THE SORTIE-GENERATION MODEL SYSTEM
VOLUME I
EXECUTIVE SUMMARY

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John B. Abell

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LOGISTICS MANAGEMENT INSTITUTE
4701 SANGAMORE ROAD
WASHINGTON, D.C. 20016

PREFACE

This volume is the first of six volumes that describe the LMI Sortie-Generation Model System. Volume I, Executive Summary, discusses the problem the system is designed to address and provides an overview of the principal parts of the system. Volume II, Sortie-Generation Model User's Guide, provides sufficient information to allow a user to run the Sortie-Generation Model (SGM). Volume III, Sortie-Generation Model Analyst's Manual, describes the mathematical structures, derivations, assumptions, limitations, and data sources of the system at a very detailed level. Volume IV, Sortie-Generation Model Programmer's Manual, specifies the details of the computer programs, file structures, job control language, and operating environment of the system. Volume V describes the maintenance subsystem and explains the construction of the maintenance input file to the SGM. Volume VI describes the spares subsystem and shows a user how to build the spares file that is used by the SGM.

Potential users are cautioned that no volume is intended to provide, by itself, all of the information needed for a comprehensive understanding of the operation of the SGM.

ACKNOWLEDGMENTS

I am indebted to Professor Edward J. Ignall of Columbia University for his many imaginative contributions to the formulation of the Sortie-Generation Model; to Professor Louis W. Miller of the Wharton School, University of Pennsylvania, who first suggested the basic structure of the multiple-server queueing system incorporated in the model; to Professor John A. Muckstadt of Cornell University for his helpful suggestions early in the model's development; and to my colleague at LMI, Mr. David L. Goodwin, who contributed greatly to the software development.

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VOLUME I

EXECUTIVE SUMMARY

THE RESOURCES-TO-READINESS ESTIMATION PROBLEM

A problem of significant concern to the DoD is a general inability to relate resources to readiness. By readiness we mean the ability of military forces to carry out their assigned missions. Military readiness is currently a principal focus of Congressional attention. In the FY 78 Defense Authorization Act, the Congress stipulated that, "The budget for the Department of Defense submitted to the Congress for fiscal year 1979 and subsequent fiscal years shall include data projecting the effect of the appropriations requested for materiel readiness requirements." The technical difficulties in appropriating and allocating resources in ways that most enhance the readiness of our military forces lie in measuring readiness and quantifying the effects on readiness of varying levels of support resources.

In this volume, we present an overview of a hybrid analytic/simulation model, the LMI Sortie-Generation Model (SGM), and its supporting software system. The SGM models the basic processes that translate resources to readiness. It is designed to estimate the effects of varying levels of certain classes of resources on the readiness of tactical fighter forces.

THE DIMENSIONS OF READINESS

Military readiness has two dimensions. One has to do with the responsiveness of a military force. This particular dimension of readiness is especially important to a "one-shot" kind of threat. The readiness of an air defense force against a manned bomber threat, for example, depends heavily on its initial responsiveness to an attack. The requirement for massive, quick response, given minimal warning, characterizes some air defense scenarios. An interesting contrast in readiness is provided by a prolonged interdictive campaign conducted by tactical fighters. The dimension of responsiveness is still present but another dimension, that of sustainability, clearly dominates the assessment of the readiness of the force in question.

The Tactical Fighter Case

In the case of tactical fighter aircraft, the most direct and meaningful measure of readiness is maximal sortie-generation capability across time. It reflects both responsiveness and sustainability. The SGM produces a sortie-generation profile, i.e., the average number of sorties flown on each wave each day over the duration of a scenario of interest, where the average is taken over some specified number of experimental replications.

THE SORTIE-GENERATION MODEL SYSTEM

The SGM system consists of the SGM itself and a rather complex system of supporting software the purposes of which are:

a. To provide a means for allocating budget resources to recoverable spares procurement and repair that takes explicit account of the military essentiality of weapon systems.

b. To construct data files to support the SGM that reflect maintenance manpower authorizations, maintenance performance, spares distribution by weapon system by base, and aircraft characteristics and distribution by base.

c. To construct notional air bases that are typical of a weapon system in the sense that they possess aircraft, maintenance manpower, and quantities of spares such that they will support analyses that may be extended directly to a force of aircraft of a given model/design (MD).

d. To preprocess and distill data from a variety of standard Air Force data systems for use by the SGM.

The software system is shown graphically in Figure 1. It consists of two subsystems, the spares subsystem and the maintenance subsystem. Data and resource allocations from the two subsystems are combined in data bases that are used as input to the SGM.

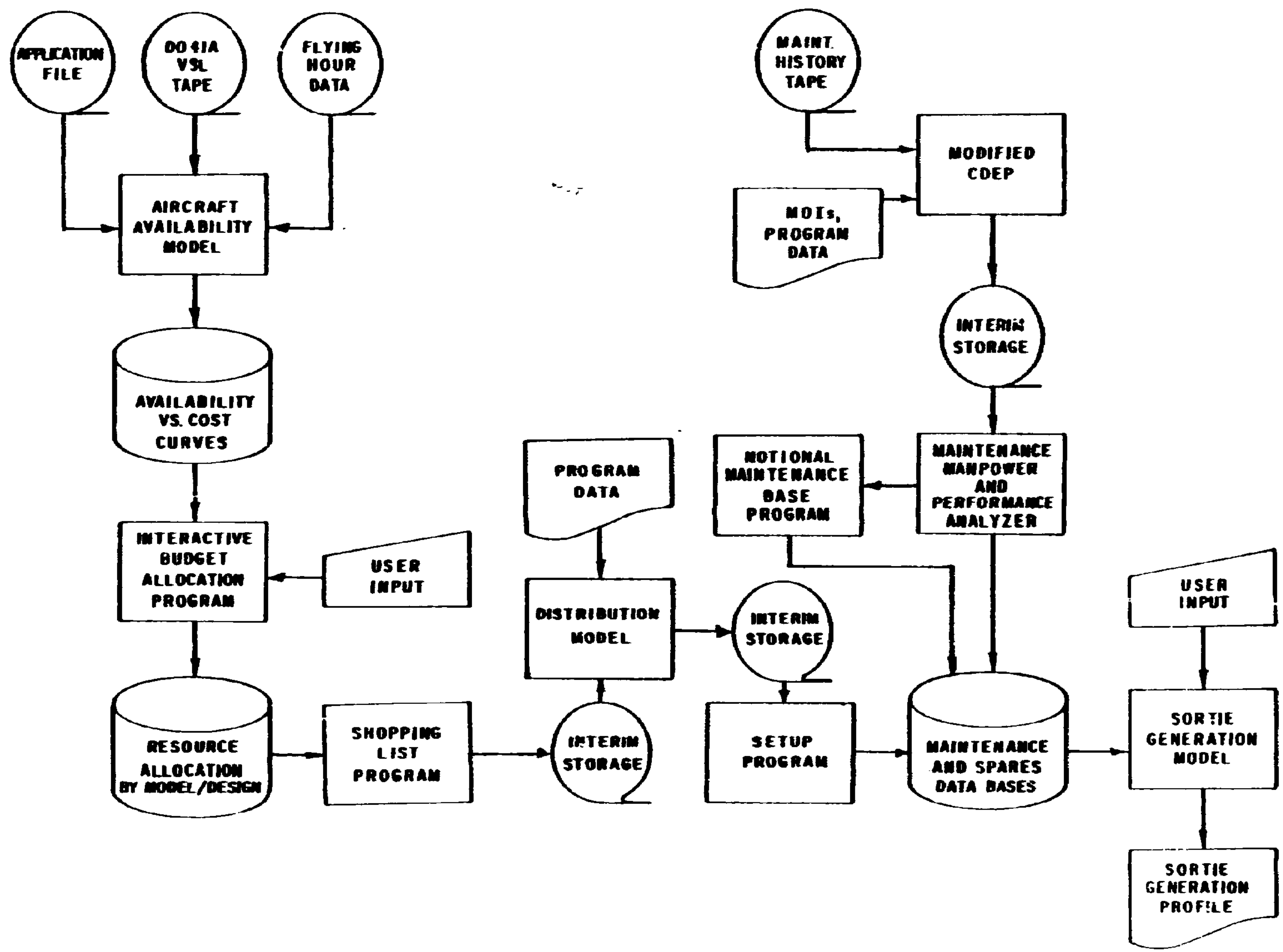


FIGURE I
SORTIE-GENERATION MODEL SYSTEM

The Aircraft Availability Model

The SGM builds upon and extends the LMI Aircraft Availability Model, a state-of-the-art, multi-echelon inventory model developed, validated, and refined at LMI over a period of several years. In the SGM system, it is the means by which budget resources are allocated to procure recoverable spares and to fund depot-level repair of recoverable spares. The Availability Model produces an availability-vs-cost curve for each model/design (MD) aircraft in the Air Force inventory (e.g., F-4 or B-52), for each model/design/series (MDS) such as F-4D or F-4E, or for any combination of MDs and MDSs. Given the assumptions made in the model, each point on the curve is an optimum, i.e., it represents the least-cost mix of spares and depot-level repair for that level of aircraft availability and it also represents the maximal availability achievable for that total cost of procurement and repair.

The input data for the Availability Model are derived from the Air Force Logistics Command's D041, D041A, and K004 data systems. They specify, for each recoverable item in the system, the current worldwide asset position including war reserve stocks, failure factors, pipeline times, flying hour programs, item application by weapon system, base repair fractions, item unit costs and repair costs, and other factors that affect the resource allocation solution and resulting mix of spares. The Availability Model takes explicit account of item commonality, i.e., the application of a component to more than one kind of aircraft, and also estimates the effects of lateral resupply. It is, in short, a powerful, flexible, resource allocation tool for recoverable spares procurement and depot-level repair.

The Interactive Budget Allocation Program

This program enables a user to specify the amount of money he wishes to allocate to each MD. The program enables the user to choose an availability increment or a budget increment, either positive or negative, and will display the current budget allocation and availability for each MD and will also display the new budget allocation and availability that would result from application of the increment to each MD. It also keeps track of and displays the total amount of budget dollars allocated to the entire force; that total includes the sum of procurement dollars and depot-level-repair dollars and the two values are optimized beyond the control of the user.

The most important feature of the interactive program is the ease with which a user is able to allocate resources across a rather large number (roughly 40) of different MDs in a way that takes military worth explicitly into account. For any specified budget or availability increment, the user is able to see exactly what his tradeoff opportunities and costs are at any point in the decision process.

When the user has allocated a budget, the program stores the results of his final decision so that, at any future time, the set of spares by stock number and the detailed depot-level-repair program may be produced.

The Shopping List Program

The output of the interactive budget allocation program, a function of the user's allocation decisions, is subsequently operated on by a program called the Shopping List Program that uses it to extract from the Availability Model output the quantity of spares of each component that results from the decision process and the set of availability-vs-cost curves that were input to the interactive program. Thus, the Shopping List Program produces a worldwide stockage level for every recoverable component in the Air Force system.

The Distribution Model

The Distribution Model operates on the output of the Shopping List Program. Its purpose is to find the distribution of stock levels for all items among all bases and the depot such that the value of expected base-level backorders is minimized. The Distribution Model takes explicit account of the worldwide distribution of aircraft by MDS and their collocation by base.

The output of the Distribution Model is a file of recoverable spares ordered by stock number that reflects their allocation to the depot and all bases world-wide. This file reflects directly the input budget originally allocated by the user of the Interactive Budget Allocation Program.

The Setup Programs

The file that is constructed by the Distribution Model becomes input to one of two Setup Programs. The purpose of the Setup Program is to translate the Distribution Model output into a spares posture for a particular base or a notional base. A notional base is one whose sortie-generation performance is typical of that of all bases equipped with a specified MD aircraft in the sense that, when multiplied by the number of bases with that aircraft, the sortie-generation profile approximates the total of the profiles at all the bases.

The Maintenance Subsystem

The maintenance subsystem serves several purposes. First, it translates maintenance actions recorded in the Air Force maintenance data collection system from work centers to Air Force Specialty Codes (AFSCs) that designate the specific skills of maintenance personnel. Second, it translates Unit Manning Documents (UMDs) into a number of authorized maintenance crews in each work center. Third, it determines the proportion of sorties that generate maintenance in each work center. Fourth, it calculates the service rate for each work center, i.e., the average number of aircraft completed per hour by a crew.

The maintenance subsystem consists of two major sets of programs. The first consists of a software system originally developed by the Air Force and modified by LMI called the Common Data Extraction Programs (CDEP). This software accepts as input Maintenance Operating Instructions (MOIs) and maintenance history tapes from Air Force bases and the Air Force Program Document (PD). The MOIs show the work-center-to-AFSC relationships at the base; the maintenance history tape contains six months' maintenance data from the base; and the PD shows the distribution of aircraft by MDS among all the bases. This set of programs produces an output tape that contains work-center-to-AFSC mappings along with maintenance manhour and performance data.

The second major set of programs reads the output tape from the first set, data from the unit manning document, and the number of sorties flown during the same time period to which the maintenance history tape applies. It then produces the data file that is input to the SGM. This final data file is a remarkably distilled record of a very large amount of data from a variety of sources; yet, it captures the key descriptors of maintenance capability. It contains, for each work center, the number of maintenance crews authorized, the service rate, and the proportion of sorties flown that induce the need for corrective maintenance by each work center, i.e., the work-center break rate (not to be confused with the aircraft break rate, a distinction that is clarified later).

The Sortie-Generation Model

The SGM is a hybrid analytic/simulation model that requires as input the spares file, the maintenance file, and scenario characteristics specified interactively by the user. It then estimates maximal sortie-generation capability across time as a function of those inputs.

The program requires the user to specify the scenario characteristics. Some of the scenario characteristics can be specified such that they are different for each day. Those that can vary by day include:

a. The number of waves or flying periods during the day.

b. The attrition rate (i.e., the probability that an aircraft is lost in combat).

c. The number of aircraft in reserve.

d. The maximal number of aircraft to be flown. This characteristic can also vary by flying period.

e. The ground abort rate.

Other scenario characteristics remain the same throughout the scenario. Those include:

a. The first and last takeoff times of the day.

b. The sortie length.

c. The minimal time required to launch an aircraft following corrective maintenance.

d. The aircraft break rate (i.e., the probability that an aircraft returning from a sortie cannot fly another sortie without corrective maintenance).

e. The initial number of UE (unit equipment) aircraft.

f. The number of days in the scenario.

g. The number of simulation replications desired.

h. Indicators that specify whether maintenance manpower and/or spares are to be constrained or unconstrained.

i. An indicator that specifies whether reserve aircraft are to be committed when available or to be used only as replacements for attrition losses.

The user must also specify the names of the spares and maintenance input files.

The SGM models the transition of aircraft from one state to another at discrete points in time. The day is divided into periods of time and the transitions occur at the points of division shown in Figure 2.

The states include:

a. Mission-capable

b. Maintenance

c. Not mission-capable, supply (NMCS)

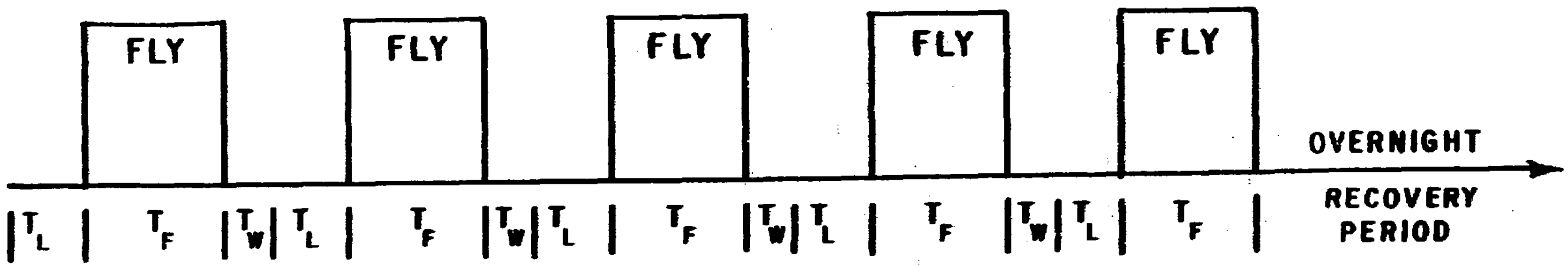
d. Combat loss

e. Reserve

A graphical depiction of the flow of aircraft among the states is shown in Figure 3. The probabilities of transition from state to state are resource-dependent.

A sortie-generation profile that is typical of those estimated by the SGM when resources are unconstrained is shown in Figure 4. Figure 5 shows a similar profile but with serious resource constraints. Figure 6 shows the profile with the addition of a two-percent aircraft attrition factor. These profiles resulted from a scenario that required five mass launches each day. The distribution of sorties flown across the five periods within a typical day for the profile of Figure 4 is shown in Figure 7. (The vertical scales in Figures 4 through 7 have been omitted for security reasons.)

It is important to note that the SGM can be run interactively; its running time is fairly short, allowing a user to examine a wide range of scenarios, factors, aircraft types, etc., in a short time. (It requires about six CPU minutes on a Honeywell G-635, for example, to run 40 replications of a 30-day scenario for a 72-UE tactical fighter wing.)



T_L = MINIMAL TIME TO LAUNCH GIVEN A MISSION-CAPABLE AIRCRAFT

T_F = SORTIE LENGTH

T_W = WAITING TIME (FIXED BY NUMBER OF PERIODS, FIRST AND LAST TAKEOFF TIMES, T_L AND T_F)

FIGURE 2

A TYPICAL FIVE - PERIOD FLYING DAY

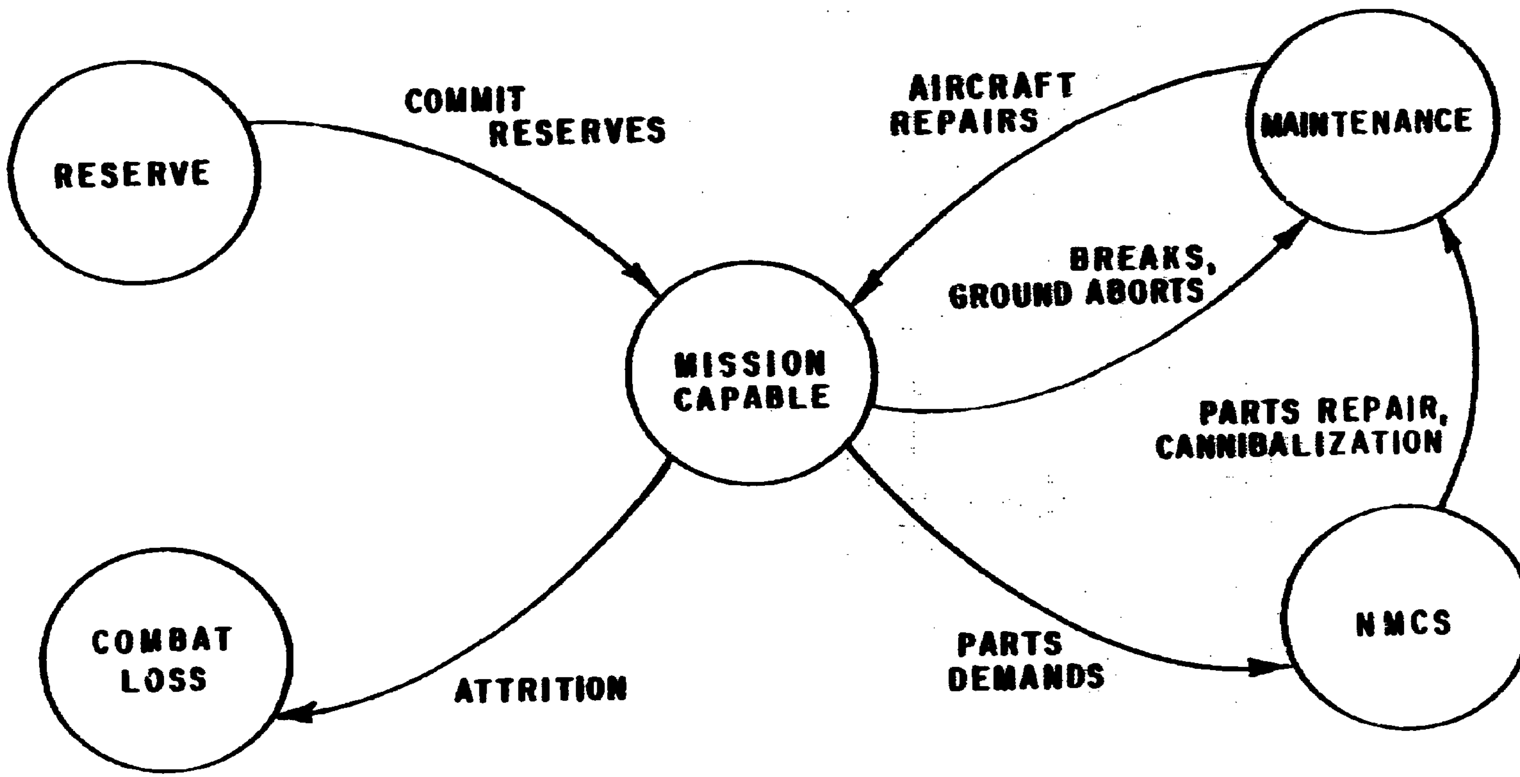


FIGURE 3

SGM STATES AND FLOWS

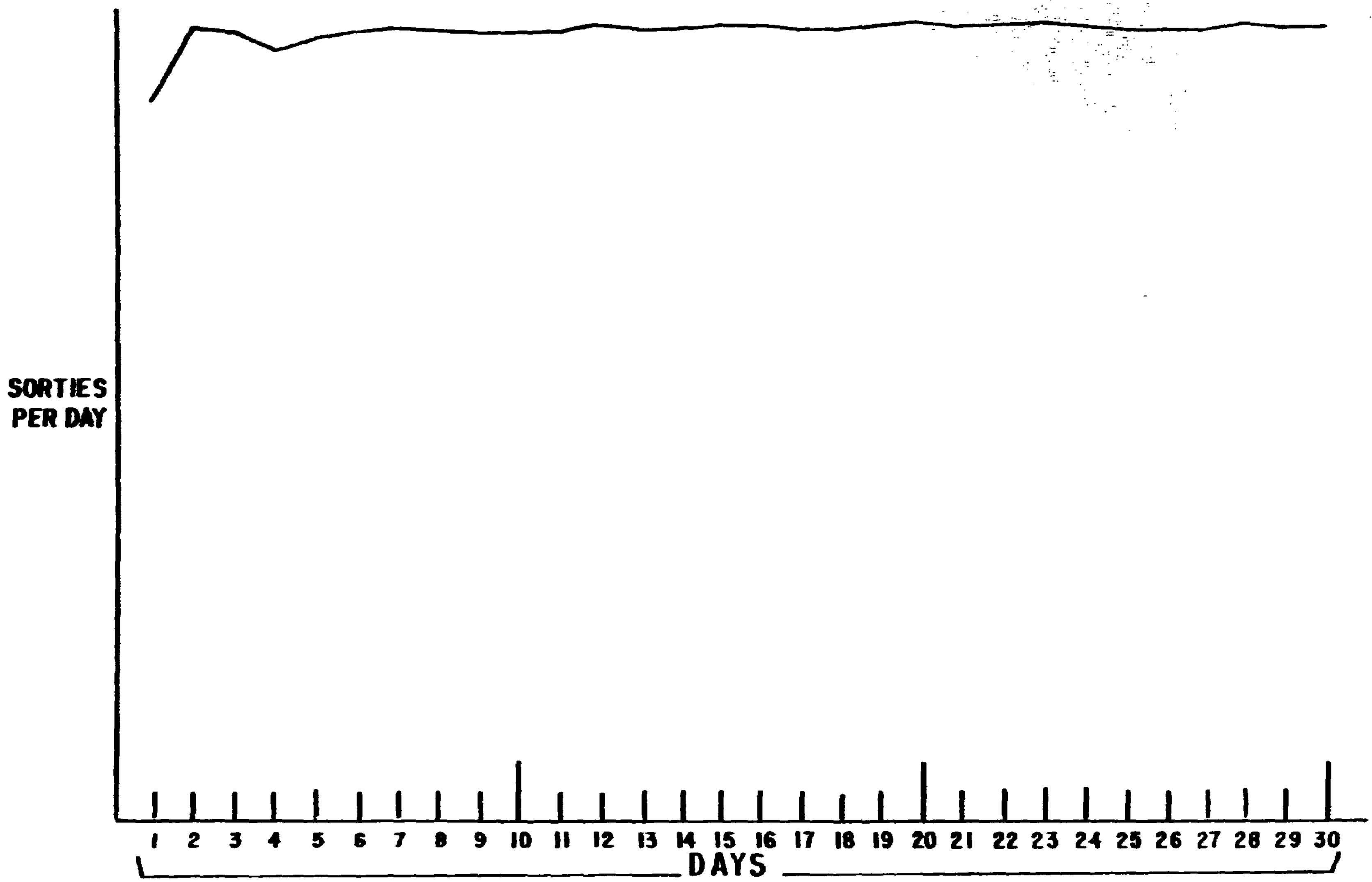


FIGURE 4

SORTIE GENERATION PROFILE

WITH UNCONSTRAINED RESOURCES

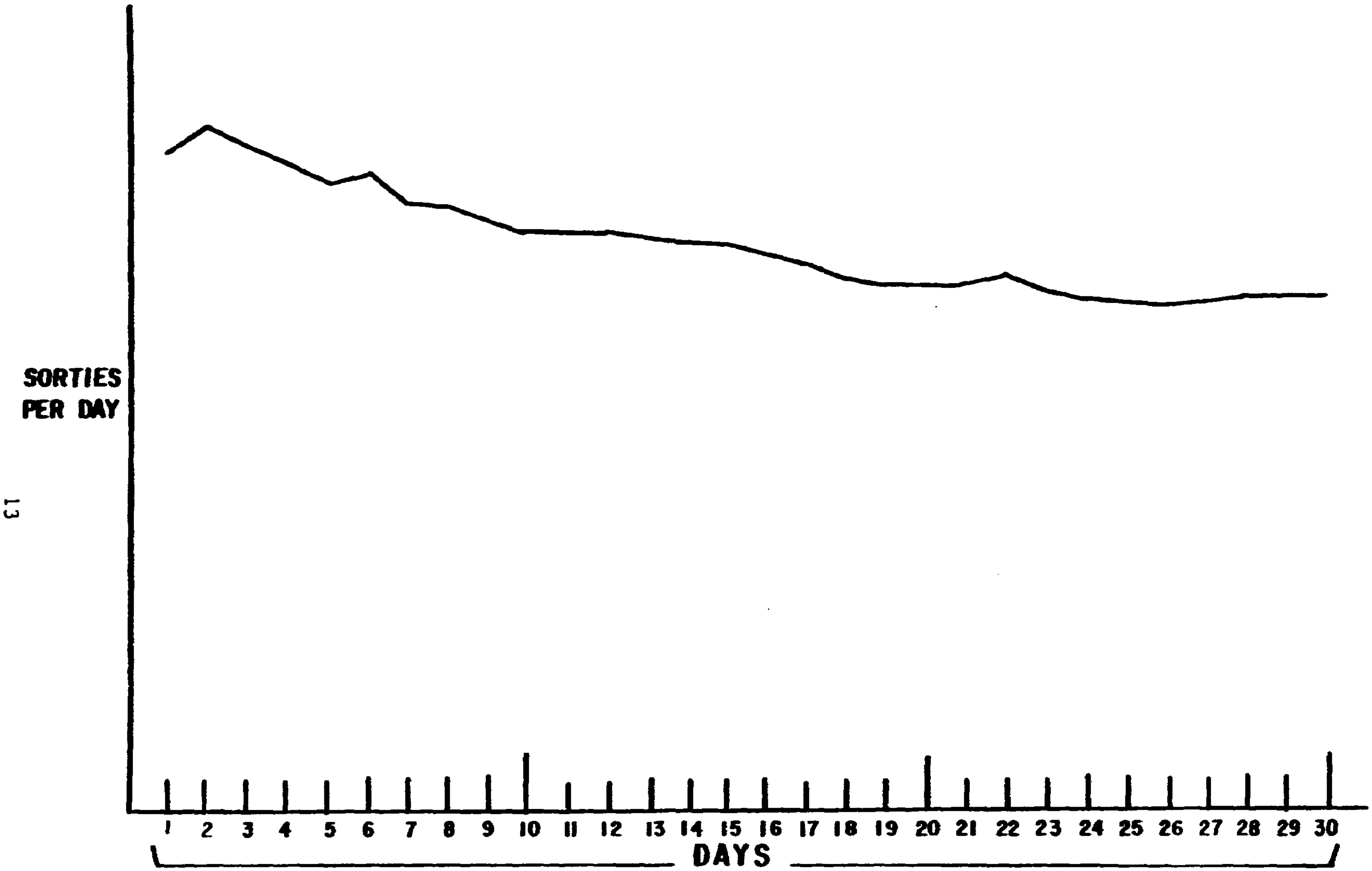


FIGURE 5

SORTIE GENERATION PROFILE

WITH CONSTRAINED RESOURCES

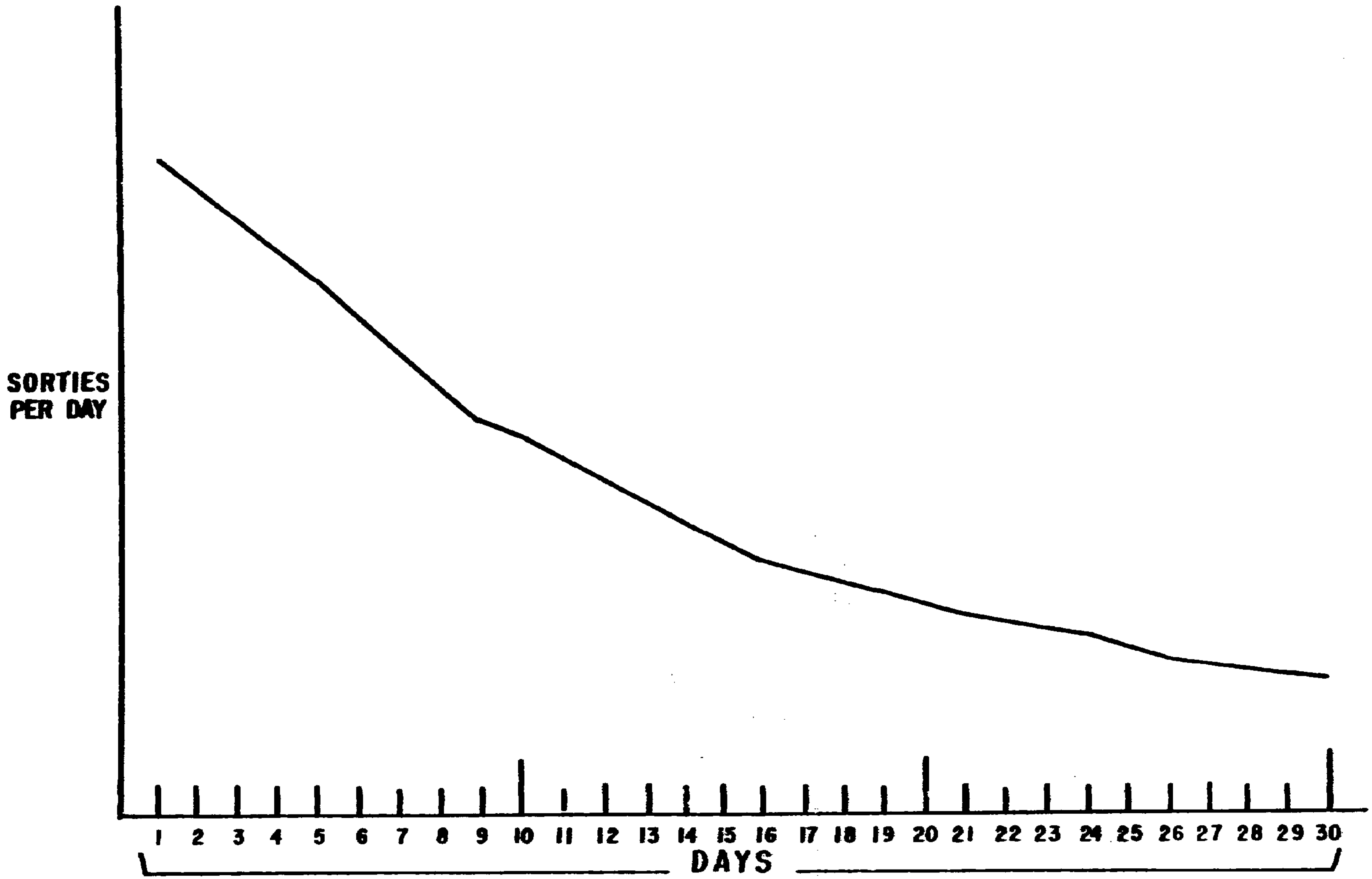


FIGURE 6

SORTIE GENERATION PROFILE

WITH CONSTRAINED RESOURCES AND TWO-PERCENT ATTRITION

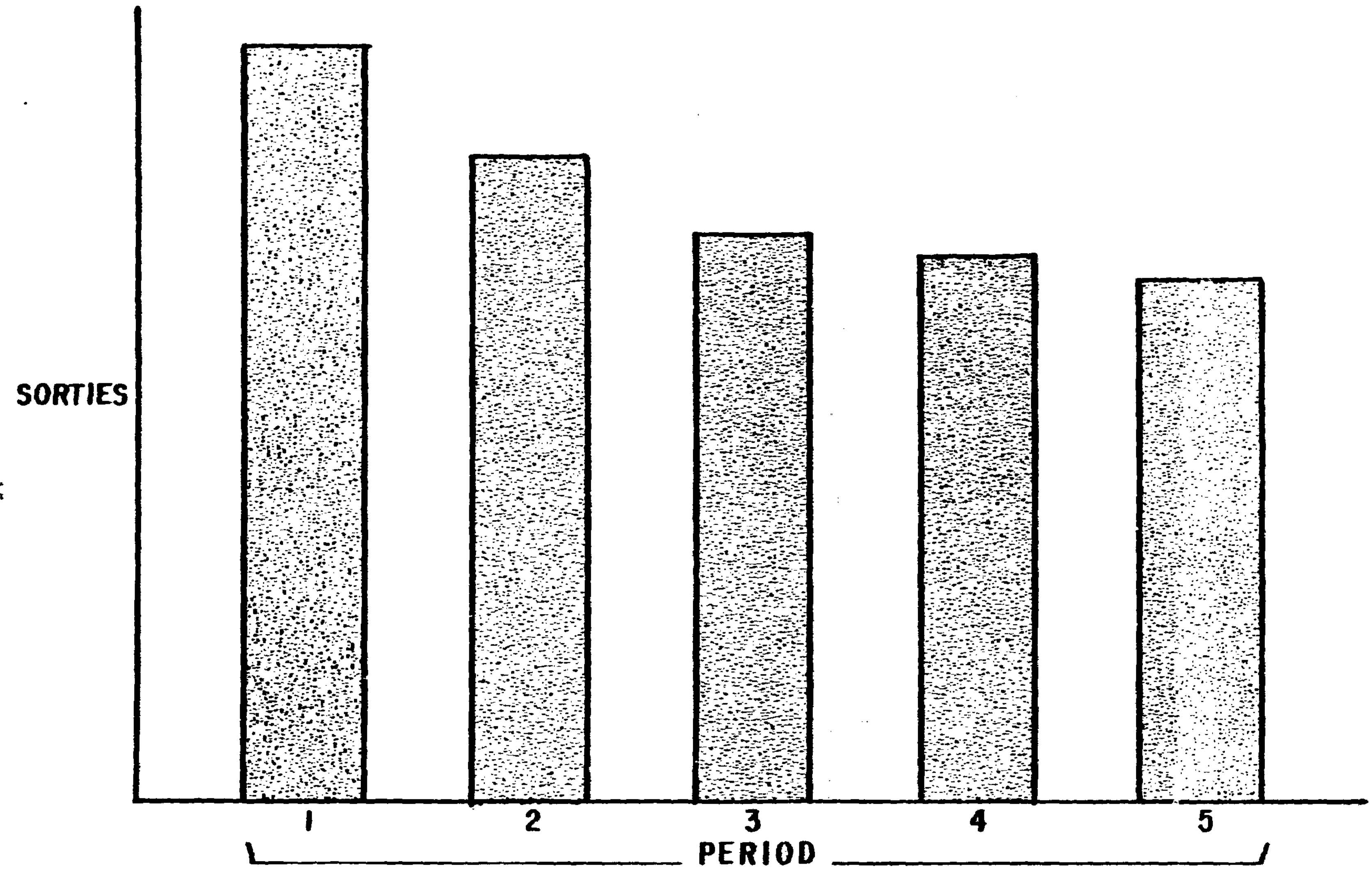


FIGURE 7

DISTRIBUTION OF SORTIES FLOWN BY PERIOD

APPLICATIONS

There are several important applications of the SGM that deserve mention. First, it is useful as a tool for assessment of resource levels in the planning, programming, and budgeting system (PPBS). It can be used to understand better the effects of alternative resource levels on readiness. Second, it can be used to provide a better analytical basis for the annual readiness report to the Congress. Third, it can be used to develop and evaluate war-reserve-materiel requirements and policies. Fourth, it can be used to evaluate the potential readiness of new weapon systems simply by replacing its historical data inputs with postulated values.

The current version of the SGM estimates maximal sortie-generation capability as a function of only a few categories of resource., however, its logic is extendable to other categories such as engines and consumables. It could also be extended to aerospace ground equipment if the appropriate data were available from Air Force data systems.

The SGM system is a significant step toward solving the problem of estimating readiness as a function of resources. It could point the way to an ultimate DoD capability to estimate resource-to-readiness relationships for all of its force types and mission categories.

APPENDIX A

FEDERAL INFORMATION PROCESSING STANDARD SOFTWARE SUMMARY

01. Summary date — Yr. 81, Mo. 09, Day 10

02. Summary prepared by (Name and Phone) — Michael J. Konvalinka (301) 229-1000

03. Summary action — New: X; Replacement; Deletion; Previous Internal Software ID

04. Software date — Yr. 81, Mo. 09, Day 10

05. Software title — The Sortie-Generation Model System Volume I Executive Summary

06. Short title — SGM

07. Internal Software ID — None

08. Software type — [X] Automated Data System; [ ] Computer Program; [ ] Subroutine/Module

09. Processing mode — [ ] Interactive; [ ] Batch; [X] Combination

10. Application area

General: [ ] Computer Systems Support/Utility; [ ] Scientific/Engineering; [ ] Bibliographic/Textual; [ ] Management/Business; [ ] Process Control; [X] Other

Specific: Logistics Capability Assessment

11. Submitting organization and address

Logistics Management Institute
4701 Sangamore Road, P. O. Box 9489
Washington, D.C. 20016

12. Technical contact(s) and phone

Mr. John B. Abell
Mr. Michael J. Konvalinka
(301) 229-1000 AV 287-2779

13. Narrative

The Sortie-Generation Model System provides the capability for relating aircraft spares and maintenance manpower levels to the maximal sortie-generation capability of tactical air forces over time.

14. Keywords

Readiness; Resource Allocation; Sortie Generation Capability; Logistics Capability Assessment

15. Computer manuf'r and model — Honeywell G-635

16. Computer operating system — GCOS

17. Programming language(s) — Cobol 600, Fortran 600/GMAP

18. Number of source program statements — 15000

19. Computer memory requirements — 49k words, 36 bits each

20. Tape drives — 4

21. Disk/Drum units — 1 Disk, 2 million words

22. Terminals — 1 time sharing

23. Other operational requirements

24. Software availability — [X] Available; [ ] Limited; [ ] In-house only

25. Documentation availability — [X] Available; [ ] Inadequate; [ ] In-house only

26. FOR SUBMITTING ORGANIZATION USE

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