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TECHNOLOGY PROJECTION: MANPOWER AND LOGISTIC FACTORS IN WEAPON --ETC(U)

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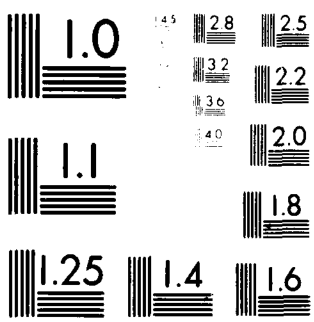

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TECHNOLOGY PROJECTION: MANPOWER AND LOGISTIC FACTORS IN WEAPON SYSTEM DEVELOPMENT

By

Gordon A. Eckstrand

LOGISTICS AND TECHNICAL TRAINING DIVISION
Wright-Patterson Air Force Base, Ohio 45433

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Final Report

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NOTICE

This final report was submitted by the Logistics and Technical Training Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio 45433, under Project 1959, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235. Dr. Gordon Eckstrand was the Principal Investigator for the Laboratory.

This technical report has been reviewed and is approved for publication.

ROSS L. MORGAN, Technical Director
Logistics and Technical Training Division

RONALD W. TERRY, Colonel, USAF
Commander

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This report outlines the importance of and requirement for considering manpower and logistic factors in weapon system acquisition programs. The scope of the area is defined, and the relationships between the Integrated Logistics System program and the Human Factors Engineering program are discussed.

Developing weapon systems which can meet peacetime readiness and wartime employment objectives at the lowest possible life cycle cost (LCC) requires the ability to integrate manpower and related support considerations into the system acquisition process in a way that allows them to influence requirements and design. A number of human factors related technologies that contribute to the achievement of this goal are described in the report. The areas covered are: Maintenance Manpower Modeling; Training Plans and Requirements;

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Maintenance Technical Data; System Ownership Costing; Human Resources in Design Trade-offs; Supporting Data Bases. For each of these component technologies, a near-term (5 years) technology projection is presented. Although each of the component technologies independently can make an important contribution to weapon system acquisition, what is needed most is a method to integrate the application of these component technologies during weapon system development or modification. Work to provide such an integrated methodology is described and a near-term technology projection in this area is provided.

In addition, far-term (10 to 15 years) projections are provided for each of the component technologies and for the integrated application of these technologies.

Finally the report provides a discussion of key issues involved in transitioning this technology into use as an accepted part of the weapon system development and modification process.

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I. SCOPE OF AREA

Studies have shown that, in most weapon systems, the operation and support (O& S) costs exceed 50% of the total life cycle costs (LCC), and in some cases, they may be as high as 80% . For example, in a recent study of the C-130E aircraft over a period of 15 years, O& S costs were 80.5% of the system LCC. Significantly, 64.2% of the O& S costs were manpower related. A few years ago, an analysis showed that more than 43% of the Air Force budget went for product support (supply and maintenance), with much of this related to salary costs. These trends have been exacerbated by the rising costs of military manpower associated with the change to an all volunteer force.

With a relatively constant defense budget, these and related statistics have made it quite clear that manpower and logistic costs must be brought under control. This realization has brought about an increasing concern that the weapon systems procured by the Air Force be designed so that they can be operated and maintained effectively at a manpower and logistics cost which is in balance with other demands on the military dollar (e.g., development of new technology and new weapon systems). This can be done only if manpower and logistics considerations and costs become weapon system design parameters in the same sense that operational and performance considerations and costs have been in the past. Furthermore, because so many of the design decisions which drive support costs are made very early in the weapon system development process, manpower and logistics factors must be addressable from the conceptual phase on.

At least partly in response to these concerns about system supportability, the Department of Defense (DoD) established the Integrated Logistics Support (ILS) Program for Systems and Equipment in the mid-1960s. The ILS program, as documented in regulations, is a composite of all support considerations necessary to assure the effective, economical support of a system or equipment throughout its life cycle. It is an integral part of system and equipment acquisition and operation and includes the integration of logistics considerations and logistics planning into the engineering and design process of systems, equipment, and modification programs. In the Air Force, the ILS program is documented in AFR 800-8, Integrated Logistics Support (ILS) Program. At least in the Air Force, ILS has had only modest success in achieving established objectives with respect to impacting the engineering and design process. The program has suffered from insufficient professional personnel knowledgeable in the weapon system development process, inadequate management support, and a lack of adequate technology. Also, both in the System Program Offices and in industry, organizational placement has often isolated the ILS people from the engineering function. Recently, however, a number of events and actions have occurred which indicate that the ILS program may be ready to assume a more active role in the weapon system development/ modification process. (a) At the DoD level, a new directive adds emphasis to the involvement of ILS in early design; broadens the program to include total manpower planning, training devices (as a whole compared to only training equipment), initial provisioning and software support; and is written to align the ILS program with the Defense System Acquisition Review Council (DSARC) milestones as initiated by Office of Management and Budget (OMB) Circular A-109 and implemented by DoD Directive 5000.1. (b) Two strong policy memoranda have been issued by the Office of the Assistant Secretary of Defense for Manpower and Reserve Affairs and Logistics (ASD/ MRA& L). (c) Within the Air Force, an Acquisition Logistics Division (AFALD) was established in 1976 as an element of the Air Force Logistics Command. This organization, headed by a lieutenant general, provides needed management emphasis and authority to the ILS program. (d) At the request of AFALD, the Air Force Institute of Technology has added a number of short and long term courses in support of the ILS program. (e) Finally, the logistics community in the Air Force has recognized the need for research and development (R& D) and has established procedures for submitting logistics research needs to the Air Force laboratories. These events and actions are a strong signal that the ILS program will be playing a major role in the future in getting manpower and logistic factors actively involved in decisions concerning weapon system design and modification.

There are obvious relationships between the ILS program and the Human Factors Engineering (HFE) program. In AFR 800-15, Human Factors Engineering and Management, (HFE) is defined as follows: "HFE is a part of the mainstream engineering effort throughout the system life cycle. It is that component of system engineering which seeks to optimize the system by integrating the human performance necessary to operate, maintain, support, and control the system in its intended operational environment." In the recent DoD Directive, Integrated Logistics Support (ILS) is defined as "A unified and iterative approach to the management and technical activities necessary to: (a) cause support considerations to influence requirements and design; (b) define support requirements that are optimally related to the design and to each other; (c) acquire the required support; and (d) provide the required support during the operational phase at minimum cost."

To indicate the relationship betwen HFE and ILS, the elements of the two programs are listed as follows:

ILS

- 0 Maintenance Plan
- 0 Manpower and Personnel
- 0 Supply Support (including initial provisioning)
- 0 Support and Test Equipment
- 0 Training and Training Devices
- 0 Technical Data
- 0 Computer Resources Support
- 0 Packaging, Handling, Storage and transportation
- 0 Facilities

HFE

- 0 Human Engineering
- 0 Biomedical
- 0 Manpower and Personnel Requirements
- 0 Training (Including Training Plan, Training Equipment, and Facilities; Maintenance Technical Data)
- 0 Human Factors Test and Evaluation

Without attempting any analysis in depth, it is obvious that there is considerable commonality between these two programs. At the very least, both programs have overlapping responsibilities for the following elements as they impact and are impacted by system design decisions: manpower, personnel, training and training equipment, and maintenance technical data. The need to integrate HFE and ILS activities is briefly noted in paragraphs 7c and 7d of AFR 800-15, but in reality, the two programs have as yet achieved little integration.

Looking at the issue from an HFE point of view, it is clear that HFE and ILS personnel must join forces in order to provide the Air Force with a technology and an applications capability for including manpower and related support considerations in the design and modification of weapon systems and support equipment. The basic reason is that neither ILS nor HFE decisions can be made without joint impacts. The R& D to develop the required technology should be carried out by the HFE community with appropriate support from the acquisition logistics community. The application effort must be a cooperative endeavor between HFE and ILS people working in the SPOs and in industry. This will require some adjustment in the field of HFE. It will require a broadening of the field with concomitant changes of emphasis in research, training, and applications. But these adjustments are long overdue. The following sections of the report briefly outline the needed technology, how much is currently available, and what remains to be done. Some comments about technology transition and applications efforts are also included.

II. NEAR-TERM PROJECTION

Component Technologies

Developing weapon systems which can meet peacetime readiness and wartime employment objectives at the lowest possible LCC requires the ability to integrate manpower and logistics considerations into the system acquisition process in a way that allows them to influence requirements and design. There are a number of human-factors-related technologies that contribute to the achievement of this goal. A near term technology projection in each of these areas is presented in the following paragraphs.

1. *Maintenance Manpower Modeling.* There is a greater uncertainty associated with maintenance manning than with any other element of new weapon system manpower requirements. Therefore, most HFE effort to date has been concentrated in this area. For new aircraft systems, the Air Force now uses a method based upon the Logistic Composite Model (LCOM) to determine maintenance manpower requirements. This method, which was developed by the Air Force Human Resources Laboratory (AFHRL), has been institutionalized as the standard method for computing maintenance manpower requirements in the Air Force. At the present time, the system program manager, the Air Force Test and Evaluation Center, the Air Force Management Engineering Agency, and the operating commands all use the same methodology for estimating wing maintenance manpower requirements for new aircraft. The method is mandated by Air Force Regulations 25-5 (Vol 1, 2, 3), Air Force Management Engineering Program (MEP), and 25-8, Logistics Composite Model (LCOM).

Although the basic LCOM maintenance manpower model is being used effectively, a number of improvements are required and are in the process of being developed. One will produce models of the interactions among the requirements for manpower, spares, and support equipment to accomplish aircraft maintenance. This will make it easier to determine the optimum mix of support resources to attain a particular target sortie rate and to indicate the incremental impact on readiness of varying levels of support resources. In another effort, more accurate maintenance metrics are being developed to replace the current ones used in the model; e.g., maintenance man-hours per flying hour. These metrics will reflect the hardware, operational, and environmental parameters which drive the maintenance demands of an aircraft system and should (a) substantially increase the sensitivity and validity of model outputs and (b) broaden the range of circumstances for which the model is appropriate. These efforts are expected to be completed within the next year.

Another needed improvement concerns the simplification of the model. At the present time, the employment of LCOM requires the development of an extensive data base involving maintenance task networks for all aircraft subsystems and equipments. Developing such a data base is a major undertaking and requires a team of expert analysts. The computer capacity and time required to run the model are also large. Some effort is currently underway to reduce the size of the input required to LCOM, and this should have some payoff in the near future. This will not solve the basic problem, however, and there is a need to develop new computer-based manpower modeling techniques which will provide valid predictions with less detailed and extensive input data and less computer time for operation.

There is also a need to adapt the maintenance manpower modeling techniques so that they can be applied to missile and ground electronics systems.

2. *Training Plans and Requirements.* Instructional System Development (ISD) is the basic method used in the Air Force to determine training requirements and to develop training plans and programs. The techniques and procedures for ISD are well documented and are being applied widely in the Air Training Command (ATC) and the operating commands with varying degrees of success.

Of particular interest here, however, is the integration of training plans, requirements, and resources into the weapon system acquisition process. Controlling training requirements can be as important as constraining manning levels during weapon system development. Here the technology is not well developed and responsibilities are fragmented between various commands: Air Force Logistics Command (AFLC) (ILS program), Air Force Systems Command (AFSC) (HFE program), operating commands, and the Air Training Command (ATC). On the management side, there is a definite need to fix responsibility in this important area. In the R& D area, there is a requirement for techniques and models for accomplishing training impact analyses early in the weapon system development process. The ISD process, as currently documented, depends heavily on detailed task and situation analyses of the jobs to be trained. Such information, of course, is not available early in the system development cycle. Therefore, the primary requirement is to develop techniques and models which can accept other types of inputs; e.g., data based upon comparability analyses and data derived from expert judgement. The HFE community also needs to improve the capability to develop these types of data in the training area. Some research has been done on the accuracy with which skilled maintenance technicians can estimate training requirements from early design phase engineering descriptions of the system. Early results were disappointing, but later work has shown that if the estimates are requested at the proper level of detail, valid data can be obtained. This work needs to be followed up and supplemented with efforts to improve the use of comparability analysis in making early training requirements determinations.

It is important to recognize that before any progress can be made toward having training influence system design, the attitude toward training as an HFE element must be changed. The present attitude regards training as the mechanism for conforming people to the hardware design, and frequently, training is expected to make up for poor design. The changes in input skills of first-term officers and airmen and the rising costs of training, require a more positive stance toward designing systems which utilize skills that are compatible with the Air Force ability to provide skills.

3. *Maintenance Technical Data.* The basic technology for developing improved maintenance technical data usually referred to as job performance aids (JPAs)—to support the performance of technicians at the organization and intermediate levels of maintenance is available and has been demonstrated. Numerous formats and options are available for job guides and proceduralized troubleshooting aids, and adequate specifications and handbooks will be available during the next year to provide guidance to SPO and contractor personnel in selecting and procuring technical data that is tailored to the characteristics of a particular system and to the needs of the maintenance personnel expected to be available. This type of technical data, when properly developed, costs more to procure initially than conventional technical orders, but results in substantial savings in ownership costs. What is needed now is a major effort to assure *full and proper* implementation of this technology. This will require at least two things: (a) SPO management personnel must be convinced that an increased front end investment in maintenance technical data must be made in order to obtain the desired system life cycle cost reductions; (b) the professional quality of personnel who support the technical data function in the SPO must be improved. Human Factors Engineers ought to be actively involved in achieving both of these objectives.

One area where additional work is needed concerns the integrated planning of maintenance training and maintenance technical data during the early phases of system development. Both training and technical data are required to support the performance of the technician in the field. In order for this to be done efficiently, early decisions must be made as to what aspects of performance will be supported entirely by training, what aspects will be supported entirely by maintenance technical data, and which will be supported by some combination of the two. Some R& D on this problem has been carried out, and preliminary criteria for making the so-called head/book tradeoff are available. These criteria need to be refined and validated, however, and demonstrations of their technical feasibility need to be carried out. On the applications side, procedures need to be developed to assure that planning for training and technical data are considered in an integrated manner during all phases of weapon system acquisition.

4. *System Ownership Costing*. Life Cycle Cost (LCC) analysis has become an increasingly important and widely applied technique in many different facets of the Air Force system acquisition process. The increasing use of LCC as a criterion in system acquisition has provided a real stimulus for the consideration of manpower and logistics factors in weapon systems development and also has provided a common metric that allows these factors to be traded-off against other operational and engineering factors. The portion of LCC methodology of greatest interest here is O& S costing, the so-called system ownership cost models. It also happens to be the area of LCC which is most in need of improved methodology.

Ownership costing techniques are potentially a powerful tool in bringing support costs into the weapon system acquisition decision-making process and in achieving the goal of developing systems which can meet operational requirements in the most cost effective manner. Such techniques can be employed at system development decision points to *select* among alternative design and support concepts, where they are an aid in making economic tradeoffs (e.g., acquisition cost versus O& S cost). Ownership costing can also be used as an aid to *develop* alternatives for reducing cost in cases where proposed or baseline configurations involve unacceptably high LCC.

In order for ownership costing techniques to serve the functions just described, they must have certain characteristics.

a. They must reflect cause-effect relationships.

b. The requirements of the model for historical data and the resources and cost accounting systems of the Air Force must be compatible.

c. They must deal with a set of cost-driving factors that involve not only system design characteristics but the operation and support concepts that influence cost as well.

d. They must be capable of operation under a wide variety of data availability conditions, to permit a "beginning to end" cost estimate capability.

e. Under certain conditions, they must be capable of producing estimates of ownership cost which are absolute rather than relative.

There are a large number of ownership costing models available today, and many of them are being used to support the weapon system and equipment acquisition process in one way or another. But most of the available models are incomplete in coverage and fall short on one or more of the characteristics listed above. In view of these deficiencies and in view of the importance of ownership costing in getting manpower and logistics factors integrated into the weapon system acquisition process, this is considered to be an important area of R& D. While it is not exclusively an HF problem, human resources costing capability is in a more primitive stage of development than is the capability for hardware cost analysis. Therefore, HFE research is required, and the HFE community can play an important role in stimulating and guiding the needed effort.

Most of the currently available ownership costing models are constantly being modified and improved, and a substantial amount of R& D on ownership costing is being carried out by non-human-factors laboratories and organizations. There are two relatively neglected areas, however, where major improvements are needed in the near term. The first is the development of ownership costing models based on cause-effect relationships. Many current models are totally parametric and are based on the distribution of costs in proportion to convenient system characteristics that may reflect but may not be the real cost-driving factors. Such models have two major deficiencies. First, they are valid only so long as no significant changes are made in the conditions under which the relationships were derived. Second, while they may be useful in forecasting ownership costs, they are of little value in suggesting ways to reduce ownership costs in cases where analysis has shown such costs to be unacceptably high. Efforts are just beginning to develop process models for ownership costing, with improved sensitivity to cause-effect relationships. AFHRL has initiated a program to develop, test, and evaluate techniques that will allow the analysis of system ownership cost, at an early point in the system development process, on the basis of demonstrable relationships between the aspects of system design, operation and support and the parameters of system ownership which incur cost. It is an important goal of this program that the relationships on which cost estimates are based be founded on evidence of causality, rather than on purely statistical inference. The initial R& D is concentrating on aircraft avionics, missile avionics, and aircraft engines. Results from this work should be available in approximately 3 years. If results are positive, it will be necessary to extend the methodology to cover other areas of weapon system design, operation, and support.

The second area of needed improvement is in the availability of relevant historical data to support ownership costing models. Such data have been difficult to find in the past. In some cases, needed data have not been collected or retained. In many cases, the functional and accounting categories used to record manpower and logistics cost information do not include required data elements, or they aggregate data in ways which are neither compatible with the cost categories used in the cost models nor amenable to later breakdown and recomposition. There is a very definite need for the Air Force to adopt a standard set of financial and resource accounting categories which are compatible with the requirements of life cycle and ownership costing. This is largely a management rather than a research problem, but as a potential user of such data, the HFE community should lend its influence in seeking to effect the needed management action.

5. *Human Resources in Design Tradeoffs.* The weapon system design process may be looked upon as proceeding by a series of design tradeoffs. Trade studies range from very informal studies with nothing documented except the final design choice, to the detailed, formal studies with complete documentation and indexing. It is difficult for any factor to have a significant influence on weapon system design unless that factor can be included as a parameter in system design tradeoffs. At the present time, the human resources impacts (manpower, personnel, training) of various design alternatives are rarely considered in any systematic way in weapon system design trade studies. However, considerable R& D on this topic has been carried out by AFHRL, and the following conclusions can be drawn from this work.

a. The choice of design alternative in many trade studies does affect system costs for manpower, personnel and training.

b. The design trade-offs most significant in terms of human resources impact can be identified.

c. Engineers will use human resources data (HRD) in design trade studies if the data are presented to them at the proper time and in the proper format.

d. Engineers not only will use HRD in design trade studies, but they tend to give significant weight to this factor.

e. A technique called Design Option Decision Trees is a promising approach for identifying the significant tradeoffs to be made and for introducing HRD.

With these generally positive results, the question arises as to why HRD is not being considered routinely in weapon system design tradeoffs. There are two areas that need improvement before this can occur.

First, there must be a management climate which mandates that it occur. The present weapon system development process is highly institutionalized, and it is difficult to effect major changes. Perhaps the recent ASD (MRA& L) memo on "Manpower Analysis Requirements for System Acquisition" can be the stimulus for necessary change. That memo specifically requires that tradeoffs be considered among manpower, design, and logistic elements. In this regard, it is important that HFE personnel, both at the working and management levels, exercise some initiative in taking advantage of the opportunity offered by this memo.

Second, from a technical point of view, the key to incorporating HRD in engineering design tradeoffs is the ability to generate, in a timely manner, data concerning the manpower, personnel, and training requirements associated with alternative design concepts. Such data must be in quantitative form, and, in order to have maximum impact, it must be possible to generate the data in the early phases of design. Two techniques are available which are useful in this regard. The first is comparability analysis. The comparability analysis equates planned design alternatives to comparable hardware in the inventory for which manpower, personnel, and training requirements are available. The second is the use of subjective estimation by experts. This technique was briefly discussed previously in paragraph II.2. Both of these methods need to be refined and tested further before HRD can be effectively included in engineering design tradeoffs.

As an incidental note, the R& D conducted by AFHRL in this area indicated that the engineering trade study process itself is in need of improvement. The results of empirical studies showed that the trade study as it now exists is partially science and partially art. Two engineers can begin with the same information about two design alternatives and arrive at two different answers. If they both choose the same design, one may find an overwhelming difference in favor of that design, and the second may find it a hairbreadth difference. This variability arises from four major sources:

a. Choice of decision parameters to be included in the matrix.

b. Choice of the weighting factors to be assigned to the included decision parameters.

c. Choice of a method for normalizing the raw data input numbers.

d. Choice of a method for combining normalized data with weighting factors.

If the variability from these sources can be reduced or eliminated, trade study results become more a function of the characteristics of the design alternatives and less a function of the engineer performing the trade-off. R& D to improve the methodology for conducting engineering trade studies is not obviously the responsibility of any particular Air Force laboratory. It is certainly as much an HFE problem, however, as an engineering problem, and it appears to be a very fruitful area for HFE R& D.

6. *Data Bases.* The area of manpower and logistics factors in weapon system development has requirements for supporting data bases which are substantially different from the data sources which support most other areas of HFE. HFE has traditionally relied heavily on data which have been collected in carefully controlled experimental and test situations. Recently, real-time man/machine simulation has been added as a technique for data collection. Such data collection methods are rarely applicable to the area discussed in this report. Instead, the models and techniques are heavily dependent for their successful application on the availability of historical data bases containing information which reflects field experience in the operation and support of weapon systems and equipment. What is ultimately needed is a convenient, usable source of design-related operating and support data using uniform methods and definitions throughout the weapon system life cycle. In order to be useful in the weapon system acquisition cycle, the data must be retrievable on short notice and in a form to support user needs. This latter requirement is a particularly difficult one.

because logistics data frequently cut across many interdependent data categories, and reformatting requires an analytical data generation *process* rather than merely a reformatting algorithm.

Although there are a number of specialized data bases and information systems in the human resources and logistics areas, the Air Force has never achieved an easily used means to feed back operational and maintenance experience to weapon system designers and support planners. The development of such a capability is a major undertaking, but is considered of great importance. This importance has been recognized at the Air Staff level and a Program Management Directive in this area has been issued.

Some R& D in this area has already been carried out by AFHRL and additional effort is planned. One major effort has developed detailed descriptions of (a) the time-sequenced steps involved in the validation and full-scale development phases of weapon system acquisition, (b) current use of logistics, maintaenance manpower, personnel and training data to support design work within these phases, and (c) the maximum need for these data in design work. In addition, requirements have been outlined for the development of a human resources data bank to provide data to system development activities occurring throughout the weapon system acquisition process. A program is just beginning to develop the specifications for a comprehensive data base and a series of user handbooks which will provide human resources logistics and cost data for use in weapon system development and planning efforts. This program will also establish and test a limited prototype data base in a system design environment. This will be followed in FY 83 by a major advanced development effort to refine the human resources, logistics, and cost data bases and handbooks and to provide technical feasibility demonstrations on several weapon system development and modification programs. It is clear that major progress is being made in this area, but that the needed effort will extend beyond the near term (5 years) addressed in this section of the report.

The Need For Integration

Each of the component technologies discussed previously, with the exception of Human Resources in Design Tradeoffs, is currently being applied to some extent in the development of aeronautical weapon systems. Each of the technologies is making a contribution to improving the supportability and reducing the cost of ownership of these systems. However, the technologies are not being applied in the most cost effective and efficient manner. Some of the technologies are applied to late in the weapon system acquisition process to have a significant impact on design. Each of the technologies operates from its own data base even though there is considerable overlap in the nature of the required data. Most seriously, the technologies are applied separately with little regard for the obvious interrelationships which exist among the factors being considered. As is so typical of much of HFE in its application to weapons system development, tools and techniques are being developed for *suboptimization*.

What is needed is a method to integrate the application of the component technologies during weapon system development. Application of the technologies should begin in the conceptual phase and should continue in a coordinated manner during all phases of weapon system development. Furthermore, a *consolidated data base* should be defined which can satisfy the requirements of all the component technologies. This kind of integrated and coordinated application will be required in order to assure continuous and comprehensive consideration of human resources and their associated costs throughout the weapon system acquisition process. Only in this way will it be possible to make the tradeoffs required to optimize a weapon system in terms of the human resources support posture it requires.

Since 1976, AFHRL has been carrying out an advanced development project to develop and demonstrate a Coordinated Human Resources Technology (CHRT) which will achieve this objective. The CHRT predicts the human resources required to support various design and support alternatives through an integrated requirements analysis. This prediction, accomplished in a timely manner, allows human resources to become a real consideration in evaluating these alternatives. CHRT also allows one to review an existing design to determine areas which place excessive demand on human resources, thus indicating a possible need for an alternative design or support approach. Included in CHRT is an ownership costing capability which allows the human resource requirement for any alternative to be evaluated for impact on ownership cost. This predictive capability is especially important during the conceptual and validation phases where such capability is presently lacking. The results of CHRT during these two phases also contribute to specific products of those phases: the personnel and training concept and plan and the tech data concept and plan. During the full scale development phase, CHRT becomes largely product oriented. This is accomplished by transitioning to an on-equipment integrated task analysis which becomes the basis for the actual content of the instructional system and job guide products and for a detailed manpower requirements analysis. As a part of the CHRT development, the characteristics of the required consolidated data base also have been defined.

This program has now reached the point where a full scale test and evaluation (T& E) of the methodology in a realistic weapon system development/modification environment is to be made. This T& E will be carried out in cooperation with the Aeronautical System Division, Deputy for Avionics Control (ASD/AX), and will evaluate the capability of the CHRT to support both in-depth longitudinal applications to a single system and quick response applications of more limited scope. This phase of the program will verify the feasibility of its operational application, demonstrate its utility, and provide data concerning the costs and benefits associated with its "real world" application. At the conclusion of the T& E, a complete technology transition package will be delivered, to include user guides, sample SOW paragraphs and training materials. The program is expected to be completed in approximately 3 years.

Project Hardman (Military Manpower versus Hardware Procurement) is addressing similar concerns in the navy. Most of their work to date, however, has been in defining and scoping the problem, and they are just beginning to develop and carry out specific tasks aimed at achieving the objectives of the program. The Army (ARI) is in the process of planning a related project entitled "Personnel Affordability.

It appears that the Air Force has a clear lead in the development of the required technology base in this area but that the Navy has done the best job in laying a groundwork of high level management visibility and support for the work. In all services, however, the real task for the future will be to obtain implementation of the technology in the weapon system acquisition process; this will be a long term effort, and it will be discussed in the next section of the report.

III. FAR TERM PROJECTION

It is difficult and risky to make any kind of technological projection 10 to 15 years in the future. It is particularly difficult to do so in this area, because it is one where the field is driven as much by high level policies and management decisions as it is by technical capabilities and opportunities. Another complicating factor is the uncertainty concerning the future of logistics R& D in the Air Force. As mentioned earlier, the logistics community is demanding its share of the Air Force R& D dollar, and plans for an Air Force logistics R& D capability are in a formative stage. *What* R& D will be done in this area and *how* it will be done depends heavily on *who* ends up with the responsibility.

Component Technologies

1. *Maintenance Manpower Modeling.* Controlling support manpower requirements for weapon systems is going to increase in importance, and there is the very real possibility that manpower constraints will be established for weapon system development and modification

programs in the future. The following technical efforts are seen as necessary to provide needed capabilities in this area. (a) Work needs to be continued to reduce the data base requirements and computer time for maintenance manpower models. In order for manpower requirements to be used effectively in early conceptual phase studies, a relatively quick reaction capability needs to be developed. (b) There are a number of environmental factors which can impact the requirement for maintenance manpower quite independent of their impact on equipment failure rates. Examples are chemical/biological warfare and dispersed base layouts adopted to reduce vulnerability. These factors have received very little study to date but need to be addressed if manpower modeling is to be valid for wartime scenarios. (c) The manpower implications of a new weapon system cannot be adequately assessed without projecting well into the future the manpower needs of both that system and the other systems with which it will be competing for manpower resources. Techniques also need to be improved for projecting the future availability of manpower in a particular mission area (e.g., tactical air). None of the military services now has a capability to make such long range projections in sufficient detail to support analyses of the relationship between aggregated manpower requirements and projected manpower availability and to develop action alternatives in the event of a serious mismatch.

2. *Training Plans and Requirements.* In the Air Force there are two major procurement systems which operate far too independently. The manpower-personnel-training system is responsible for procuring human resources. People are selected, classified, trained, utilized, sustained, separated, and retired according to a plan designed to achieve certain personnel force objectives. The weapons development system is responsible for procuring hardware resources. Weapons and support equipment are conceived, developed, tested, evaluated, and deployed to meet required operational capabilities of the services. But these two systems, the systems for procuring human and hardware resources, need to be interfaced more closely now at every stage of operation than they are. At the present time, training impact analyses and training concept/plan development during early stages of weapon system development are based largely on the assumption that current manpower-personnel-training policies are fixed and unchangeable. This certainly places a severe limitation on the development of weapon systems which can meet their operational objectives at the least cost of ownership. A capability needs to be developed to exercise alternative manpower-personnel-training concepts in relation to system design alternatives early in the weapon system acquisition process. While system program managers can specify and plan for the personnel and training needs of their particular system, they cannot judge how these needs will compete, conflict, or complement the similar needs of other related systems in the force. Thus, a capability needs to be developed to assure that the personnel and training system of the Air Force can be adjusted and altered in response to the aggregated needs of the weapon systems in a certain mission area. This is a difficult problem but one which requires attention in the far term.

3. *Maintenance Technical Data.* The present maintenance technical data system in the Air Force has become virtually unmanageable. Technical orders for a modern weapon system average 400,000 to 600,000 pages. The time required to make a change in a technical order averages 5 months, with 30% of the changes exceeding 8 months. It is estimated that one-third of all maintenance workhours are spent in information search. Clearly the days of the paper-based technical order system are numbered. Some type of computer-based information system is required. An automated job performance/maintenance aid system which utilizes computer terminals to store and present technical data has the potential for meeting the needs of field technicians at lower costs. A computer-based system would permit data to be presented in the step-by-step formats required by job performance aids and would offer many additional performance enhancement features not possible with a paper-based system. Ready access to any technical order on the system would eliminate the lengthy search time now encountered in locating information in technical orders. In addition, the system would allow changes and updates to technical orders to be done faster and more efficiently. AFHRL has initiated an advanced development program to develop and test a prototype

computer-based technical data system to facilitate the productivity of Air Force maintenance activities. The prototype system will be designed to automate the storage, updating, retrieval, and presentation aspects of the technical data system using an automated job performance/maintenance aid system. Special attention will be given to determining the basic needs of technicians of varying skill levels and the characteristics of hardware and software systems to meet those needs. The initial prototype will address only the intermediate (field shops) maintenance environment. Results from this effort are expected to be available in late 1983. At that time, the plan is to develop and test a portable/rugged prototype for organizational (flightline) maintenance. Specifications for an operational system for both organizational and intermediate maintenance should be available in late 1985. At that time, if proper management support is available, it will be possible to begin converting to a computer-based maintenance aids system. Such a system would make it possible for a weapon system to adapt to a wider range of skills and abilities in the maintenance force.

4. *System Ownership Costing*. The major far term improvements needed in ownership costing techniques are as follows. (a) The work on the development of ownership costing models that are based on cause-effect relationships will need to be continued. Ultimately, it will be necessary to establish cost impact visibility at the line replaceable unit (LRU) and component level if ownership costing models are to be of maximum use in evaluating alternative hardware and software designs and in suggesting ways to effect cost reduction. Also, considerable research will be required to establish causal relationships at a detailed level and to identify cost driving factors in the various advanced technologies which support weapon system development, if such models are to be useful very early in the design process. Finally, future research on cost estimating methods must take into account in a more detailed manner operational and maintenance concepts and policies which impact cost. (b) Many costing models tend to emphasize one or at most a few elements of ownership cost (e.g., depot maintenance manpower, spares, aircraft maintenance manpower). An important long term goal will be the development of models that will generate compatible estimates for all ownership cost elements. Unless such a capability is developed, system developers will again be playing the suboptimization game and will be chasing costs from one element to another rather than producing real reductions in total ownership costs.

5. *Human Resources in Design Trade-offs*. The far-term requirements for effort in this technology are in two areas; improved data bases to support trade studies and broadening the technology to include other logistic factors. The improvement of data bases is the subject of the next paragraph. A very important item for the future R& D agenda will be to broaden this technology so that related logistics factors can be added. What is desired is a capability to look at the alternatives in a design trade study in terms of their *total* logistic impact rather than just the human resources impact. It is the total logistics impact which should be traded off against other engineering and performance factors.

6. *Data Bases*. A long-term effort to develop a product performance feedback system (PPFS) for the Air Force has been directed by the Air Staff. The PPFS is to be a source of design-related operating and support information for use by system designers, analysts, and support planners. The data are to be provided on short notice in a form to support the user's need. The PPFS will be developed using a series of uniform data elements which describe logistics aspects of the reliability, maintainability, and support resource requirements, parameters, and usage. These elements will be developed early in the acquisition program and tracked throughout the system's life cycle. Early in the acquisition program, the engineering and logistics data elements are to be developed and stored in the Logistics Support Analysis Record (LSAR) for that particular system. The data elements contained in the LSAR can be applied to the system design effort in the form of design constraints and as the source of information for risk analysis, effectiveness studies, and system design tradeoff studies. Elements of the program LSAR are to be input to an existing comprehensive data base which includes test and operational data and which contains comparable elements of the Air Force feedback program. The PPFS will in essence provide a single thread manpower and logistics

information system from the conception of a system until it is phased out of the inventory. As a system matures operationally, its data become available for use in the design, development, or modification of other systems.

This program will be a major undertaking with great potential for improving the supportability of Air Force weapon systems. While AFLC is expected to be primarily responsible for the development of the PPFS, there is much that can and should be contributed by the HFE R&D program during the next 5 to 15 years.

7. *Other Technologies.* There are a number of other areas related to ILS which have received little, if any, support from HFE research or applications efforts. Examples of such areas are level of repair analyses; alternative maintenance and support concepts; level of automation in test equipment; and software support. Decisions made in each of these areas can have a significant impact on manpower and other system support requirements and costs. While these areas are not exclusively HFE concerns, they all seem to have at least some HFE aspects. Whether it is a near-term or far-term issue can be argued, but it is suggested that these and other areas of ILS should be investigated to determine the extent of the contribution that can be made by HFE inputs.

The Need for Integration

The test and evaluation of the Coordinated Human Resources Technology (CHRT) in a realistic weapon system development/modification environment should be completed during the next 3 to 4 years. At that point, a major effort will be required to transition the technology and get it institutionalized, both in the Air Force and in industry, as a part of the weapon system acquisition and modification process. Some of the problems involved in achieving this are discussed in the next section. In terms of further development of the CHRT, two areas of needed effort can be identified.

1. The manpower, personnel and training aspects of a system acquisition or modification program are closely related to other support considerations; e.g., spares, support equipment. Therefore, the CHRT should be extended to deal in an interactive manner with other related support resources. In other words, it should be broadened to become a major tool for implementing and accomplishing the ILS program. As this new model or method becomes more inclusive, it will be important for it to be modularized so that it can be applied either totally or in segments which are appropriate to particular problems.

2. While the design of a weapon system has a very significant impact on ownership costs, decisions which drive such costs continue to be made after the system has been deployed. For example, program managers can design the system for a specific support concept, but they have no assurance that the user and AFLC will implement that concept. The program manager can assume or propose an operating scenario, but the user will ultimately determine how the system is employed. It is important, that the integrated methodology developed for use during the weapon system acquisition process be modified so that it can serve equally well as a tool for decision making after the system has been deployed. The data bases, models, and methods need to be transitioned along with the system in order to assure that support costs are given appropriate consideration in post-deployment decision making.

The Need for Implementation

As stated in the previous sections of this report, substantial progress has been made in developing techniques and methods for integrating manpower and logistic factors into the weapon system development process. Some of the techniques and methods have been transitioned into use; a notable example being the maintenance manpower model. Progress is expected to continue in this technical area. Some improvements will be made in component technologies, but the major contribtuion is expected to be the development and demonstration of a method for the coordinated or integrated consideration of manpower and logistic factors during weapon system development and deployment. The achievement of this goal is seen as a major advance in HFE. This technology will be useful and beneficial to the Air Force, however, only if it can be transitioned into use, only if it can gain acceptance as a part of the weapon system acquisition and modification process. This will be a major task, indeed, which will require the best efforts of the HFE community. Some key issues involved in this technology transition are discussed below.

The weapon system acquisition process is highly institutionalized and resistant to major change. It has traditionally operated on the philosophy that manpower, personnel, training, and logistics factors are things to be considered after the engineers have done their job; the engineer designs the hardwares and then the manpower and logistics people come along to provide the support resources required to operate and maintain the system. This picture, while certainly overdrawn, has more truth to it than many would care to admit. The idea of manpower and logistic factors being actively involved in the design process from the conceptual phase on; the idea of designing to externally established manpower constraints; the idea of increasing acquisition costs, or even decreasing system performance, in order to gain some advantage in system supportability in the future—these ideas are not accepted easily in the weapon system acquisition world. It will undoubtedly take considerable time and the operation of many forces to produce the necessary changes. Some of these forces are pretty much beyond the control of the HFE community, such as DoD policies and directives; selection and training of personnel to man weapon system program offices; and the weight given to various factors in the AFSARC and DSARC reviews. The HFE community can lobby in these areas, but the leverage is not great. There are some things that can be done, however, to help bring about the necessary changes. The HFE community can provide clear, cogent demonstrations of the technical feasibility and effectiveness of integrating manpower and logistics factors into the weapon system development process. Particularly important will be hard data on the *costs* of applying the technology and the *benefits* to be derived. Also, it will be important to have documented examples of the negative consequences which have occurred as a result of failure to properly consider manpower and logistics factors. With these kinds of data, a strong case can be made.

If implementation of the technology reviewed and assessed in this report is to be achieved primarily through the Air Force HFE program, then there will have to be certain changes in that program as well. Three of the necessary changes are briefly described as follows:

1. HFE needs to begin immediately to define and establish an appropriate relationship with the ILS program. The concept of ILS provides a good framework for consideration of all support aspects of new weapon systems. It has been implemented in all the military services as an integral part of acquisition and modification programs. It is institutionalized as a responsibility of the program manager. It is clear that ILS is an accepted concept, albeit not yet well applied. The HFE community should join forces with the ILS community and build on that acceptance.

2. It will be necessary for HFE personnel to accept greater responsibility for manpower, personnel, training, and maintenance technical data during weapon system development. Although all of these are clearly identified as elements of HFE in AFR 800-15, the HF engineers in the weapon system program office have generally given little attention to these elements and have concentrated their attention on the Human Engineering and Biomedical elements. Likewise, the HF engineers will have to give up some of their fascination with cockpit and aircrew station design and devote more of their attention to the less glamorous but equally important issue of system supportability.

3. Finally, there are changes that must be made in the education and training of HFE personnel. It will be necessary for the HFE community to abandon or at least deemphasize the rigid distinction between "human engineering" (which has been concerned with the effects of human capabilities and limitations on the design of equipment) and "personnel and training research" (which has been

largely concerned with adapting man to the constraints built into the hardware). The effective integration of human components into weapon systems clearly requires a unified approach to all stages of system development. I personally believe that the greater integration among the various areas of military psychology, which this approach requires, would be a desirable thing. A really effective HFE technology requires the ability to trade off such things as manpower quantities, training, job instructions and equipment design. These tradeoffs can be identified only by someone who has a knowledge and appreciation of all of the factors involved. Obviously, such a person would have to be supported by specialists in the various areas, but the broadly trained HF engineer would be the first line of defense in assuring that *all* of the important issues in the human side of weapon system development were being appropriately addressed. This is not the place to address the details of changes that need to be made in the training of HFE personnel, but clearly it will involve both the education and training of new personnel in this field, and upgrade and continuing education for people currently in the field. This issue needs to be addressed by a special committee or task force in the very near future.

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