AFHRL-TP-91-3

(2)

AIR FORCE

AD-A230 895

HUMAN RESOURCES

TOP-DOWN SYSTEM TOOL FOR LOGISTICS

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January 1991

Interim Technical Paper for Period April 1990 – December 1990

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5601

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This technical paper is printed as received and has not been edited by the AFHRL Technical Editing staff.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
January 1991

3. REPORT TYPE AND DATES COVERED
Interim Paper – April 1990 – December 1990

4. TITLE AND SUBTITLE
Top-Down System Tool for Logistics

5. FUNDING NUMBERS
C – F33615-88-C-0004
PE – 63106F
PR – 2940
TA – 00
WU – 01

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Systems Exploration, Incorporated
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Logistics and Human Factors Division
Air Force Human Resources Laboratory
Wright-Patterson Air Force Base, Ohio 45433-6503

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFHRL-TP-91-3

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This report describes an approach to manpower requirements estimation using the Air Force Systems Engineering process. This approach links manpower variances to variances in equipment reliability, maintainability, and other design controllable factors. Measures of merit for manpower allocation are proposed and process and data models for human resources integration in design are described. New mathematical approaches to the manpower estimation problem are also described.

14. SUBJECT TERMS
Logistics Support and Analysis
maintainability
manpower
reliability
systems engineering

15. NUMBER OF PAGES
78

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

AFHRL Technical Paper 91-3 January 1991

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This publication is primarily a working paper. It is published solely to document work performed.

SUMMARY

This paper describes the relationship between the Air Force's Systems Engineering (SE) approach to weapon system design and acquisition management, and manpower, personnel, and training (MPT) estimation. A practical interface between SE and MPT is proposed to serve as a basis for MPT resource allocation and trade-off technology for use in design engineering. This interface relies on Measures of Merit (MOMs) for human resources variables and integration with established processes, particularly Logistics Support Analysis (LSA). MPT Process and Data Models are also proposed as an analytic framework for development of useful new analysis tools for human resource reckoning.

Candidate MOMs identified for further study are:

1. Maintenance Tasks by Subsystem
2. Reliability by Subsystem
3. Maintenance Task Times
4. Maintenance Crew Size by Task
5. Manpower by Air Force Specialty (AFS)
6. Manpower Slots per Primary Assigned Aircraft (PAA)
7. AFS Structure
8. System Training Requirements
9. Required Accessions by AFS per year

Future development of TDSTL depends on credible ways of measuring these MOMs and on better ways of estimating the critical manpower variable. These issues are discussed in connection with SUMMA (Small Unit Maintenance Manpower Analyses) and Hardman III, two new human resources technologies that seem especially relevant to TDSTL development.

PREFACE

The research was performed for the Air Force Human Resources Laboratory by Systems Exploration, Inc. under Task Order 23 of Contract F33615-88-C-0004. The AFHRL Work Unit is 2940-00-01. The research was undertaken in support of MPT Research Need A89I030 entitled "Optimizing Trades Between Weapon System Design Parameters and Manpower, Personnel, and Training Factors Using Engineering Top Down Design Allocation Methods."

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I. INTRODUCTION

Purpose

The purpose of the Top Down System Tool for Logistics (TDSTL)[1] research is to develop a useful framework for implementing Manpower, Personnel, and Training (MPT) analysis in the Air Force. MPT technology development efforts here and elsewhere stand to benefit from a more rigorous, pragmatic, and specific statement of MPT requirements and goals as they apply to the existing acquisition process. Hence, in this phase of TDSTL research our strategy has been to identify as exactly as we can what the MPT data and analysis requirements really are, and how they can be assembled into an analysis framework. To do this we have adopted the Systems Engineering (SE) model of system design as the preferred framework.[2]

The SE management and logistics analysis activities applicable to MPT are here named the *MPT/SE Process Model.* This definition forms the basis for a description of data and algorithms used within the MPT/SE arena, which is called the *MPT/SE Data Model.* The MPT/SE Data Model then becomes the primary basis of proposed measures of merit (MOMs) for MPT analysis. These MOMs become, in turn, the basis for new research that will develop a more complete model for MPT analysis within the SE process.

The class of models broadly classed as MPT is already quite large, and some are known to be useful and useable. The major problems with most of these MPT tools are that they are more or less detached from the design engineering ethos, and segregated within remote, irrelevant islands. In contrast, the TDSTL has a frankly pragmatic outlook, attaching MPT to the real world as we find it, and seeking relevance as much as perfection for MPT applications.

The TDSTL research described here is linked to a companion effort called Integrating Manpower Analysis with Computer-Aided Design, or IMACAD. The IMACAD research will prototype and evaluate an automated design manpower interface with SE using computer graphics workstation technology. The basis for this linkage will be the MPT/SE Process and Data models developed in the TDSTL research.

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[1] The TDSTL abbreviation is pronounced "Toadstool."

[2] See MIL-STD 499A "Engineering Management" for a detailed description of Systems Engineering ideas. Other useful information, though unpublished, is found in the "ASD Systems Engineering MPT Notebook" (ASD/ENET)

Background

The technical management model underlying all large Air Force systems is the SE process, which consists of five steps. Figure 1 relates the SE process to the WSAP, or Weapon System Acquisition Process.

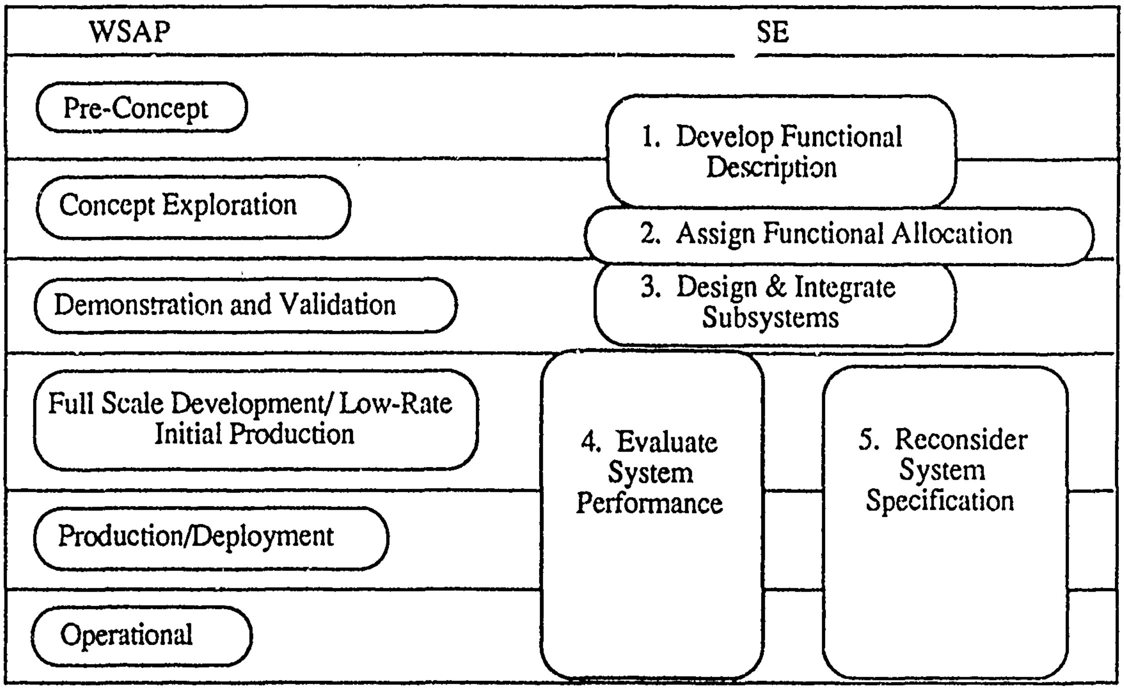

Figure 1. WSAP and SE Process.

The Five Steps of the System Engineering Process

1. Develop Functional Description. The system functionality is determined by developing candidate strategies that might fulfill some set of mission requirements. For example, an Air Force requirement may be to attack an air base 100 km behind the enemy's forward position. Two candidate functional descriptions may be proposed: (a) an aircraft capable of carrying a sufficient payload at high speed without being detected by radar, or (b) an unmanned cruise missile. Competing candidate functional descriptions are evaluated. A final functional concept for a weapon system is selected and fully developed. The functional description contains system performance parameters that serve as goals or constraints for system performance. MPT issues at this stage are usually represented as manpower spaces per system, as support environment constraints, or as reliability and maintainability (R&M) system goals.

2. Assign Functional Allocation. The weapon system functionality is apportioned into subsystem capabilities. For example, the functional requirements of system payload, range, and speed are allocated to engine thrust, gross airframe weight, weapon system delivery capacity, landing gear load requirements, fuel system requirements, and so on. This functional allocation process is taken down to a level where either existing components to suit the function can be identified, or the component that needs to be developed can be specified in terms of its technology, size, risk, cost, and logistics burden. The resulting system description is intended to give management a clear idea of how the final product will behave. At this point, allocated MPT issues are usually restricted to equipment R&M parameters. Manpower spaces per system are not allocated down to specific subsystems or components. The allocated system functional baseline that results is the subject of the Preliminary Design Review (PDR), an important prelude to system hardware design.

3. Design and Integrate Subsystems. The system functional descriptions are translated into real hardware designs. For example, an oleo strut is identified or designed to absorb the projected landing gear loads. MPT issues are still bound up in equipment R&M projections. System considerations are now calculable from the predicted R&M characteristics and the projected logistics support environment. The design baseline system is evaluated at the Critical Design Review (CDR) that precedes hardware fabrication and assembly.

4. Evaluate System Performance. The ability of the system to perform its required function is tested. MPT requirements are compressed into manpower metrics and they are computed using measured R&M characteristics or maintenance data on fielded comparable systems

5. Reconsider System Specification. The functional requirements are continually reviewed throughout the weapon system's fielded life to take account of continual changes in the mission requirements, the threat, and available technology. This ongoing review process produces numerous Engineering Change Proposals (ECPs). Occasionally it leads to a complete redesign.

The SE approach to weapon system technical management marries the definition, development, and integration of hardware to specific sets of operational requirements. Well-understood relationships between the weapon system's component parts and the expected behavior of the overall weapon system, such as that among weight, thrust, and speed, contribute to the success of this orderly development strategy in two ways. First, knowledge of the part-to-whole relationships permits greater engineering and management control. The part-to-whole relationships allow specification of attainable design goals for the subsystems, and for these to meet system operational requirements. Second, knowledge of the part-to-whole relationships permits design flexibility and innovation. That is, knowledge of these relationships allows trade-offs and adjustments to particular subsystem attributes during the system design in response to new requirements and new opportunities that may arise during design.

At present, logistics concerns beyond equipment R&M do not fit readily within the SE approach. This is because many individual elements of a weapon system's logistics profile, particularly the MPT elements, are not easily relatable to the design characteristics of specific systems. Rather, they belong to the broader requirements supporting several constituent systems. For example, the problem of allocating manpower with R&M to subsystems does not work well because maintenance career fields do not map precisely to the standard equipment decomposition arrangement. Most Air Force Specialties (AFSs) deal with more than a single system, and many systems require multiple AFSs. The potentially relevant part-to-whole relationships, such as the test and support equipment burden for individual systems, are not well understood or easily arrived at either. Other examples are found in the indirect linkage between maintenance manpower and equipment R&M characteristics, and the lack of prescriptive relationships that might link maintenance technician skill level with specific equipment design characteristics.

The best understood--or, at any rate, best accepted--interaction between mission capability and logistics generally is through the design interface of R&M. The operational relationship to R&M is clear. The less often equipment breaks (R), and the faster it is repaired (M), the more capable the system will be. All commonly used R&M metrics are additive and well behaved, and arithmetic using them is straightforward. Hence, R&M metrics are readily used by design engineers. But much is missing. For beneath this relationship between R&M and operational capability is a complex set of relationships between R&M, availability, MPT, and support costs that needs to be considered in economically fielding a new system. Current practice entails the early development of acceptable R&M design goals which are followed during weapon system development without much regard for the total logistics-oriented MPT resource impacts.

The credibility and effectiveness of R&M design constraining is reduced by (a) inaccurate reliability estimates; (b) unknown effects of operational policy; (c) overreliance on standard removal and replacement times, which can greatly understate the difficulty of the maintainer's actual task; (d) maintainability estimates requiring previously developed comparable systems or the construction of a prototype for testing; (e) poorly nderstood relationships between equipment complexity and MPT support impacts during subsystem design; and (f) the high schedule impact, program risk, and cost of a redesign activity. Experience shows that only large deficiencies warrant the level of program risk that would be introduced by a redesign slippage. R&M shortfalls may be perceived as more safely handled by scaling up the out-year support costs. In this way, reliability deficits, if they appear, will be spread over the entire weapon system life cycle.

Hand-in-hand with the lack of simple, direct relationships between logistics and operational capability assessment is the difficulty in exploiting the trade-offs in logistics part-to-whole relationships. System R&M parameters, which are easily calculated, are typically used for routine impact evaluation instead of the more laborious and compicated *Manpower by AFS* statistic. Consequently, MPT issues are often handled arbitrarily and implicitly, or treated as mere planning problems. The ability to set system goals and constraints, manage system development accurately and flexibly, and perform trade-offs within the larger logistic domain, including MPT, requires a better explication of the relationships between the design interface for R&M and the total logistics burden. Here is the objective of TDSTL.

II. MPT/SE PROCESS MODEL

The MPT/SE Process Model proposed here is simply a list of MPT-related tasks. This list is the basis for the companion MPT/SE Data Model. The Process Model was developed in a top-down fashion but without the aid of a formal task decomposition procedure such as IDEF (Mayer & Young, 1988a). MPT activities are listed under their appropriate stage in the SE activity. Temporal relationships among the tasks are not specified because we wanted to retain maximum flexibility in evaluating or developing alternative strategies for MPT analysis. The IDEF approach was deemed unnecessary for this purpose. However, understanding of the Data Model might be enhanced by graphic representation using some IDEF1 modeling conventions. (See Figures 3 & 4 in Section III).

Defining the MPT Domain

The primary use of the MPT/SE Process Model is to define what the MPT domain encompasses. The working definition of the MPT domain for this purpose includes maintenance manpower estimation, Air Force Specialty (AFS) job design, and training resource identification for an individual weapon system and for its support equipment. MPT for this purpose excludes those issues falling exclusively within the design interface disciplines of human factors engineering (HFE) and reliability engineering. These are related fields that provide valuable MPT parameters. Unfortunately, the boundary lines are not always as clear or as clean as we might like. For example, HFE task time estimating techniques are not MPT, but the task time data are within the MPT domain. Likewise, the particular technique used to estimate reliability for a new component is outside the MPT domain, but the reliability estimate itself is an important input to the MPT domain. Also excluded from TDSTL are issues having to do with wider force management. We do not deal with sustainment of career fields, assignment policy, grade structure, accession testing, cross training, training development, MAJCOM manpower allocation, and other matters belonging to the Air Force MPT management system at the macro level. In other words, our scope specifically excludes what might be called *MPT in the large.* We include only *MPT in the small* within TDSTL.

Other excluded activities within the workaday MPT domain are the development of specific reporting and planning documentation, and training development in the form of Instructional System Development, or ISD. The various MPT reporting and documentation requirements, important though they are, were excluded because the focus of TDSTL is the information and analysis processes within SE, not the WSAP or the System Program Office (SPO) communications problem. These are elaborately detailed elsewhere.[3]

A comment about the real world we have observed is needed here. The position of MPT within the Integrated Logistics Support (ILS) community does not seem to allow a clean separation of MPT into a separate planning activity or career path. Manpower estimates pervade almost all aspects of ILS analysis: training, facilities, base support, transportation, support equipment, and, of course, prime equipment maintenance. Moreover, manpower can, to a certain extent, be substituted for other resources such as spare parts to achieve higher sortie rates. For both practical and technical reasons, an examination of MPT issues in an actual acquisition program would do well to stay within the established ILS framework. The real world of SPO-level logistics makes no distinction between the MPT specialist and the general logistician. Hence, the distinction between MPT and logistics analysis made here is an arbitrary and somewhat artificial one, a demarcation laid down solely to scope the effort and to sharpen the issues. But MPT is inextricably linked with ILS in the real world. It fits within reliability engineering, maintenance resource planning, and other logistics elements.

Table 1 presents the proposed MPT/SE Process Model. Appendix A contains descriptions of the identified tasks. The analytic activities for MPT can be summarized as (a) assembling operational and system R&M information; (b) computing manpower by AFS; and (c) estimating parameters that require manpower in their formulation, such as training and personnel requirements.

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[3] See, for example, the MPT Integration System (MPTIS) proposal by Akman (1987) and the Army MANPRINT program documents. Among its other problems, MPT is preoccupied with details of the acquisition process rather than details of its analytic process.

Table 1. MPT/SE Process Model

1.0 Develop functional description.
- 1.1 Identify operational requirements.
- 1.2 Propose/develop comparable system.
- 1.3 Perform comparability analysis.
  - 1.3.1 Compute comparable manpower.
  - 1.3.2 Compute comparable training requirements.
  - 1.3.3 Compute comparable accession requirements.

2.0 Assign functional allocation.
- 2.1 Update operational requirements.
- 2.2 Allocate MPT MOMs to subsystems.
- 2.3 Estimate MPT MOMs from functionally allocated baseline system.
  - 2.3.1 Compute allocated manpower.
  - 2.3.2 Compute allocated training requirements.
  - 2.3.3 Compute allocated accession requirements.

3.0 Design and integrate subsystems.
- 3.1 Update operational requirements.
- 3.2 Estimate MPT MOMs from subsystem design.
  - 3.2.1 Compute predicted manpower.
  - 3.2.2 Compute predicted training requirements.
  - 3.2.3 Compute predicted accessions requirement.

4.0 Evaluate system performance.
- 4.1 Update operational requirements.
- 4.2 Estimate MPT MOMs from field experience data.
  - 4.2.1 Compute predicted manpower.
  - 4.2.2 Compute predicted training requirements.
  - 4.2.3 Compute predicted accessions equipment.

5.0 Reconsider system specification.
- 5.1 Update operation parameters.
- 5.2 Propose and evaluate revised system support concepts.
- 5.3 Evaluate candidate system upgrades.

A very simple system data flow is evident in this model. Primary logistics characteristics are the inputs to the *Compute Manpower* analysis activity. *Manpower by AFS* is the output from this node. It becomes a major part of the input to the training and personnel analysis nodes. Implicit in the model is the interactive use of MPT analysis in setting system performance requirements or monitoring system development and performance at each step of the SE process.

MPT Within System Development

MPT analysis within the earliest phase of system development should consist mainly of the identification and advocacy of logistics requirements and technical approaches that would allow tangible improvements in net supportability of the new system over existing systems. This search for efficient logistics alternatives is normally grounded in comparability analysis (Tetmeyer, 1971, Tetmeyer & Moody, 1974). Coupled with this proactive search, generally, is an analysis of the sortie generation or operational availability impact of the emerging system's projected logistics support system. The distinction between MPT and other logistic elements at this point is somewhat arbitrary since sortie generation assumes an array of interrelating resources, including trained and experienced manpower, which must be managed in an integrated fashion.

Figure 2, from the Air Force Logistics Support Analysis Primer (AFLCP 800-17), depicts the design influence emphasis of the early logistics analysis. Many other depictions of this process exist, but this is the clearest and simplest one we have found. The figure also shows the subsequent shift in focus to resource planning ("ID Resources") that characterizes logistics analysis as system development proceeds. In essence, first influence design, then plan the support.

The TDSTL MPT Process and Data Models are based upon these simple, basic ideas. But the models for MPT we expect to use will need to be altered where they fall outside of "as is" practice. For example, one candidate MPT model, the Small Unit Maintenance Manpower Analysis (SUMMA) model (Miller, 1988; Boyle, 1989) combines early manpower and AFS structure analysis into a single optimization problem. But the SUMMA model departs from the "as is" AFS policy view. That is, the AFS structure for a new system is customarily copied directly from the predecessor system, which is not necessarily the comparable system. The MPT Data and Process Models of TDSTL will be used to determine whether the requisite data for this analysis are available at the point that deviation from standard practice is proposed (i.e., if the new system is feasible) and how the remaining MPT tasks would be affected by the change in procedure (e.g., by the "to be" AFS policy).

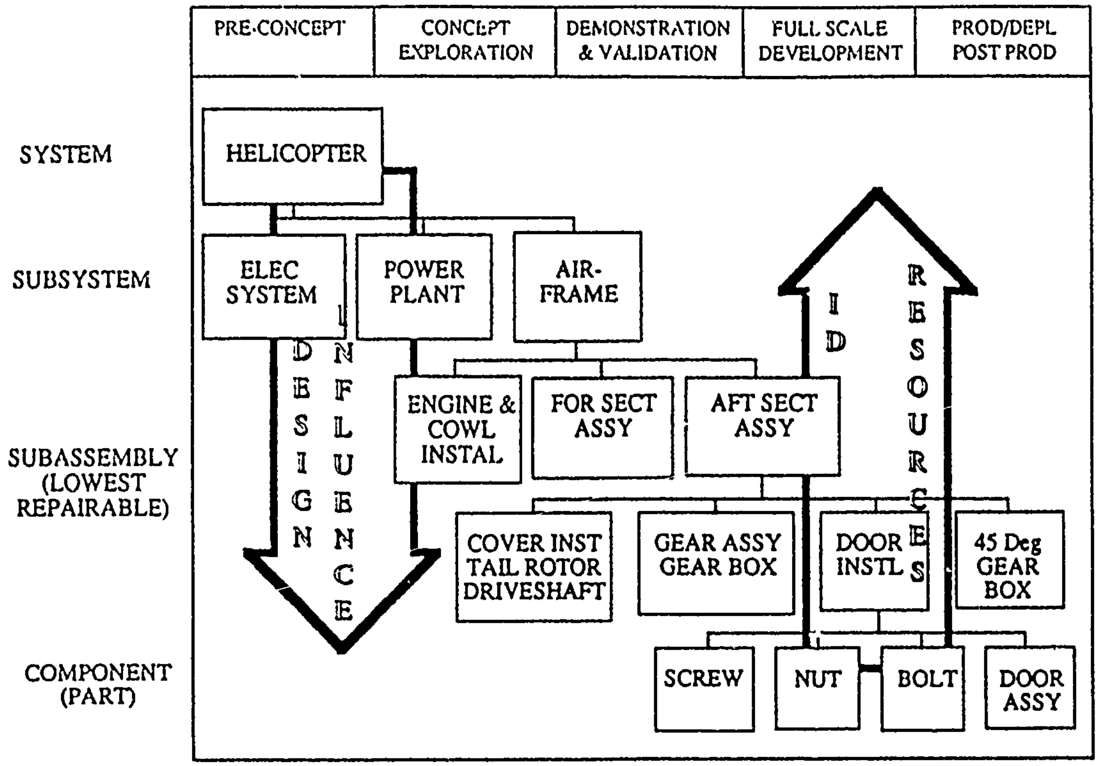

Figure 2. Role of LSA in Logistics Design and Planning.

III. MPT/SE DATA MODEL

The proposed MPT/SE Data Model (Appendix B) was created by first developing a tentative list of the data elements applicable to the MPT/SE Process Model. Then major logistics data sources were searched for relevant inputs. These were the Logistics Support Analysis Record (LSAR) and the Logistics Composite Model (LCOM). Data definitions were searched for relevant MPT data elements. These elements were used to update the MPT/SE Data Model. Lists of LSA and LCOM data are presented in Appendices C and D, respectively. The detailed MPT/SE Data Model is presented in Appendix E.

One benefit of the Data Model is to increase the precision with which one may talk about the MPT process. This discipline will be useful in comparing and planning development of MPT and logistics analysis tools. The immediate use of the MPT/SE Data Model is to provide a basis for defining practical Measures of Merit (MOMs) for use as control variables within the SE process. The Process and Data models are also used to analyze two MPT development efforts, the SUMMA and HARDMAN III, as candidates for MPT analysis within TDSTL. The IMACAD effort will use the MPT Data Model to develop a manpower analysis tool for use throughout the SE process. The follow-on TDSTL II effort will use the Data Model to estimate the precision with which various MPT parameter estimates can be made during the SE process and to recommend algorithms for implementation in logistics analysis tools.

The MPT Data Model is a list of the data routinely used and transformed by the MPT analyst during each phase of the SE process. The data classes tend to reappear from one level of the SE process to the next. The basic problem for MPT analysis in this context is to predict system operational and logistics performance from design parameters and system specifications. This problem is essentially unchanged whether the system is a tentative alternative design being assessed for MPT supportability early in design or a fielded system for which a manpower study is being performed. As design moves along, the accuracy and detail of the input data increase, but the analytic problem is more or less unchanged throughout.

As noted, the MPT Data Model was developed by integrating LSA (MIL-STD 1388-1A and MIL-STD-1388-2A) requirements with LCOM data requirements (Dengler, 1981; Drake & Wieland, 1982). This is substantially the same approach used in the most recent study of the WSAP to locate and evaluate MPT-relevant tools and data bases.[4] Notably lacking in these two data environments are detailed training material requirements estimation and development; planning and predicting the requirements for maintenance technical orders and job aids; and detailed cost modeling data. Recent alterations to the LCOM structure and the Unified Life Cycle Engineering project (Brei et al., 1988) partially address these areas.

Logistics Support Analysis (LSA) Data

LSA is the established process within the Integrated Logistics Support (ILS) program that incorporates all aspects of System Engineering. ILS is, in fact, the means by which Systems Engineering for logistics supportability is implemented in the Air Force. The LSA provides a comprehensive model of all logistics trade studies, and the LSAR enumerates most of the data elements applicable to MPT in the SE process. For this reason, LSAR should be thought of as the basic roadmap for MPT analysis development within the SE process.

The LSAR is organized into Data Records, which are further subdivided into cards, and further subdivided into blocks. Cards 01 - 06 are identification cards on A - C records. LSAR is organized by the LSA control number and provides cross-referencing to planning documentation,

[4] See Rossmeissel et al. (1990, Draft). "MPTS in the WSAP: Analysis of Manpower, Personnel, Training & Safety During the Acquisition of Air Force Systems: Requirements and Capabilities."

manufacturer's part numbers, federal supply code for manufacturers, work unit codes, and other links to technical data or government identification schemes. These technical details have been avoided in the development of the MPT data model. An LSAR/MPT data translation table is presented in Appendix C.

The important SE distinction among "Comparable," "Allocated," "Predicted," and "Measured" MPT parameters is imperfectly made in the LSAR. Only the R&M parameters are included in this. In particular, the B record distinguishes among comparability, allocated, predicted, and measured R&M characteristics, and the D1 record distinguishes between predicted and measured mean man-hours per AFS. This information was presumably included in LSA for its usefulness in interpreting the qualified data. Inasmuch as the LSAR data are viewed as an evolving--as opposed to an archival--record about an emerging system, this is a reasonable inclusion. The logical next step in interpreting the historical data is to develop a quantitative estimate of the uncertainty of the various types of system MPT performance estimators.

The card format of the LSAR data is not very compact. Multiple locations are noted for identifiers and important data items. Moreover, much of the data on the forms can be derived from other elements, for example, only two of "crew size," "total man-hours," and "task duration" are required to compute the third parameter, but LSAR data will typically require all three data elements. The cross-referencing against the MPT/SE data model does not attempt to identify these overlapping requirements or data dependencies.

But not all SE/MPT data applicable to TDSTL are inherent in the LSAR format. Missing from LSAR data are manpower utilization, general training requirements, and personnel-oriented parameters of "shop" supervision, non-chargeable maintenance man-hours, training, and AFS turnover rates.

LCOM Data

LCOM is a maintenance simulation system developed in the mid-1960s by the Rand Corporation. LCOM is used to simulate the relationships among resources (airplanes, manpower , support equipment, and parts) and sortie generation capability. Its use in manpower allocation is institutionalized within the Air Force by regulation and by the existence of dedicated organizations and a distinct career field to analyze air base operations within each Major Command (MAJCOM), Air Force Logistics Command (AFLC), and acquisition organization. LCOM essentials are explained in Boyle (1990). LCOM data bases describe maintenance task requirements in terms of task networks. These data bases often provide a rich source of primary information supporting MPT analysis, as shown in Appendix C.

Task demand rate is modeled in LCOM by first setting a per-sortie failure rate for each of an aircraft's subsystems and then allocating this failure rate among the subsystem's components in a probabilistic fashion. This means that the failure mechanism for a Shop Replaceable Unit (SRU), usually described in terms of failures per operating hour, is modeled by calculating and recording the per-sortie failure rate for the SRU's subsystem and calculating the conditional probability that this particular SRU will fail, given a failure of the subsystem. The LCOM Data Preparation Subsystem converts failure data on existing Air Force systems into LCOM format. Corresponding pre-processor programs also are available to translate LRU data into SRU failure rates. This very detailed modeling capability of LCOM is not yet included in the TDSTL Data Model.

A detailed means to represent configurations for different missions, the reconfiguration activity, and the concomitant aircraft scheduling activity is a feature of LCOM. This facility is valuable in detailed examinations of the aircraft turnaround problem with LCOM, but it is of no value for MPT beyond what task loading the reconfiguration tasks themselves entail.

Figure 3 presents a broad view of the MPT data flow within the larger logistic domain. The most salient features are the relative simplicity of the MPT data flow and the central importance of the "Manpower by AFS" statistic. This statistic is sensitive to the manner in which tasks are allocated to AFSs. Specifically, if AFSs are defined broadly, fewer people will be required; if narrowly, more people. The trade-offs between broad and narrow AFS definition are the subject of the SUMMA MPT model (Boyle, 1989).

Reliability is given in terms of expected operation hours or cycles to failure (with Poisson failure distributions for unscheduled maintenance) or constant time intervals (for scheduled maintenance). Any scheme to perform manpower estimation needs to translate from the operational time reference to the 24-hour maintenance environment. Thus, the "Task Demand" pipeline is introduced into the model to simplify the graphic representation of the data model. Table 2 provides information on the data transformation required of routinely presented maintenance demand data.

Figure 4 presents the data flow according to the "Comparable," "Allocated," "Predicted," and "Measured" distinction used in reliability prediction. It should be noted that there is no

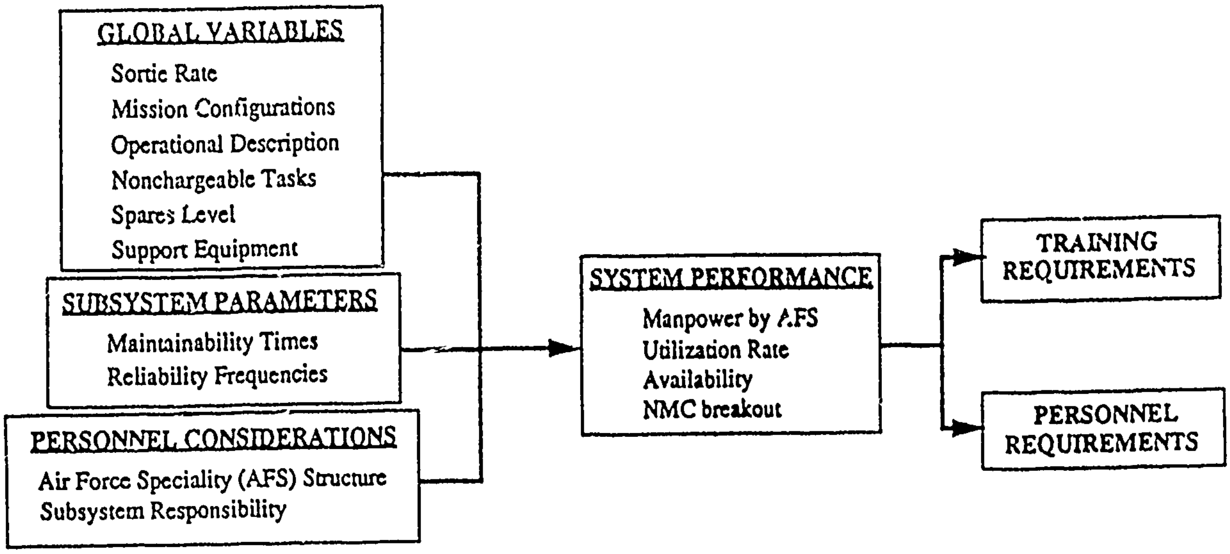

Figure 3. MPT Analysis Framework Design and Planning.

Table 2. Reliability to Task Demand Translation

Metric:	Per/Sortie	Time/Sortie	Cycles	Calendar Time
Maintenance				
Unscheduled Maintenance	X	X	X	
Scheduled Maintenance				
Mission Profile Change	X			
RCM (Preventative)	X	X	X	X
Inspection				
Post-Flight	X			
Pre-Flight	X			
Daily				X
Periodic	X	X	X	X

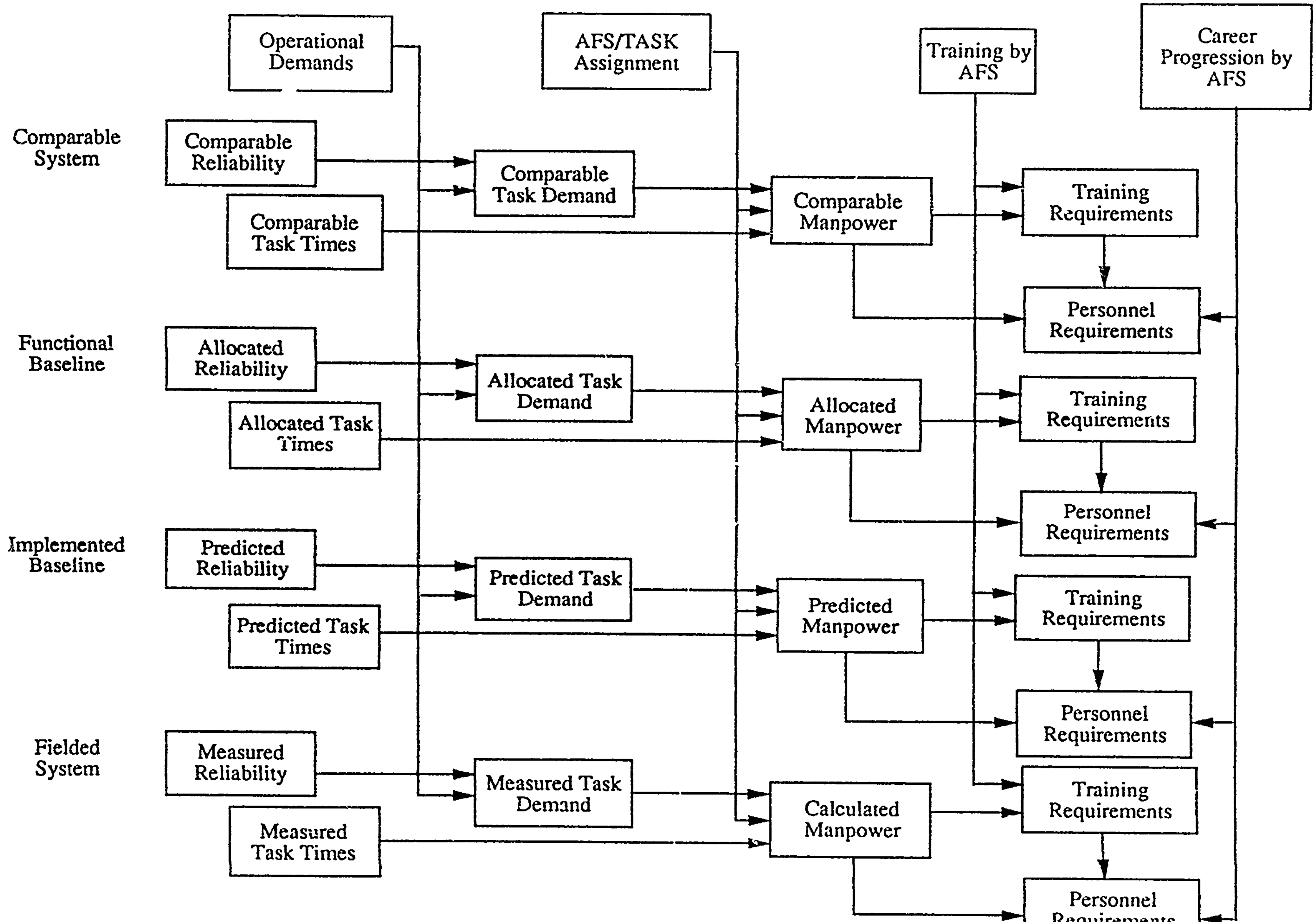

Figure 4. Final High-Level Data Model.

"Measured" manpower. Field manpower is really "Predicted" since it is allocated against a set of hypothetical conditions.

Of particular interest for TDSTL are the analytical possibilities available for computing manpower from the more fundamental parameters. Three approaches are in general use in the Air Force for this purpose: Monte Carlo simulation (i.e., LCOM), analytic queuing modeling, and the R&M practice of multiplying task time by reliability and dividing by a manpower utilization factor to get manpower. The Air Force standard approach is LCOM. The complexity of maintenance demand argues for the simulation approach since some of the simplifications required to use the analytic queuing approaches may not provide sufficiently accurate answers for all purposes. On the other hand, a simulation approach is more time consuming and requires greater analyst sophistication. Since *Manpower by AFS* is the critical measure for the MPT domain, the relative accuracy of these three approaches should be determined in a systematic way. This is planned as part of the follow-on TDSTL effort.

Several data elements not included in the MPT data model bear mention. Most notable is the "utilization" statistic. This statistic is the proportion of time that maintenance technicians are usefully employed in maintenance. Some inactive time is inevitable in an unscheduled maintenance environment. The statistic is often reported as a MOM in both operational and acquisition circles. The figure can be ambiguous and misleading, though, because higher manpower utilization rates can reflect lower availability, more efficient job structuring, lower manpower, or more efficient maintenance scheduling.

The only practical value of manpower utilization as a MOM for TDSTL is during its use in LCOM manpower studies to help select where to adjust manpower when manpower is being constrained (i.e., when the minimal manpower required to achieve a given sortie rate is being determined), and as a scaling factor in R&M studies to convert maintenance manhours per flight hour to manpower slots. Manpower utilization is used in the first case to approximate marginal improvement in sortie generation. This is not readily computed, to be sure, and thus has very limited analytical use. This second use of the utilization statistic is equally tenuous. Thus, utilization was excluded from the MPT Data Model. The other major omissions are task analysis data. These data provide much of the basis for safety analysis, as well as training material and technical order development. But from an MPT analysis perspective, it is the C Record level of analysis, or subsystem R&M data, that forms the baseline for TDSTL. The detailed task analysis data from Record D simply arrive too late in the SE process to be of practical use for design influence.

IV. MEASURES OF MERIT (MOMs)

Purpose and Selection

The purpose of the evaluation of MPT MOMs is to identify and suggest MPT parameters for use as control variables within the SE process. As noted, MPT parameters are more encompassing than straight R&M or support environment requirements/prohibitions, but they are not always readily or unimpeachably calculable. Criteria for candidate MOM nomination were based solely on pragmatics. A MOM had to be present (or calculable) within the MPT Data Model, or used in established programs, or identified in previous surveys on the subject to be considered.

Air Force documents surveyed for possible MPT MOMs consisted of two recent reviews (Naval Weapons Center, 1986; Delane, 1989), supportability direction, and the LSAR and LCOM data definitions. Recommendations of previous surveys were restricted to maintainability in the form of average man-hours per maintenance action or flight hour.

To determine what MOMs are in actual use early in the acquisition process, we reviewed early program documentation for the Advanced Theater Transport (ATT) and the Special Operations Forces (SOF) aircraft efforts. ATT documentation consisted of the draft Statement of Need (SON) and requirements coordination matrix. Pre-concept trade studies from McDonnell-Douglas, Boeing, and Lockheed were also examined. Draft Statement of Operational Requirements Document (SORD) and Statement of Work (SOW) documents for a second round of pre-concept studies were also examined. SOF documentation consisted of the Draft SON and programmatic information being developed by Air Force Wright Aeronautical Laboratory/Flight Dynamics (AFWAL/FG) for eventual incorporation into a Procurement Decision Package (PDP) or SOW.

The ATT and SOF efforts contained maintenance slots per aircraft, support equipment, and deployment burden goals in the SONs; hard logistics requirements of direct impact on manpower were restricted to R&M and Precision Measurement Equipment (PME) requirements. The manpower trade studies used the usual maintenance man-hours per flight hour times task time approach. This is not to say that no other MOMs applicable to MPT could have been used, or should have been used. It is only to say that these are the MOMs the real world uses now.

Candidate MOMs

This leads to a limited set of candidate MOMs to be used as control variables, singly or in combination, within the SE process for TDSTL development. The candidate MOMs are:

Maintenance Tasks by Subsystem
Reliability by Subsystem
Maintenance Task Times
Maintenance Crew Size by Task
Manpower by AFS
Manpower Slots per Primary Assigned Aircraft (PAA)
AFS Structure
System Training Requirements
Required Accessions by AFS per Year

Maintenance Tasks by Subsystem

The maintenance concept can restrict the system under development by mandating a level of repair on equipment. The restriction of avionics equipment maintenance to on-equipment and depot level maintenance is a good example of this. Restrictions of this sort may not always be appropriate since it is generally an item's reliability that drives its repair level. In this case, it would seem best to control reliability directly as opposed to controlling only its implications. If the intention of a MOM in this area is to restrict support equipment, test stands, and so on, the better way of going about it would be to apply these particular constraints straightforwardly. If the intention of restrictions in this area is to control task times by eliminating lengthy tasks, such as in-place repairs, distortions to the maintenance system may result. The cost for any additions to the logistics pipeline is shown in usually expensive spares and in complex back-shop maintenance equipment.

Reliability by Subsystem

Reliability is of such paramount importance in determining both logistics considerations and operational effectiveness that is is hard to find a drawback to applying reliability constraints to a system under development. The impact of reliability on manpower should be monitored during system development, though, if reliability improvement is being used to reduce manpower.

Manpower asymptotes with respect to increased equipment reliability. Minimum task crew size and launch/recovery work begin to drive manpower requirements rather than unscheduled maintenance requirements as things break less often.

Maintenance Task Times

Maintenance task time requirements are fundamental to the Air Force way of planning maintenance. Particularly important are aircraft turnaround times. Task times should not be used as a control variable without the associated equipment reliability also being considered. Therefore, maintenance task times are a necessary but not sufficient requirement for optimum MPT management and resource control.

Maintenance Crew Size by Task

Many Air Force maintenance tasks require several technicians working in concert for completion. This is called the minimum task crew size. From the MPT standpoint, this increases manpower requirements. Inasmuch as crew size is directed by military standards for safety and human factors, it would be best to constrain crew size, where this is deemed desirable, by directly addressing safety issues through engineering task design.

Manpower by AFS

This statistic seems to provide a good summary of the system's maintenance burden as most of the recurring system cost is accrued on a per-billet basis: wages, training, supervision, facilities, and so on. The use of this statistic should be in concert with a target AFS structure or criteria for redefining the existing maintenance structure. The major drawback with Manpower by AFS as a control variable is the computational strain. The official manpower requirement will usually come from an LCOM study. Potentially much quicker simulation studies are now possible than in the days of punched cards, but the LCOM technology is still not popular among R&M engineers. They still seem to prefer the maintenance man-hours times reliability method for its computational simplicity. Much is lost through this expediency, though, as the LCOM approach is apt to be more accurate. The critical question here is how accurate the manpower estimate needs to be. This question will be addressed by the follow-on TDSTL study, which will compare LCOM solutions to solutions provided by mathematical models.

Manpower Slots per PAA

This statistic is highly dependent upon basing concept, as was shown in the SUMMA front-end analysis (Boyle, 1989). Moreover, this statistic is normally computed only for base-level (i.e., flightline and intermediate shop) maintenance billets. Thus, the drawback of this MOM is the possibility that too much maintenance will be relegated to the depot level, resulting in a highly deployable system, given unlimited spares, but an overly expensive system overall, since manpower costs are driven to the depot, which is normally not included in MPT analysis.

AFS Structure

Currently, the Air Force is reorganizing its maintenance AFSs according to the Rivet Workforce suggestions. The basic idea is to combine, merge, or otherwise "restructure" maintenance AFSs. The result of this job enlargement is a reduction of unit manpower requirements and a more flexible workforce for combat deployments. AFS structure is the most important new variable in MPT analysis for the Air Force. Unfortunately, AFS definition is typically not controlled other than by necessitating additional LSAR justification where a new skill is thought to be required. The issue of AFS restructuring enters into problems of task compatibility and training synergism. The interested reader is referred to the SUMMA literature (Miller, 1988; Boyle, 1989) for detailed discussions of the MPT aspects of AFS job redefinition.

System Training Requirements

The System Training Requirements expand upon the Manpower by AFS statistic by allowing the contractor to trade off one AFS policy with another while holding training constant. Possible distortions to the MPT system from attempting this tactic could be a maintenance workforce which is undermanned in the more complex specialties, that is, one in which these specialties are driven harder than the less training-intensive AFSs.

Required Accessions by AFS Per Year

The use of this statistic as a control variable would drive the system toward favoring AFSs that turn over less readily or require less time to become fully proficient. This could be a valuable MOM in developing an optimum MPT workforce.

Flexibility in trading off one concern for another can only be preserved if the system MPT MOMs are handled within an integrated analysis/tracking framework. Cost analysis, in essence a "design to cost" strategy within a constrained, integrated logistics analysis framework (i.e., one not including number of systems or individual system capability in the trades), seems the most promising framework within which to perform trades among logistics considerations, including MPT.

The follow-on TDSTL will examine the accuracy with which these statistics can be computed and measured, and the extent that these, or some subset of these, MOMs constitute a comprehensive set of control variables.

V. SMALL UNIT MAINTENANCE MANPOWER ANALYSES (SUMMA)

This section and the following use the MPT/SE Process and Data Models to evaluate two important MPT analysis tool development efforts of recent years, SUMMA and HARDMAN III.

Background

The first effort behind the Air Force's rekindled interest in MPT during the late 1980s was the AFHRL SUMMA effort. The project's initial purpose was to provide a tool to evaluate the impact of subsquadron-level deployment on manpower requirements and to perform a sample analysis using this system. As decentralized logistic system performance is known to be very sensitive to the distribution of limited resources such as spares, tools, and manpower, and the optimal reallocation of these resources only improves the situation slightly over an ad-hoc allocation policy, the SUMMA effort eventually focused on the AFS definition problem. Naturally, an AFS restructuring analysis is most applicable to the earliest system development phases. A restructured workforce would require three to five years preparation prior to initial operations of the new system with Air Force personnel.

The central manning problem in small unit deployments is formally classified as a queuing problem. In general, economy of scale is sacrificed when using numerous small operations in these situations, resulting in greater system-wide requirements for manpower in the dispersed situation than in the centralized one. The solution to the problem is in distributing the limited manpower resource in such a way that MPT costs are minimized while attaining a minimally acceptable system availability rate. There are three plausible strategies to solve this problem: (a) provide more overall manpower, (b) accept lower system performance, or (c) qualitatively change the nature of the manpower resource by accepting higher training and personnel costs in return for lower overall numbers. The most attractive solution is the third solution, expanding the breadth of the maintenance technician's job responsibility. In other words, combine the AFSs in some way.

Thus, the SUMMA effort quickly moved to address the interacting MPT effects of changing the existing AFS policy. In an SE context, the SUMMA analysis strategy is to decouple task analysis and task allocation from AFS specification early in the Develop Functional Description phase of the process. In essence, this changes the nature of comparability analysis from nesting subsystems within AFSs to nesting subsystem responsibility to homogeneous "task bundles" which are, in effect new AFSs or jobs. Early AFS determination is replaced by an AFS-free task analysis, with AFSs being formed as "task bundles" grouped by an integer programming strategy. Table 3 presents the SUMMA in the context of the SE/MPT Process and Data Models.

Evaluation

Within the framework of the MPT/SE process model, the purpose of the SUMMA analysis is to replace the comparability AFS-to-task assignment assumptions with an early task analysis to derive comparable and, perhaps, allocated manpower by AFS. The new MPT data requirements emerging from this alteration are the training requirements for individual tasks and for whole jobs.

These data are developed within the initial SUMMA activity by dividing each AFS's training into a common and AFS-specific portion and deriving a system of prorating the AFS-specific portion of the training.

The drawback to adopting a SUMMA task/specialty solution stems from our lack of knowledge and/or lack of confidence regarding the relationships among training requirements, job characteristics, and personnel requirements that such job alteration schemes imply. Specifically, we have no way of knowing, a priori, whether the AFSs derived from a SUMMA analysis are feasible beyond adapting a subject-matter expert's opinion. The current AFS structure has evolved over the post-World War II era in response to constraints on personnel quality, high turnover, training time, and cost limitations. Essentially, every time system complexity has outgrown an AFS's performance capability, and remedial training and personnel actions have not ameliorated the problem, the AFS has been broken out into new AFSs or shreds, each being more specialized. Assuming that this ad-hoc procedure has been done in a fashion that approximates optimality, the current AFS structure is nearly optimal given the personnel and turnover constraints under which

Table 3. SUMMA Processes and Data Requirements

1.2	Propose/develop comparable system.	
	INPUTS:	Technology Type by Subsystem
		Sortie Type
	OUTPUTS:	AFS/Subsystem Assignment
		Reliability by Subsystem (Comparable Reliability)
		Maintenance Tasks by Subsystem
		Maintenance Task Times
1.2.1	Compute training burden for task bundles.	
	INPUTS:	AFS/Subsystem Assignment
		Task Descriptions
		Training Requirements by AFS
	OUTPUTS:	Training Requirements by Task Bundle
1.3	Perform comparability analysis.	
1.3.1	Compute comparable manpower.	
	INPUTS:	Training Requirements by Task Bundle
		Reliability by Subsystem (Comparable Reliability)
		Support Equipment
		Maintenance Tasks by Subsystem
		Maintenance Task Times
		Maintenance Crew Size by Task
	OUTPUTS:	AFS/Subsystem Assignment
		Comparability Required Manpower by AFS
1.3.2	Compute comparable training requirements. (NO CHANGE)	
	INPUTS:	Comparability Required Manpower by AFS
		Training Requirements by AFS
	OUTPUTS:	Comparability System Training Requirements
1.3.3	Compute comparable accessions requirement. (NO CHANGE)	
	INPUTS:	Comparability Required Manpower by AFS
		Comparability System Training Requirements
		Historic Personnel Turnover Rate by AFS
	OUTPUTS:	Comparability Required Accessions by AFS per year

the system operates. Recombining AFSs, and accepting the concomitant larger training burden, may look optimal on paper but it needs to consider constraints imposed on the solution by personnel quality and the impact of the AFS transformations on turnover.

On the other hand, the prorating approach to training requirements estimation used in SUMMA may yield non-additive training results in the opposite direction. Training synergism may result in an overall reduction in specialty training. Further progress in this area is obviously unlikely until either these issues are addressed empirically or a SUMMA-based AFS solution is tried out in the real world. Regrettably, this is an expensive and risky undertaking.

As implemented, the AFS structuring facility aside, the SUMMA product is a reasonably complete MPT comparability analysis tool for use early in the SE process. The shortfall with the SUMMA tool for later SE use, when accuracy of the estimates becomes more important, is the lack of evidence supporting the system's queuing analysis processor. As reported in Kirshner and Boyle (1990), the existing SUMMA system is shown to compare fairly well with LCOM under a limited set of circumstances, particularly where system manning is driven more by minimum crew size than by queuing effects. But a more systematic comparison of the queuing facility against known results would be beneficial in establishing the robustness of this facility.

From a software point of view, the SUMMA model can be viewed as a set of auxiliary analysis programs for use within the LCOM community. The AFS structuring facility in SUMMA is designed to read and write LCOM data sets. Basing the system upon an established analysis environment has the obvious advantage of tying into a body of expertise and potential users. The drawback is the additional training required for first use of the SUMMA analysis tool. And LCOM itself is not known for its ease of use.

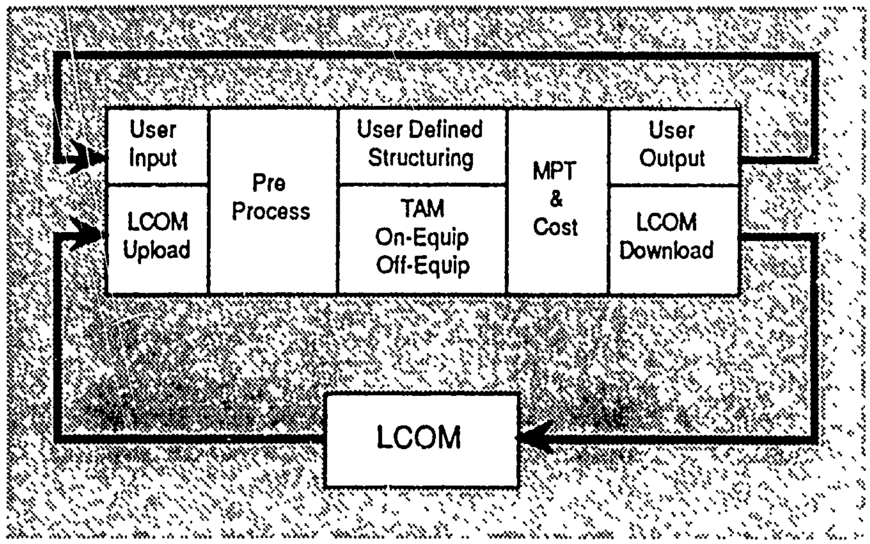

Figure 5. SUMMA Analysis Sequence.

The Specialty Structuring System (S^3) effort is an extension of SUMMA. The main difference is that the S^3 is specifically targeted at the system development environment while SUMMA was not. It is also intended for use during the Develop Functional Description phase of the SE process, although extending the system to monitoring parameters during the later phases of the SE process and tying the data reporting to the requirements of the WSAP reporting requirements are planned.

VI. HARDMAN III

Background

In the early 1980s, the Army instituted a new series of MPT and human factors improvement projects. These projects were characterized by the creation of a new control apparatus, the Army MANPRINT Office, with expectations that new and better MPT and human factors tools would be developed. The Army's HARDMAN I program was an adaptation of a Navy MPT program of the same name. This latter program was, in essence, an adaptation of an earlier round of MPT tools developed by AFHRL, first called Coordinated Human Resources Technology (CHRT), later called Acquisition of Supportable Systems Evaluation Technology (ASSET).[4]

[4] The basic ideas of CHRT/ASSET from the 1970s linger on in the form of comparability analysis and R&M

CHRT/ASSET consisted of a family of systems analysis tools organized around a consolidated maintenance task data base, aimed at deriving human resources requirements for new systems. Human resources is another term for MPT.[5]

HARDMAN III is the latest effort in technically-oriented MPT tool development by the Army Research Institute for the Behavioral and Social Sciences. HARDMAN III documentation reviewed on this ambitious program consisted of system architecture and concept exploration documents, documentation of the personnel characteristics requirements prediction subsystems, and program overview briefings. The personnel characteristics prediction concepts have been the initial focus of the HARDMAN III development effort, as these represent previously underdeveloped capabilities.

Like many MPT projects, HARDMAN III was not developed as an extension of LSA, or of the existing WSAP reporting and management scheme. This independence has the advantage of producing an analysis system free of distortions introduced by trying to fulfill the requirements of a preexisting reporting scheme like LSA. The drawback of this independence is the subsequent requirement to interface the system with the established logistics analysis and planning structure. Work is currently underway to develop cross-references between the partially defined HARDMAN process and data universes and LSAR.

HARDMAN III differs from SUMMA in that it is a set of stand-alone programs which combine to perform a more complete MPT analysis. In addition, the human factors domain is partially integrated into the HARDMAN III set of tools. The domain of the HARDMAN III system exceeds the present study's operational definition of MPT by extending itself into costing, force management, and requirements analysis, as well as human factors. The description of the HARDMAN III presented below outlines these extensions.

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prediction primarily. LCOM is sometimes associated with this suite of tools but it was developed separately. HARDMAN III is not to be confused with the Navy HARDMAN program, or with earlier versions of Army HARDMAN analytics, or with CHRT/ASSET. It is genuinely new.

[5] In the 1950s and 1960s, MPT was referred to as the "personnel subsystem," again using the systems engineering model, which was new then. The more things change ... .

Module Descriptions

Figure 6 presents the most recent conceptualization of the HARDMAN III system architecture. The individual modules are discussed below. The astute reader will note several potentially beneficial links missing from the HARDMAN tools. Immediately apparent examples are lack of feedback of the cost analysis module, Army Manpower Cost (AMCOST), and how the MPT tools do not feedback into the mission requirements analysis. These non sequiturs are due to the HARDMAN III being mainly in the individual requirements development and prototyping stage. Subsequent elaboration of the architecture will no doubt contain a closer coupling among the separate modules. Consequently, except in a few cases, the interrelations among modules is not emphasized here.

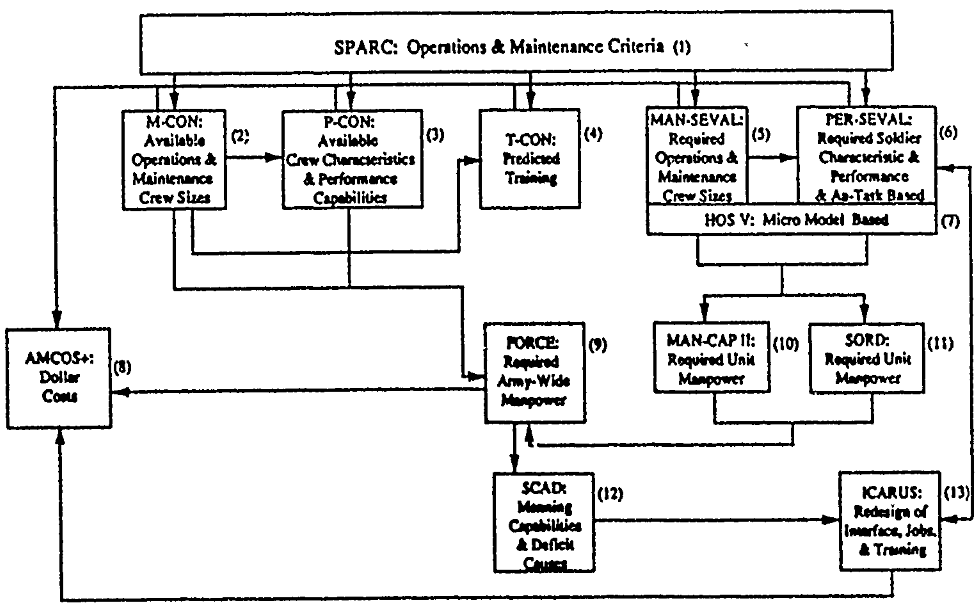

Figure 6. HARDMAN III System Architecture.

System Performance and RAM Criteria Estimation Aid (SPARC)

The M-CON, P-CON, and T-CON tools all develop parameters, constraints, or relationships for injection into the SE process. The SPARC (Dahl, Laughery, Archer, & O'Brien, 1987) tool allows the automated development of system performance requirements, with output similar to the familiar SORD process. This tool accesses a very large comparability data base and provides system requirements data for subsequent task analytic and comparability activities within the HARDMAN III analysis framework.

The input flexibility of the SPARC system includes a generic ability to accept Army ground combat models. Inputs and requirements from this source, such as mobility parameters and system attrition rates, differ qualitatively from analogous Air Force requirements generated from mission effectiveness studies. In the latter, performance requirements are derived in the forms of mission payload, range, and other parameters of interest to aeronautical systems. The underlying cause of this is that, in the Air Force, the weapon operator function can often be analyzed independently of the maintainer and other logistic support. With HARDMAN III, the Army makes no such distinction. The operator *is* the maintainer. Also, job specialization and maintenance centralization in the Army are less pronounced than in the Air Force, making eventual manpower calculations easier in many respects. This results in considerable deviation from the MPT/SE data model prior to the development of required tasks by subsystem and R&M data. This is to be expected, given the differences between the Army and the Air Force requirements analysis process.

Still, comparability analysis is fundamental to the Army MPT requirements development process. The practical question is whether the Army tools provide any fresh approaches to solving the Air Force requirements analysis problem. The answer appears to be that no immediately applicable analysis approaches significantly different from the Air Force processes are used in the HARDMAN III SPARC requirements analysis process (see Table 4).

M-CON

This tool is designed to develop manpower constraints from characteristics of the predecessor system force. Four measures are developed: (a) maximum allowable crew size, (b) maximum manhours, (c) operator manpower, and (d) total maintenance manpower. The M-CON tool thus fulfills the requirements of TDSTL Process Model Task 1.3 called Perform Comparability Analysis. Operator manpower is added to the analysis and changes in terminology to account for Air Force and Army differences are needed.

P-CON

This tool's purpose is to develop estimates of personnel quality versus performance characteristics to support trade-offs on personnel quality issues. This is a comparability analysis in that a baseline data base is constructed by developing a quality profile assembled from the predecessor system. The analogous Air Force function occurs in the requirements process by proposing and coordinating a predecessor system that provides a talent pool representative of that required by the new system, an event that gets recorded as the "Skill Specialty Code Available Man-

Table 4. HARDMAN III SPARC MPT Analysis

MPT ACTIVITIES:

1.0 Develop functional description.

1.1 Identify operational requirements.

INPUTS:

None.

OUTPUTS:

Task Demand Rate by System

Task Allocation to Specialty

1.2 Propose/develop comparable system. (Referred to as a "Baseline system")

INPUTS:

Technology type by subsystem

Mission Type (Corresponding to "Sortie Type" in data model)

OUTPUTS:

Specialty/task assignment (combining the AFS/Subsystem assignment & Tasks by Subsystem data elements)

Task Times

Crew Sizes

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hours" on the LSAR A11 card. Any increases in the Air Force personnel requirement are in the development of new AFSs, an activity unavoidable until dealing with predicted or measured maintenance requirements, i.e., in the post-CDR environment.

A personnel capability trade-off, of sorts, can occur in the LSA "Evaluation of Alternatives" analysis for the Air Force, but this is generally couched in qualitative terms, as underlying data are generally lacking for technology alternatives not yet fielded. The Army personnel quality situation, though, is much different from the Air Force, as a sizeable proportion of the Army force consists of ASVAB Category II and III individuals. The HARDMAN III project will soon produce a credible data base to provide quantitative support for these personnel trade-offs. Until such a data base appears, the P-CON module will have limited applicability to the Air Force MPT analysis community. At the moment, P-CON provides no analogy for the MPT Process Model proposed for TDSTL.

T-CON

This tool develops training trade-off parameters for use in training method selection. Underlying this model is another forthcoming Army-specific data base. The Air Force equivalent function is, again, associated with the predecessor system training requirements; the MPT/SE Process task is 1.3.2, called Compute Comparable Training Requirements.

The current definition of the T-CON tool's function would preclude its use within the SE process of the Air Force. The Air Force training community makes the decision for training materials through the Instructional System Development (ISD) process. It is not clear whether T-CON would fit within that process.

Manpower-Based System Evaluation (MAN-SEVAL)

MAN-SEVAL is the manpower estimating tool. It is based upon a microcomputer hosted simulation, Systems Analysis of Integrated Networks of Tasks (SAINT). The calculations entail developing operator mission and maintenance time lines, and simulating a combat scenario to determine task loading and manpower requirements. The analysis differs from the Air Force problem by coupling operator characteristics with the maintenance network. The manpower calculation process requires detailed task information of about the same level as LCOM, and corresponds to the MPT/SE Compute Manpower tasks.

Personnel-Based System Evaluation (PER-SEVAL)

PER-SEVAL is a task simulation approach to determine the required quality of accessions to enter the maintenance career field associated with a new weapon system. The data requirements for this system come from the differential personnel quality performance data base that feeds the P-CON tool. Outcomes are sets of Manpower by Military Occupational Specialty (MOS)[5] with which system design trades can presumably be made.

This sort of integrated operator/maintainer time line analysis is, generally speaking, beyond the state-of-the-art. And it may be unnecessary to the development of Air Force systems in any case. Time line analysis is routinely performed for Air Force crew station design to identify bottlenecks in the user interface design cycle and to establish performance standards for proficiency

[5] MOS is the Army equivalent to the Air Force AFS. They both define occupational or job categories.

and training. Industrial Engineering task decomposition analysis is routinely used to determine maintenance performance standards. This is generally focused, in the development of Air Force systems, on combat turns and other time critical activities. The activity provides no real MPT parameters other than predicted task times. No activity analogous to PER-SEVAL has been included in the proposed MPT/SE Process Model. In light of the differences we observe in the operator/maintainer role definitions between the two Services, it is difficult to envision the immediate application of the PER-SEVAL to the MPT/SE process proposed here.

Human Operator Simulator (HOS)

HOS (Version V) is the underlying task simulation that supports the PER-SEVAL system. The task data requirements fall somewhere between the level of those required for the LSAR C and D Records. The function of the HOS V is to the generic Army battle scenario what LCOM is to base operations for the Air Force. If HOS V were well integrated with the LSAR data definitions, this analysis would benefit from a close examination of HOS V as well. This reanalysis is beyond the scope of the current effort, however.

Army Manpower Cost (AMCOST)

AMCOST is the cost analysis tool being developed to run on the HARDMAN III data. Cost modeling is not included in the MPT/SE process model since cost modeling is already an SE activity. A closer integration of Air Force MPT analysis will need to consider cost in more detail since cost is the most relevant metric with which to perform more training versus more manpower trade-offs. Discussion of this topic can be found in Miller (1988) and Boyle (1989).

FORCE

This is a proposed Army-wide management and planning tool. This class of analysis is considered outside the scope of MPT/SE analysis as defined for this study inasmuch as it deals with trade-offs among multiple weapon systems. The MPT/SE activity concerned with force-wide constraints is Task 1.3.3 Compute Comparable Accessions Requirement. Here, the impacts of the new system's overall manpower requirements are ascertained and submitted to USAF Headquarters for force planning and management. The advantage of integrating this function with a system designed for use during system acquisition is clear, but the data integration problem, restricted accession numbers and quality required, take it somewhat outside the scope of Air Force acquisition processes.

Manpower Capabilities (MAN-CAP) and SORD

MAN-CAP is a unit-level manpower simulation patterned after the Air Force's LCOM model. The Air Force equivalent to the SORD is some form of the now-abandoned Integrated Manpower Personnel and Consolidated Training System (IMPACTS) summary. The analysis activities capable of supporting these reports are the subject of the MPT/SE Process Model.

Soldier Characteristics Availability Data Method (SCAD) and Integrated Characteristics and Availability Redesign Utility System (ICARUS)

SCAD is an auxiliary program to the force management program that attempts to diagnose and prescribe steps to redress shortfalls in the Army's total manning profile. ICARUS is a proposed specialty management tool that supports the SE system redesign/respecification activity. Within the MPT/SE Process Model the analogous function is the requirements determination function, boiling down to Manpower by AFS constraints. The ICARUS function is handled by the 5.0 Reconsider System Specification task associated with routine analysis of field performance data and the evolving threat. As the SCAD and ICARUS modules are not yet in development or possess firm functional requirements, it is likely that these modules will be redefined in future versions of the HARDMAN III architecture.

Evaluation

The HARDMAN III architecture covers the MPT domain with three exceptions. The first is not explicitly making the comparability/allocated/predicted/measured distinction. This shortfall reflects the requirement analysis for the system not making the distinction among these classes of data. In all likelihood, the only impact will be in not considering alternatives to the HOS V simulation in manpower analysis. The only shortfall of this would be in an eventual development of the analysis system along mathematical programming lines, where the computational and control specification complexity of a simulation language will limit the system design options.

The second shortfall is in not computing the accession requirement. This too could impact future development of the system. This sort of analysis is necessary in computing a complete cost for a fielded force, including training, rank, and time-in-grade requirements.

The third shortfall, from an Air Force perspective, is in not explicitly considering the task-to-AFS allocation problem. Specifically, HARDMAN III does not readily handle AFS definition options. Although it might be altered in some way to handle SUMMA types of analysis, HARDMAN III was not intended to look at an altered MPT environment. Hence, a full-up HARDMAN III analysis on an Air Force system would beg the questions of most interest to Air Force MPT people: How many AFSs should there be, and what does it take to create them?

None of these shortfalls is fatal. The HARDMAN III system architecture i ,volving and it appears that it could accommodate any of these concerns in future versions. Problematical is the HARDMAN concern with the personnel quality issue. The Army claims, on the one hand, that it has data to support this design analysis strategy, and, on the other, that it is developing a task analysis strategy based upon a human factors model linking user response time to system interface complexity (Fitts' law). Whichever is the case, an empirical demonstration of one or the other of these approaches is needed before a prescriptive approach such as this warrants fielding.

Precisely targeting aircraft system development to a certain intellectual capacity of the maintainer force is simply beyond the state of the art. Human factors recommendations in aircraft maintenance tend toward recommendations of known workable design solutions or prototype evaluations to select the "best" option from a predesigned range. With increasing periods of technical development occurring between new system development, these solutions will become increasingly less attractive. Moderating the user interface complexity on very complex systems are the issues of R&M and testability. A closer coupling of the HARDMAN III notions with these logistics considerations is desirable in achieving an analytic solution to the complexity issue.

VII. CONCLUSIONS

The MPT/SE Process Model of this study seems to provide a useful framework for describing and comparing MPT analysis activities. This framework, and its associated Data Model, suitably coordinated, will serve as a framework for future AFHRL work in MPT and logistics analysis. Specifically, the TDSTL follow-on effort will examine the R&M and manpower data sources and calculation techniques to determine the accuracy with which these parameters can be specified. We will also determine suitable analysis alternatives for each application chosen. Of particular concern is the manpower calculation.

The MPT MOMs identified by this effort shall be further developed, with case histories serving as testbeds to demonstrate the feasibility and desirability of these parameters in MPT analysis. This effort will serve as the front end to the development of prototype analytic tools for use in the short- and medium-term environment. Two other analysis efforts applicable to TDSTL development are discussed below.

Integrated MPT Analysis and Computer-Aided Design (IMACAD)

The IMACAD effort is developing a manpower analysis tool applicable to the Develop Functional Description phase of the MPT/SE process model. IMACAD will do for comparability what SUMMA has done for AFS determination, namely, develop analytic flexibility within the information environment with which we must deal. The trade-off between R&M parameters, on the one hand, and Manpower by AFS, on the other, is incompletely exploited in the present environment. The R&M community tends toward maintenance manhours rather than the more germane Manpower by AFS as the MOM.

The IMACAD product will be a manpower comparability analysis workstation with links to future personnel and training analysis facilities. Part of the TDSTL follow-on will incorporate the IMACAD framework to develop and compare manpower analysis alternatives. The goal of the effort is to provide a maximally sophisticated analysis facility while holding the analyst interface complexity to a level equal to or below that currently in use within the R&M community, i.e., that of a reliability allocation spreadsheet model.

Design Evaluation for Personnel, Training, and Human Factors (DEPTH)

Culminating this Air Force research is a planned AFHRL/LRL effort to integrate the SUMMA, IMACAD, and human factors technologies into a unified workstation environment. The MPT Process and Data Models developed under TDSTL and IMACAD are intended to benefit this undertaking by defining the logistic planning interface to the design interface areas of human factors and reliability engineering. The other major AFHRL projects providing technology for this effort are the Crew Chief, R&M in Computer-Aided Design (RAMCAD), and SUMMA.

Technology Requirements

Beyond the previously mentioned R&M to manpower disconnect, other disconnects within the MPT environment can be pointed out. The most obvious one is the perennial lack of documentation among equipment design characteristics, job design, and training and personnel requirements. Previous attempts to solve this problem, ranging from attempts to measure equipment and job complexity to human reliability measurement, have met with little lasting success. The Army HARDMAN effort, and several pre-DEPTH efforts are attempting to address this problem from one direction or another. The Crew Chief program attempts to (partially) solve the problem analytically by physically modeling the environment and deriving anthropometric measurements of the various maintenance tasks. The Comparative Anatomy of Maintenance Tasks (CAMT) research is reviewing competing formats of comparability task data with the aim of finding the one most conducive to accurate comparability analysis. These efforts underscore basic gaps in our knowledge of human performance.

The Unknown Relationships Problem

The problem of unknown MPT relationships eventually arises in all thoughtful MPT efforts. Task and hardware correlates of maintenance technician skill level requirements, particularly, are mentioned as a statistic that would let us streamline Air Force maintenance by reducing task time, training, false removal rates, and other maintenance costs. Sensitivity analyses (such as reported in Garcia & Racher, 1981) show significant manpower deltas due to estimated task time differences between unskilled and journeyman-level aircraft maintainers. Unfortunately, we know little that could prove prescriptive about this particular relationship.

Figure 7 presents graphically other relationships, about which we know little, that could be of use prescriptively. The open squares are areas about which we know nothing of much prescriptive value. The squares marked 1 are the main concern of the science of human factors. Squares marked 2 are the science of testability. Squares marked 3 are what training research deals with. No information exists correlating maintainers' performance criteria with the Air Force classification system. Performance criteria are in general not collected. Personnel performance information in the system development process comes solely from comparable and predecessor systems' maintenance technician population.

Substantial progress in MPT planning will come with the integration of knowledge about the relationships listed in Figure 7 with the R&M-based MPT analysis that is the current state of the art. It would be gratifying to see sponsorship available for investigation of these potentially valuable relationships.

The Air Force's ability to exploit a closer personnel management of the skill level/task time relationship in the real world is questionable. We can expect, at most, an improvement of scarcely 6 percent in average task time and a concomitant manpower reduction of one maintenance technician

	Training Time	Native Ability	Unnecessary Removals	Task Performance Time	Equipment Attributes	Training Success Portability
Training Time	--------					3
Native Ability		--------				
Unneccesary Removals			---------		2	--------
Task Performance Times				---------	1	--------
Equipment Attributes			2	1	--------	
Training Success Probability	3		--------	--------		--------

Figure 7. Unknown Relationships Matrix.

in 20 assuming a maintenance task time standard deviation to mean ratio of .29 (the standard value used within the LCOM community) and a correlation between task time and a predictor of .30 (a typical finding in selection research). This prediction is made assuming only the top 50 percent of individuals on the predictor are assigned to maintenance jobs.

Equipment Design Characteristics

The MPT/SE Process Model points up the close association between MPT and R&M analysis. If this is a fruitful direction for integration, then the incorporation of failure mode analysis and testability considerations into measures of system complexity is the logical next step in improving the user interface with equipment design. LSAR data already include information on how a fault is to be detected on the B1 record. Potentially important variables in this domain include the variables Failure Mode Indicator, Ambiguity Group, Fault Isolation Time, and Means of Detection. The initial goal of investigating this information would be to determine how much additional training is required to handle multiple failure mode indicators and means of detection. The design implications of this information would be the emergence of a trade-off among degree of automated fault isolation, test equipment, and training requirements.

Further Developments

Several further developments of TDSTL are planned. The first effort is IMACAD, being performed concurrently with TDSTL. A direct follow-on to TDSTL (TDSTL II) is also planned. The culmination of these and related efforts is in the DEPTH project.

IMACAD

The IMACAD project is a development and demonstration of a next generation design interface that more closely integrates the SE equipment design strategy, R&M, and MPT issues. The approach pursued is to develop manpower analysis as an extension of the current R&M allocation and monitoring process. The automated tool developed is a workstation for the supportability engineer that ties logistic considerations to "hard" engineering design parameters, such as reliability, weight, size, power consumption, and packaging, which are the issues that the supportability engineer discusses with the design engineers.

The improvement the IMACAD workstation provides is in providing the logistic implications of the engineering design parameters in a timely fashion, empowering the design team to examine alternatives during the design activity itself, rather than dealing with preordained reliability design goals, developed without reference to the actual detail design opportunities or limitations. Opportunities for tangible logistics economies through manpower savings, or changes in support equipment or level of repair requirements, will be identified by the supportability engineer, who will query the design team as to the feasibility of changes to the primary engineering parameters to enable the logistic possibility identified by the IMACAD process. Likewise, the impact of design implementation shortfalls, and the range of plausible compensatory actions, could be assessed during the design process, resulting in less overall redesign and system development delay.

The implementation of the IMACAD system as a supportability engineering function rather than at the bench-level design station is due to the system-wide nature of logistic issues and the requirement that the design engineer only deal with issues over which he has control. The final report suggests methods for integrating IMACAD with training, personnel, and engineering analyses.

TDSTL II

The follow-on TDSTL effort expands the IMACAD software toward use as an LSA-based trade-study alternative to R&M, simulation manpower modeling, and cost analysis by integrating and demonstrating these additional functions in the system. The major effort will be an evaluation and validation of available analytic manpower estimation techniques. Ties to diverse levels of repair analysis, including depot workload, training resource prediction, and personnel issues, will be developed and demonstrated in the development of cost analysis features to the system. An extensive demonstration of the system is tentatively planned, either as a separate effort or as part of the DEPTH effort.

DEPTH

Whereas TDSTL and IMACAD explored the MPT issues amenable to improved control through a revision of the R&M design interface, the DEPTH project seeks to improve the ties between human factors analysis, MPT, and logistic analysis. The most promising approach is through computer man-modeling, which replaces detailed manual task analysis and human factors prototyping with a detailed analysis of a three-dimensional model of the emerging design. Analytic ties between R&M analysis and the man-model then occur through task time estimations from the man-modeling system. The anthropometric and ergonomic personnel characteristics, safety, and related workplace information are also developed by the man-modeling system.

The conventional human factors task analysis is avoided, being replaced by an automated task identification/task analysis generation process. This process avoids detailed task analysis altogether and generates the other task analysis products: training materials and TOs, directly from the man-modeling facility.

Additional analyses that may be profitably integrated into an integrated (and, incidentally, revised) human subsystem analysis include repair-level analysis and testability analysis, as trades between these two issues, and R&M and MPT issues exist but are only performed as a function of meeting minimum turn times, very early in the design cycle.

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LIST OF ACRONYMS

A_a	Achieved Availability
A_i	Inherent Availability
A_o	Operational Availability
AFHRL	Air Force Human Resources Laboratory
AFHRL/LRA	Air Force Human Resources Laboratory/Acquisition Logistics Branch
AFHRL/LRL	Air Force Human Resources Laboratory/Logistics Systems Branch
AFLC	Air Force Logistics Command
AFS	Air Force Specialty
AFWAL/FG	Air Force Wright Aeronautical Laboratory/Flight Dynamics
AGE	Aerospace Ground Equipment
AMCOS	Army Manpower Cost
AOR	Annual Operating Requirements
ATT	Advanced Theater Transport
AVAIL MAN-HOURS	Skill Specialty Code Available Man-Hours
BOC	Best Operational Capability
CAMT	Comparative Anatomy of Maintenance Tasks
CDR	Critical Design Review
DOD	Department of Defense
FSN	Federal State Number
HFE	Human Factors Engineering
HOS V	Human Operator Simulator (Version V)
ICAM	Integrated Computer-Aided Manufacturing Definition
ICARUS	Integrated Characteristics and Availability Redesign Utility System
IDEF	Integrated Computer-Aided Manufacturing
IMACAD	Integrating Manpower Analysis with Computer-Aided Design
IMPACTS	Integrated Manpower Personnel and Consolidated Training System
ISD	Instructional System Development
LCOM	Logistics Composite Model
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
LSAR	Logistics Support Analysis Record
MAJCOM	Major Air Command
MAMDT	Mean Active Maintenance Downtime

LIST OF ACRONYMS (Cont.)

MAN-CAP	Manpower Capabilities
MANPRINT	Manpower and Personnel Integration
MAN-SEVAL	Manpower-Based System Evaluation
MAX TTR	Maximum Time To Repair
MIL-STD	Military Standard
MOMs	Measures of Merit
MOS	Military Occupational Specialty
MPT	Manpower, Personnel, and Training
MTBF	Mean Time Between Failure
MTBM INDUCED	Mean Time Between Maintenance, Induced
MTBM INHERENT	Mean Time Between Maintenance, Inherent
MTBM NO DEFECT	Mean Time Between Maintenance, No Defect
MTBPM	Mean Time Between Preventative Maintenance
MTBMA	Mean Time Between Maintenance Actions
MTTR	Mean Time To Repair
NO SSC	Number of Persons Per Skill Specialty Code
O/M LVL	Operations/Maintenance Level
PAA	Primary Assigned Aircraft
PDP	Procurement Decision Package
PDR	Preliminary Design Review
PER-SEVAL	Personnel-Based System Evaluation
PERS ID	Person Identifier
PME	Precision Measurement Equipment
QPA	Quantity Per Aircraft
QTY SSC AVAIL	-Quantity Skill Speciality Code Available
R&D	Research & Development
R&M	Reliability & Maintainability
RAMCAD	Reliability & Maintainability in Computer-Aided Design
S^3	Specialty Structuring System
SAINT	Systems Analysis of Integrated Networks of Tasks
SCAD	Soldier Characteristics Availability Data Method
SE	Systems Engineering
SEI	Systems Exploration, Inc.

LIST OF ACRONYMS (Cont.)

SE REQUIRED	Support Equipment Required
SLC	Skill Level Code
SOFA	Special Operations Forces Aircraft
SON	Statement of Need
SORD	Statement of Operational Requirements
SOW	Statement of Work
SPARC	System Performance and RAM Criteria Estimation Aid
SPO	System Program Office
SRU	Shop Replaceable Unit
SSC	Skill Specialty Code
SSEVAL	Skill Specialty Evaluation Code
SUMMA	Small Unit Maintenance Manpower Analyses
TDSTL	Top-Down System Tool for Logistics
TRN EQP	Training Equipment Requirements Code
WSAP	Weapon System Acquisition Process
WUC	Work Unit Code

APPENDIX A: FINAL MPT/SE PROCESS MODEL

FINAL MPT/SE PROCESS MODEL

Top-Level Structure

1.0 Develop functional description.
2.0 Assign functional allocation.
3.0 Design and integrate subsystems.
4.0 Evaluate system performance.
5.0 Reconsider system specification.

Table 1 lists the task breakout under each SE task.

Level MPT Task Descriptions

1.0 Develop functional description. This analyst assembles information about the emerging weapon system viable concepts for use in subsequent analyses. The major activity within this activity is the determination of the maintenance task demands.

1.1 Identify operational requirements. The analyst assembles information about the system's mission. The main purpose behind this is to aid future translation of R&M parameters from operational time metrics to 24-hours per day, available maintenance time.

1.2 Propose/develop comparable system. The comparability system is a combination of subsystems of similar technology used on aircraft of similar configuration and mission as the emerging system. The analyst must develop and coordinate a straw man R&M profile and maintenance concept, incorporating subject matter experts and the variety of existing field experience to determine reasonable expectations for emerging system R&M performance.

1.3 Perform comparability analysis. The analyst predicts the logistic behavior of the emerging system through the comparability system. Typically, the logistic requirements to sustain a given sortie rate are computed with limited trade-off results also often being developed.

1.3.1 Compute comparable manpower. Three algorithms are identified: (a) the R&M approach sums the maintenance requirements across systems and multiplies this by utilization to obtain manpower; (b) queuing theory employs analytic probability modeling to derive manpower numbers; and (c) simulation models compute logistic resources numerically.

1.3.2 Compute comparable training requirements. A manpower by AFS statistic allows an estimate of the total and sustaining training burden entailed by the system to be estimated.

1.3.3 Compute comparable accessions requirements. The manpower by AFS statistics and the ongoing training requirement allow the computation of total personnel in the system required to sustain the requisite end strength.

2.0 Assign functional allocation. The analyst must collect R&M data from the reliability and human factors engineer to support an evaluation of the system performance using allocated, as opposed to comparability, system metrics.

2.1 Update operational requirements. The sortie type and rate need to be checked in case of change of system mission, number of systems, threat, and so on.

2.2 Allocate MPT MOMS to subsystems. R&M and AFS to task assignments are finalized. These need to be noted for subsequent analysis. Trade-off analysis would be very helpful in this process. This is the purpose of the IMACAD effort.

2.3 Estimate MPT MOMs from functionally allocated baseline system. This paragraph repeats the activities of paragraph 1.3, using allocated data.

2.3.1 Compute allocated manpower.

2.3.2 Compute allocated training requirements.

2.3.3 Compute allocated ascessions requirement.

3.0 Design and integrate subsystems. The emergence of a hard design of an emerging system allows more accurate predictions of system performance to be developed within the engineering activity. The R&M prediction process is augmented by prototyping and laboratory study in critical areas. The logistic impact of deviations from allocated design parameters is the major concern to the analyst. Anecdotal sources lead one to believe that this information is not available in a timely fashion.

3.1 Update operational requirements. The sortie type and rate need to be checked in case of change of system mission, number of systems, threat, and so on.

3.2 Estimate MPT MOMs from subsystem design. This paragraph repeats the activities of paragraph 1.3, using allocated data.

3.2.1 Compute predicted manpower.

3.2.2 Compute predicted training requirements.

3.2.3 Compute predicted accessions requirement.

4.0 Evaluate system performance. The MPT domain becomes the manpower domain. Differing operating and maintenance concepts that evolve as a system are employed by various commands, and in various environments justify separate manpower analyses for diverse operations.

4.1 Update operational requirements. The sortie type and rate need to be checked in case of change of system mission, number of systems, threat, and so on.

4.2 Estimate MPT MOMs from field experience data. This paragraph repeats the activities of paragraph 1.3, using allocated data.

4.2.1 Compute predicted manpower.

4.2.2 Compute predicted training requirements. This activity becomes institutionalized in the training command.

4.2.3 Compute predicted acessions requirement. This activity becomes institutionalized in the personnel community.

5.0 Reconsider system specification. The impact of proposed configuration changes to a weapon system needs to be evaluated, although generally speaking, most modification programs certify themselves out of any logistic analysis requirements. Of more interest are the periodic studies looking at alternative support concepts such as a revised level of repair or AFS assignments.

5.1 Update operation parameters. The sortie type and rate need to be checked in case of change of system mission, number of systems, threat, and so on.

5.2 Propose and evaluate revised system support concepts. The current support concepts support engineering activity centers on reliability improvement or acquiring additional spares As logistic elements often can compensate for each other, the potential improvement from MPT changes may need to be estimated in this context.

5.3 Evaluate candidate system upgrades. This activity is, essentially, a comparability analysis, using the existing weapon system as its own comparable system.

APPENDIX B: FINAL MPT DATA MODEL BY TASK

FINAL MPT DATA MODEL BY TASK

1.0 Develop functional description.

1.1 Identify operational requirements.

INPUTS: None

OUTPUTS: Number of PAA
Sortie Type
Sortie Rate by Type
Sortie Duration by Type

1.2 Propose/develop comparable system.

INPUTS: Technology Type by Subsystem
Sortie Type

OUTPUTS: AFS/Subsystem Assignment
Reliability by Subsystem (Comparable Reliability)
Maintenance Tasks by Subsystem
Maintenance Task Times

1.3 Perform comparability analysis.

1.3.1 Compute comparable manpower.

INPUTS: AFS/Subsystem Assignment
Reliability by Subsystem (Comparable Reliability)
Support Equipment
Maintenance Tasks by Subsystem
Maintenance Task Times
Maintenance Crew Size by Task

OUTPUTS: Comparability Required Manpower by AFS

1.3.2 Compute comparable training requirements.

INPUTS: Comparability Required Manpower by AFS
Training Requirements by AFS

OUTPUTS: Comparability System Training Requirements

1.3.3 Compute comparable accessions requirement.

INPUTS: Comparability Required Manpower by AFS
Comparability System Training Requirements
Historic Personnel Turnover Rate by AFS

OUTPUTS: Comparability Required Accessions by AFS per year

2.0 Assign functional allocation.

2.1 Update operational requirements.

INPUTS: None

OUTPUTS: Number of PAA
Sortie Type
Sortie Rate by Type
Sortie Duration by Type

2.2 Allocate MPT MOMs to subsystems.

INPUTS: Maintenance Tasks by Subsystem

OUTPUTS: Reliability by Subsystem (Allocated Reliability)
Maintenance Task Times
Allocated System Reliability
Allocated System Maintainability

2.3 Estimate MPT MOMs from functionally allocated baseline system.

2.3.1 Compute allocated manpower.

INPUTS: AFS/Subsystem Assignment
Reliability by Subsystem (Allocated Reliability)
Support Equipment
Maintenance Tasks by Subsystem
Maintenance Task Times
Maintenance Crew Size by Task

OUTPUTS: Allocated Required Manpower by AFS

2.3.2 Compute allocated training requirements.

INPUTS: Allocated Required Manpower by AFS
Training Requirements by AFS

OUTPUTS: Allocated System Training Requirements

2.3.3 Compute allocated accessions requirement.

INPUTS: Allocated Required Manpower by AFS
Allocated System Training Requirements
Historic Personnel Turnover Rate by AFS

OUTPUTS: Allocated Required Accessions by AFS per year

3.0 Design and integrate subsystems.

3.1 Update operational requirements.

INPUTS: None

OUTPUTS: Number of PAA
Sortie Type
Sortie Rate by Type
Sortie Duration by Type

3.2 Estimate MPT MOMs from subsystem design.

3.2.1 Compute predicted manpower.

INPUTS: AFS/Subsystem Assignment
Reliability by Subsystem (Predicted Reliability)
Support Equipment
Maintenance Tasks by Subsystem
Maintenance Task Times
Maintenance Crew Size by Task

OUTPUTS: Predicted Required Manpower by AFS

3.2.2 Compute predicted training requirements.

INPUTS: Predicted Required Manpower by AFS
Training Requirements by AFS

OUTPUTS: Predicted System Training Requirements

3.2.3 Compute predicted accessions requirement.

INPUTS: Predicted Required Manpower by AFS
Predicted System Training Requirements
Historic Personnel Turnover Rate by AFS

OUTPUTS: Predicted Required Accessions by AFS per year

4.0 Evaluate system performance.

4.1 Update operational requirements.

INPUTS: None

OUTPUTS: Number of PAA
Sortie Type
Sortie Rate by Type
Sortie Duration by Type

4.2 Estimate MPT MOMs from field experience data.

4.2.1 Compute predicted manpower.

INPUTS: AFS/Subsystem Assignment
Reliability by Subsystem (Measured Reliability)
Support Equipment
Maintenance Tasks by Subsystem
Maintenance Task Times
Maintenance Crew Size by Task

OUTPUTS: Predicted Required Manpower by AFS

4.2.2 Compute predicted training requirements.

INPUTS: Predicted Required Manpower by AFS

Training Requirements by AFS

OUTPUTS: Predicted System Training Requirements

4.2.3 Compute predicted accessions requirement.

INPUTS: Predicted Required Manpower by AFS
Predicted System Training Requirements
Historic Personnel Turnover Rate by AFS

OUTPUTS: Predicted Required Accessions by AFS per year

5.0 Reconsider system specification.

5.1 Update operation parameters.

INPUTS: None

OUTPUTS: Number of PAA
Sortie Type
Sortie Rate by Type
Sortie Duration by Type
AFS/Subsystem Assignment
Reliability by Subsystem (Measured Reliability)
Maintenance Tasks by Subsystem
Maintenance Task Times
Maintenance Crew Size by Task

5.3 Propose and evaluate revised system support concepts.

INPUTS: Number of PAA
Sortie Type
Sortie Rate by Type
Sortie Duration by Type
AFS/Subsystem Assignment
Reliability by Subsystem (Measured Reliability)
Support Equipment
Maintenance Tasks by Subsystem
Maintenance Task Times
Maintenance Crew Size by Task

OUTPUTS: Predicted Required Manpower by AFS
Predicted System Training Requirements
Predicted Required Accessions by AFS per year

5.4 Evaluate candidate system upgrades.

INPUTS: Number of PAA
Sortie Type

Sortie Rate by Type
Sortie Duration by Type

OUTPUTS: Predicted Required Manpower by AFS
Predicted System Training Requirements
Predicted Required Accessions by AFS per year

Data Elements

AFS/Subsystem Assignment
Allocated Required Accessions by AFS per year
Allocated Required Manpower by AFS
Allocated System Maintainability
Allocated System Reliability
Allocated System Training Requirements
Comparability Required Accessions by AFS per year
Comparability Required Manpower by AFS
Comparability System Training Requirements
Historic Personnel Turnover Rate by AFS
Maintenance Crew Size by Task
Maintenance Task Times
Maintenance Tasks by Subsystem
Number of PAA
Predicted Required Accessions by AFS per year
Predicted Required Manpower by AFS
Predicted System Training Requirements
Predicted Required Manpower by AFS
Reliability by Subsystem (Allocated Reliability)
Reliability by Subsystem (Comparable Reliability)
Reliability by Subsystem (Measured Reliability)
Reliability by Subsystem (Predicted Reliability)
Sortie Duration by Type
Sortie Rate by Type
Sortie Type
Support Equipment
Technology Type by Subsystem
Training Requirements by AFS

APPENDIX C: LSAR MPT DATA ELEMENTS WITH MPT/SE DATA ELEMENTS CROSS-REFERENCED

LSAR MPT DATA ELEMENTS WITH MPT/SE DATA ELEMENTS CROSS-REFERENCED

Note: The distinction among comparable, allocated, predicted, and measured parameters is not included in the cross-reference information. The only possible confusion from this is the distinction between system maintainability and individual task time blurs where level of analysis is not specified; both are listed where applicable.

Data Record A (Operations and Maintenance Requirements)

Card A06
Annual Operating Requirements (AOR): Sortie Rate by Type, Sortie Type
Annual Number of Missions: Sortie Rate by Type
Annual Operating Days: Sortie Rate by Type
Mean Mission Duration: Sortie Duration by Type
Total Systems Supported: Number of PAA
Number of Operating Locations: Number of PAA

Card A07
Minimum Acceptable Mean Time Between Failures (MTBF): System Reliability
Minimum Acceptable Mean Time Between Maintenance Actions (MTBMA): System Reliability
Minimum Acceptable Mean Time to Repair (MTTR): System Maintainability
Minimum Acceptable Mean Active Maintenance Downtime (MAMDT): System Maintainability, System Reliability
Best Operational Capability (BOC) Mean Time Between Failures (MTBF): System Reliability
BOC Mean Active Between Maintenance Actions (MTBMA): System Reliability
BOC Mean Time to Repair (MTTR): System Maintainability
BOC Mean Active Maintenance Downtime (MAMDT): System Maintainability, System Reliability

Card A08
Maximum Time to Repair (MAX TTR): System Maintainability
Precentile (of maintenance actions not to exceed MAX TTR): System Maintainability
Inherent Availability (Ai): System Reliability System Maintainability
Achieved Availability (Aa): System Reliability, System Maintainability
Operational Availability (Ao): System Reliability, System Maintainability
Administrative and Logistic Delay Time (ALDT): System Maintainability

Card A09

Operations/Maintenance Level (O/M LVL): AFS/Subsystem Assignment

Number of Systems Supported: Number of PAA

Unscheduled Maintenance Mean Elapsed Time: System Maintainability

Unscheduled Maintenance Mean Man-Hours: System Maintainability

Unscheduled Maintenance Maximum Time to Repair: System Maintainability

Unscheduled Maintenance Percentile (of maintenance actions not to exceed MAX TTR): System Maintainability

Scheduled Maintenance Man-Hour per Operating Hour: System Maintainability

Unscheduled Maintenance Man-Hour per Operating Hour: System Maintainability

Scheduled Maintenance Annual Man-Hours: System Maintainability

Unscheduled Maintenance Annual Man-Hours: System Maintainability

Turnaround Mean Elapsed Time: System Maintainability, Maintenance Task Times

Turnaround Mean Man-Hours: System Maintainability, Maintenance Task Times

Card A10

Daily Inspection Mean Elapsed Time: System Maintainability, Maintenance Task Times

Daily Inspection Mean Man-Hours: System Maintainability, Maintenance Task Times

Preoperative Inspection Mean Elapsed Time: System Maintainability, Maintenance Task Times

Preoperative Inspection Mean Man-Hours: System Maintainability, Maintenance Task Times

Postoperative Inspection Mean Elapsed Time: System Maintainability, Maintenance Task Times

Postoperative Inspection Mean Man-Hours: System Maintainability, Maintenance Task Times

Periodic Inspection Mean Elapsed Time: System Maintainability, Maintenance Task Times

Periodic Mission Inspection Mean Man-Hours: System Maintainability, Maintenance Task Times

Mission Profile Change Mean Elapsed Time: System Maintainability, Maintenance Task Times

Mission Profile Change Mean Man-Hours: System Maintainability, Maintenance Task Times

Card A11

Operations/Maintenance Level: AFS/Subsystem Assignment

Skill Specialty Code (SSC): AFS/Subsystem Assignment, Required Manpower by AFS

Skill Level Code (SLC): AFS Subsystem Assignment, Required Accessions by AFS per Year, Required Manpower by AFS

Quantity Skill Specialty Code Available (QTY SSC AVAIL): Required Accessions by AFS per Year, Required Manpower by AFS

Skill Specialty Code Available Man-Hours (AVAIL MAN-HOURS): Required Accessions by AFS per Year, Required Manpower by AFS

Data Record B (Item Reliability and Maintainability Characteristics)

Card B06

Inherent Availability (Ai): System Maintainability, System Reliability

Achieved Availability (Aa): System Maintainability, System Reliability

Operational Availability (Ao): System Maintainability, System Reliability

Card B07

Reliability/Maintainability Indicator Code (Comparability, Allocated, Predicted, Measured): Mean Time Between Failures (MTBF): System Reliability

Mean Time Between Maintenance Actions (MTBMA): System Reliability

Mean Time Between Maintenance Inherent (MTBM INHERENT): System Reliability

Reliability Growth Rate: System Reliability

Mean Time Between Maintenance Induced (MTBM INDUCED): System Reliability

Mean Time Between Maintenance No Defect (MTBM NO DEFECT): System Reliability

Mean Time Between Preventative Maintenance (MTBPM): System Reliability

Mean Time To Repair (MTTR): System Maintainability

Maximum Time To Repair (MAX TTR): System Maintainability

Percentile (of maintenance actions not to exceed MAX TTR): System Maintainability

Card B11

Reliability Centered (Preventative) Maintenance Task Code: Maintenance Tasks by Subsystem

Reliability Centered (Preventative) Maintenance Task Time: System Maintainability, Maintenance Task Times

Data Record B1 (Failure Modes and Effects Analysis)

No Relevant Entries.

Data Record B2 (Criticality and Maintainability Analysis)

Card B16

Failure Rate (Component): System Reliability

Card B18

Task Time (Component): System Maintainability, Maintenance Task Times

Data Record C (Operation and Maintenance Task Summary)

Card C06

Task Code: Maintenance Tasks by Subsystem

Task Frequency: System Reliability

Training Equipment Requirements Code (TRN EQP): System Training Requirements

Tool/Support Equipment Requirements Codes: Support Equipment

Data Record D (Operation and Maintenance Task Analysis)

Task Code: Maintenance Tasks by Subsystem

Person Identifier (PERS ID); indirect means to compute crew size: AFS/Subsystem Assignment, Required Manpower by AFS

Mean Man-Minutes: System Maintainability, Maintenance Task Times

Mean Minute Elasped Time: System Maintainability, Maintenance Task Times

Skill Specialty Code: AFS/Subsystem Assignment

Mean Man-Minutes per Skill Specialty Code: System Maintainability, Maintenance Crew, Maintenance Task Times Size by Task

Mean Minute Total Elapsed Time: System Maintainability, Maintenance Task Times

Data Record D1 (Personnel and Support Requirements)

Card D06

Task Code: AFS/Subsystem Assignment, Maintenance Tasks by Subsystem

Predicted Mean Elapsed Time: System Maintainability, Maintenance Task Times

Measured Mean Elapsed Time: System Maintainability, Maintenance Task Times

Skill Level Code (SLC) (Basic, Intermediate, or Advanced): AFS/Subsystem Assignment, Required Accessions by AFS per Year

Skill Specialty Code (SSC): AFS/Subsystem Assignment

Skill Specialty Evaluation Code (SSEVAL) (Adequate, Modification, Establish new SSC): AFS/Subsystem Assignment

Number of Persons Per Skill Specialty Code (NO SSC): Required Manpower by AFS, Maintenance Crew Size by Task

Predicted Mean Man-Hours Per Skill Specialty Code: System Maintainability, Maintenance Crew Size by Task, Maintenance Task Times

Measured Mean Man-Hours Per Skill Specialty Code: System Maintainability, Maintenance Crew Size by Task, Maintenance Task Times

Data Record E (Support Equipment or Training Material Description and Justification)

Support Equipment Required (SE REQUIRED):

Calibration Required: Maintenance Tasks by Subsystem

Calibration Interval: System Reliability

Calibration Time: System Maintainability, Maintenance Task Times

Mean Time Between Failures (MTBF): System Reliability

Mean Time Between Maintenance Actions (MTBMA): System Reliability

Mean Time To Repair (MTTR): System Maintainability, Maintenance Task Times

Quantity Per Activity: Number of PAA

Total Quantity: Number of PAA

Skill Specialty Code (SSC): AFS/Subsystem Assignment

Additional Skills and Special Training Requirements: System Training Requirements

Data Record E1 (Unit Under Test and Automatic Program(s))

No Relevant Entries.

Data Record F (Facility Description and Justification)

No Relevant Entries.

Data Record G (Skill Evaluation and Justification)

Skill Specialty Code Assigned New Duty Position (SSC ASSIGNED NEW DUTY POSITION): AFS/Subsystem Assignment

Skill Specialty Code From Which Personnel Can Be Obtained: AFS/Subsystem Assignment, Required Accessions by AFS per Year

Minimal Task Score Acceptable:

Military Rank/Rate: AFS/Subsystem Assignment, Required Accessions by AFS per Year

Civilian Grade: AFS/Subsystem Assignment

Physical and Mental Requirements: Required Accessions by AFS per Year

Educational Qualifications: Required Accessions by AFS per Year, System Training Requirements

Additional Training Requirements: System Training Requirements

Data Record H (Support Items Identification)

No Relevant Entries.

Data Record H1 (Support Items Identification)

No Relevant Entries.

Data Record J (Transportability Engineering Characteristics)

No Relevant Entries.

<u>APPENDIX D</u>: LCOM MPT DATA ELEMENTS

LCOM MPT DATA ELEMENTS

Form 10 (Performance Summary Report)

No Relevant Entries.

Form 11 (Task Network)

Task ID: The Work Unit Code (WUC) of the activity.

Selection Parameter: The failure distribution underlying the task demand and the parameter for that distribution.

Form 12 (Task Definitions)

Task ID: The WUC of the activity.

Task Type: The distinction between scheduled versus unscheduled is made.

Task Duration: Self-explanatory.

Associated Resources, Resource Requirements, Task Specific Resource Substitution (Form 12A): Support equipment or spares.

Form 13 (Resource Definitions)

Resource Identification: Resource Name; not a federal stock number (FSN).

Resource Type: Aircraft, parts, manpower, or Aerospace Ground Equipment (AGE).

Authorized Quantity: Self-explanatory.

Quantity Per Aircraft (QPA): Number of a single part installed on the aircraft. Used to calculate cannibalization effects within the model.

Form 14 (Failure Clock Decrements)

Parameters used in failure rates and distribution calculations.

Form 15 (Distributions)

Parameters used in failure rates and distribution calculations.

Form 16 (Shift Change Policies)

Parameters used to develop shift policy statistics for manpower calculation.

Form 17 (Mission/Activity Entry Points)

Mission ID: Sortie Type
Presortie External Configurations: Determines preflight work demand; heterogeneous sortie profiles will have more task demand than will homogeneous task profiles.

Form 18 (Priority Specifications)

Parameters used to model task demand and service discipline.

Form 20 (Sortie Generator)

Number of Missions or Activities: Sortie Rate.
Take-off or Activity Time: Determines sortie demand distribution.
Mission Size: Number of aircraft required for each mission.
Mission Length: Self-explanatory.

Form 21 (Aircraft Assignment Search Pattern)

Parameters required to determine pre-sortie task requirements.

Form 22 (Internal Equipment Authorization/Changes)

Parameters required to determine pre-sortie task requirements.

Form 23 (Internal Equipment Group Definitions)

Parameters required to determine pre-sortie task requirements.

APPENDIX E: DRAFT MPT DATA MODEL

DRAFT MPT DATA MODEL

1.0 Develop functional description

- 1.1 Identify operational requirements
  - Sortie rates
  - Sortie duration
  - Sortie type
  - Number of assigned aircraft
  - Base layout (transportation times between work sites)
- 1.2 Propose/develop comparable system
  - Technology type
  - Sortie type
  - Support equipment type
  - AFS responsibilities
  - Reliability
  - Maintenance requirements
  - Task times
- 1.3 Perform comparability analysis
  - AFS responsibilities
  - Shift policy
  - Reliability
  - Maintenance requirements
  - Task times
  - Sortie rates
  - Sortie duration
  - Sortie type
  - Support equipment type
  - Support equipment amount
  - Spares level
  - Number of assigned aircraft
  - Base layout (transportation times between work sites)
  - Required manpower by AFS
- 1.4 Identify predecessor system
  - Predecessor AFS structure
  - Available manpower by AFS
  - Training requirement by AFS

1.5 Develop preliminary MPT profile
   - Predecessor AFS structure
   - Available manpower by AFS
   - Training requirement by AFS
   - Required manpower by AFS
   - Required accessions
   - Required training

1.6 Propose MPT MOMs
   - Support equipment type
   - AFS responsibilities
   - Reliability
   - Maintenance requirements
   - Task times
   - Shift policy
   - Support equipment amount
   - Spares level
   - Number of assigned aircraft
   - Base layout (transportation times between work sites)
   - Required manpower by AFS
   - Predecessor AFS structure
   - Available manpower by AFS
   - Training requirement by AFS
   - Required accensions
   - MPT MOMs

2.0 Assign functional allocation

2.1 Update operational requirements*

2.2 Allocate MPT MOMs to subsystems
   - AFS responsibilities
   - Reliability
   - Maintenance requirements
   - Task times
   - Support equipment
   - Spares level

- 2.3 Estimate MPT MOMs from functionally partitioned system**
  - AFS responsibilities
  - Reliability
  - Maintenance requirements
  - Task times
  - Shift policy
  - Sortie rates
  - Sortie duration
  - Sortie type
  - Support equipment type
  - Support equipment amount
  - Spares level
  - Number of assigned aircraft
  - Base layout (transportation times between work sites)
  - Required manpower by AFS

3.0 Design Subsystems

- 3.1 Update operational requirements*
- 3.2 Estimate MPT MOMs from subsystem design**
  - AFS responsibilities
  - Reliability
  - Maintenance requirements
  - Task times
  - Shift policy
  - Sortie rates
  - Sortie duration
  - Sortie type
  - Support equipment type
  - Support equipment amount
  - Spares level
  - Number of assigned aircraft
  - Base layout (transportation times between work sites)
  - Required manpower by AFS
- 3.3 Interact with design activity

4.0 Integrate subsystems

- 4.1 Update operational requirements*

4.2 Estimate MPT MOMs from system design**

AFS responsibilities
Reliability
Maintenance requirements
Task times
Shift policy
Sortie rates
Sortie duration
Sortie type
Support equipment type
Support equipment amount
Spares level
Number of assigned aircraft
Base layout (transportation times between work sites)
Required manpower by AFS

5.0 Test and evaluation

5.1 Update operational requirements*

5.2 Estimate MPT MOMs from test results**

AFS responsibilities
Reliability
Maintenance requirements
Task times
Shift policy
Sortie rates
Sortie duration
Sortie type
Support equipment type
Support equipment amount
Spares level
Number of assigned aircraft
Base Layout (transportation times between work sites)
Required manpower by AFS

6.0 Reconsider system specification

6.1 Update operation parameters*

6.2 Compute MPT MOMs from field experience**

AFS responsibilities
Reliability
Maintenance requirements
Task times
Shift policy
Sortie rates
Sortie duration
Sortie type
Support equipment type
Support equipment amount
Spares level
Number of assigned aircraft
Base Layout (transportation times between work sites)
Required manpower by AFS

6.3 Propose and evaluate system support concepts

AFS responsibilities
Reliability
Maintenance requirements
Task times
Shift policy
Sortie rates
Sortie duration
Sortie type
Support equipment type
Support equipment amount
Spares level
Required manpower by AFS

6.4 Propose and evaluate system upgrades

AFS responsibilities
Reliability
Maintenance requirements
Task times
Shift policy
Sortie rates
Sortie duration

Sortie type

Support equipment type

Support equipment amount

Spares level

Required manpower by AFS

*These activities loop back to some previous point in the SE process.

**depending upon MOMs selected