs for using expedite and hi-priority orders. These costs were designed to cover the longer hours of work, higher wage rates, increased planning and programming, higher raw-material prices, and disruption of production caused by such orders. They were expressed as percentage increases of factory unit costs for corresponding percentage increments of existing production rates.

Termination costs were laid down for the cancellation of an order. These varied with the length of time for which work had been in process. A flat charge was made for processing any amended shipping instructions sent to the factory.

All of the factory operations and costs were common to both logistics systems. Each had recourse to a specified quantity of items in the factory buffer stock. In addition, if it so desired, LS-2 had the special privilege of requiring the factory to establish a larger buffer stock. Appropriate charges were levied against LS-2 for this convenience, of course.

APPENDIX V

TRANSPORTATION MODEL

The transportation system simulated in the experiment consisted of four major categories: mileages, transit times, rates, and classification ratings. The figures used in each category were developed from published data or from special studies. Thus, highway mileage tables provided the information necessary to establish the transit times and some of the rates. Studies of the length of time required to process documents through a shipping activity and to move materiel from a shipping to a receiving activity formed the basis for calculating transit delay times. After these delay times had been reduced to the Laboratory time scale, a schedule was drawn up indicating the over-all time required to ship between any of the simulated activities. These times were figured in relation to three modes of transportation: commercial air, motor truck, and rail. The managers therefore had a choice among the fastest, medium, and slowest transit times. On the basis of published classifications, individual motor and rail-freight ratings were assigned to each part in the catalog. Expressed as percentages, these ratings were then applied to the standard published freight rates in order to find the transportation cost of shipping any item. Air cargo shipments are not subject to classification in the real world, so it was necessary to obtain air rates for sampled parts from the Air Force district traffic officers in whose territory the simulated activities were located. These air rates were those in effect between the nearest commercial airport and the shipping and receiving activities; they included charges for any ground transportation and handling.

Ordinarily, the supply priorities of stock items determined the proper mode of transport. Transit delays were automatically inserted between a requisition or shipping order and receipt by another activity. Provision was made, however, for a superpriority transportation mode to be used for any AOCP item. If the most expeditious means available involved more

than 1 day's transit time from origin to destination, this superpriority mode could be employed. Such shipments were considered as if they had been handled in private or leased vehicles between the shipping activity and the airport or truck-rail depot of the carrier providing the fastest transit time. Similar handling was provided between the carrier's terminal and the receiving activity. The over-all transit time was rarely more than 1 day whenever this superpriority mode was used. A flat charge for the faster service was levied on top of the published rates between the carriers' airports or depots.

APPENDIX VI

IRAN-PRD MODEL

Inasmuch as LP-1 was concerned primarily with the effectiveness of supply support, the maintenance facilities were not modeled to the same degree of detail as the supply activities. Nevertheless, realism was required in the maintenance activities. The data for real-world IRAN and PRD flow times, material standards, labor standards, overtime, costs, and parts-repair batch sizes were provided by a maintenance specialist from San Bernardino Air Materiel Area. As in the case of the other models, they were then reduced to the Laboratory time scale.

The IRAN facility simulated in each logistics system was not designated for operation until the beginning of the second year of the run. The schedule of IRAN due dates for the first year of its activity was determined in advance. Thereafter, the IRAN manager, in conjunction with the base managers, was responsible for the preparation of the IRAN schedule. His constraints were a 1-year average IRAN cycle, a standard flow time through IRAN of 1 month (i.e., 10 Laboratory days) per aircraft if parts were available, and a limit of no more than 4 aircraft per base to be in IRAN at any one time. Aircraft destined for phase-out within 6 months after the IRAN due date were excluded from the schedule. Within IRAN, the manager was given authority to work 1 extra day overtime per month. This maximum of 3 overtime days per quarter could be expended at any time during the quarter, but unexpended overtime could not be accumulated for use in succeeding quarters. Requests for overtime had to be made before the fifth day of the quarter if authorization was to become effective by the tenth day of the quarter. This was a simulation of the delays encountered in the real world in securing extra manpower or overtime shifts. Any additional IRAN overtime beyond the authorized 3 days per quarter required approval from AMC. A flat charge of \$10,800 was made for each extra IRAN day used by either system; no less than full IRAN shifts were permitted.

The actual IRAN was effected within the IBM 704, which automatically removed, inspected, repaired, or replaced the necessary parts or assemblies. This was done according to the instructions given by the program tape. A so-called "Q" account was established from which the material required to complete the IRAN was drawn. The IRAN Manager's role was essentially one of informing the 704 of aircraft scheduled to go into and out of IRAN and of seeking to correct anticipated or actual stock shortages in the IRAN "Q" account.

The PRD for each logistics system was modeled to work under the constraints of available manpower and available serviceable parts to be used in repairs; i.e., the PRD Manager scheduled work for parts repair on the basis of the labor standards previously established for each reparable item. Therefore, once the required parts were available and once the total labor standards of parts scheduled for repair equalled the total number of man-hours available, the PRD was deemed working at full capacity. A "Q" account was established for the PRD from which material could be drawn to effect the necessary repair. Manpower estimates were made by the PRD Manager on the basis of a Master Repair Schedule prepared for him by higher authority. He was permitted to work overtime at a rate of 2 per cent of the total assigned daily man-hours. These overtime hours could be worked at any time during the quarter, but no carryover to later quarters of unused overtime was allowed. Overtime at the PRD was charged at the rate of \$4.50 per hour, compared with \$3.00 per hour for regular assigned manpower. As with the IRAN, requests to higher authority for additional overtime or changes in manpower allocation had to be made before the fifth day of a quarter if such requests were to be honored by the tenth day of that quarter.

Once the PRD Manager informed the 704 that parts were awaiting repair, the rest of the process was handled automatically. If parts were available to the "Q" account, after the appropriate delay, the machine notified the manager that an item had been repaired and returned to the system's serviceable stock.

APPENDIX VII

IAM MODEL

Like its real-world counterpart, the IAM model used in LP-1 was designed to put a dollar price tag on supply and maintenance inventories and transactions. One immediate purpose of the model was to supplement the manager's item data with convenient dollar summaries of the serviceable, reparable, and TOC inventory positions for the three cost categories, as well as to indicate how these inventories were affected by increase and decrease transactions during an interval. The IAM Model was also designed to facilitate and enhance both current and post-experiment analysis.

The IAM model contained merely the main features of the real-world system. Instead of the 120-odd IAM codes used to generate real-world IAM reports, only seven codes were established for the experiment. These codes were used to produce reports suitable for both the floor managers and the LP-1 analysts. The seven codes covered increase transactions (i.e., receipts, turn-ins from maintenance, and adjustments) and decrease transactions (i.e., shipments, issues to maintenance, adjustments, and disposal). The 704 kept track of these transactions by item. At the end of each quarter, the items recorded were multiplied by their catalog price to give the total dollar value of the particular transactions. These results were then presented to the activity managers as IAM Reports and showed how the serviceable, reparable, and TOC inventory in each cost category had changed since the previous report. Quarterly issues as shown in the Quarterly Stock Balance and Consumption Report were also priced out and presented so as to indicate the change from the issues of the previous quarter.

At the depot level, the IAM Reports were intended to assist the managers in a number of ways. For example, by comparing the dollar value of issues with the dollar value of the stock control levels shown in

the report, a manager could determine the accuracy of his levels; by comparing issues with inventory, he could test the adequacy of those inventories. Similarly, a comparison of the dollar value of the stock control level with inventories provided a picture of what ought to be on hand with what actually was on hand. Any serious discrepancies discovered in these comparisons might occasion some kind of management action.

Along with the IAM Reports, an Annual Segmentation Report was prepared, which summarized by dollar value the major requirements and the support available in on-hand (serviceable or reparable) or on-order inventories to meet these requirements. The main use of the Annual Segmentation Report was to provide the managers with a picture of how well they were prepared to meet their future requirements.

At the base level the IAM Reports had the same format as the depot-level reports. The base managers were thus given a dollar picture of their various inventory balances as well as the dollar value of their quarterly issues. From these data they were able to infer how well their stock control levels, inventories, and issues were balanced, as well as the way their maintenance (i.e., reparable inventory build-up) program was operating.

All of these IAM Reports were prepared for the activity managers in both logistics systems. It was clear from the policy differences, however, that they would have much less meaning and utility for LS-2 than for LS-1.

Although other types of data were planned for use in the LP-1 analysis (e.g., combat-ready-aircraft days, AOCP days, AOCM days, stockout days, spares expenditures, maintenance costs, transportation costs, and holding costs), it was also determined that some of the IAM data described above would be employed for analytic purposes. Specifically, the dollar value of receipts from the factory, inventories required and retained on hand to accomplish mission requirements, total system assets distributed between base- and depot-level activities, serviceable shipments to base activities, reparables shipped to the PRD, material expended in repair, serviceables returned from repair, and excess items shipped to Disposal—all of these items were recorded. When the changes in these inventories and transactions were related to other costs and performances, a comparison of the two systems' inner workings emerged.

APPENDIX VIII

WEIGHTING PROCEDURE FOR DEMAND INPUT

Deferred procurement rests on two basic ideas: (1) low-demand items will ordinarily outnumber high-demand items; and (2) since at the time of initial provisioning it is impossible to distinguish high- from low-demand items, it is sensible to wait until these characteristics become apparent before committing large amounts of money to spares purchases. When these two thoughts are combined, it is clear that if little or no money is spent on what subsequently turns out to have been the low-demand items, that money will have been saved and released for use elsewhere. If deferral has been practiced on some items that turn out to have high demand frequencies, no harm will have been done. The eventual knowledge of these high-demand items will permit a more sensible buy. In the meantime, of course, support through the factory will have caused some expedite charges and other costs. But these will normally be far less than the money saved on deferral of the low-demand items.

Now it is obvious that the cost of deferred procurement will become exorbitant if demand frequencies are generally and uniformly high. There will then be no means of saving enough money on deferral of low-demand items to offset the cost of supplying high-demand ones. This is precisely what happened in the Laboratory when unrealistically high demand rates were incorporated into the failure model.

Since the F-100 aircraft had formed the basis of the LP-1 parts sample,¹ it was possible to identify the extraordinary nature of the demand environment by comparing the proportions of real-world and Laboratory items having various issue frequencies. The extent of the Laboratory deviation from real-world demands for the F-100 aircraft is shown in Table 12, and the pattern is portrayed in Fig. 9. It can be seen that in the real world approximately 60 per cent of the F-100 Hi-Valu parts had zero issues in

¹See Appendix II, p. 75, above.

100,000 flying hours, while in the Laboratory only 15 per cent of the Hi-Valu parts had issues as low as this. At the other end of the scale, only 1 per cent of the F-100 parts were issued more frequently than 100 every 100,000 flying hours, while 15 per cent of the LP-1 parts had this high issue frequency.

Table 12

COMPARATIVE PROPORTIONS OF REAL-WORLD AND LABORATORY
HI-VALU ITEMS BY CONSUMPTION CLASS

(1) Consumption Class (issues per 100,000 flying hours)	(2) Percentage of F-100 ^a Hi-Valu Items	(3) Percentage of Laboratory Hi- Valu Items	(4) Cumulative Per- centage of F-100 Hi-Valu Items	(5) Cumulative Percent- age of Laboratory Hi-Valu Items
0.0-1.0	60.1	15.1	60.1	15.1
1.1-2.5	10.6	3.8	70.7	18.9
2.6-5.0	11.4	3.8	82.1	22.7
5.1-12.5	8.1	15.1	90.2	37.8
12.6-25.0	4.6	17.0	94.8	54.8
25.1-50.0	3.4	18.8	98.2	73.6
50.1-100.0	0.7	11.3	98.9	84.9
>100.0	1.1	15.1	100.0	100.0

^aTaken from the F-100 *Worldwide Stock Balance and Consumption Report* for February, 1957.

When the originally recorded expenditures of each logistics system in each of the consumption classes are compared (see columns 5 and 6, Table 13), it is evident that the deferring system (LS-2) spent less money than the 1956 system so long as demand frequencies were relatively low (i.e., no more than 12.5 issues per 100,000 flying hours, or the first four classes cumulated in column 1, Table 13 on page 94). Once the frequencies became higher (i.e., the last four classes, column 1, Table 13), however, the balance turned the other way and the deferring system spent more

money. Since the lower-consumption classes in which LS-2 spent less money than LS-1 corresponded to approximately 90 per cent of the F-100 items (see columns 4 and 5, Table 12), there was a clear need to find out what would have been spent by both systems if the real F-100 consumption class proportions had been present in the Laboratory failure model.

Fig. 9—Real-world (F-100) and Laboratory Hi-Valu issue rates

To estimate how much LS-2 would have spent if the real-world demands had been used, the expenditures on spares falling in each of the eight consumption classes were multiplied by a weighting factor (see column 4, Table 13). This weighting factor represented how many times the respective F-100 consumption class proportions were greater or less than their counterparts in LP-1. The results of weighting are given in columns 7 and 8 of Table 13. When these weighted expenditures were totaled, they showed that LS-2 spent \$517,128 compared with \$904,372 for LS-1.

Table 13
COMPARATIVE WEIGHTED AND UNWEIGHTED HI-VALU EXPENDITURES BY CONSUMPTION CLASS

(1) Consumption Class (issues per 100,000 flying hours)	(2) Percentage of F-100 Hi-Valu Items	(3) Percentage of Laboratory Hi-Valu Items	(4) Weighting Factor	(5) LS-1 Unweighted Expenditures (\$)	(6) LS-2 Unweighted Expenditures (\$)	(7) LS-1 Weighted Expenditures (\$)	(8) LS-2 Weighted Expenditures (\$)
0.0-1.0	60.1	15.1	3.98	71,074	20,919	282,875	83,258
1.1-2.5	10.6	3.8	2.79	53,800	12,775	150,102	35,642
2.6-5.0	11.4	3.8	3.00	21,753	8,302	65,259	24,906
5.1-12.5	8.1	15.1	0.54	476,985	281,286	257,572	151,894
12.6-25.0	4.6	17.0	0.27	209,853	303,662	56,660	81,989
25.1-50.0	3.4	18.8	0.18	234,189	428,354	42,154	77,104
50.1-100.0	0.7	11.3	0.06	206,772	204,400	12,406	12,264
>100.0	1.0	15.1	0.07	536,339	715,286	37,544	50,070
TOTAL	100.0	100.0		1,810,765	1,974,984	904,572	517,127

APPENDIX IX

LP-1 PERSONNEL

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