Research Note 83-6

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PERSONNEL AFFORDABILITY: A STATE OF THE ART REPORT

C. Alan Boneau
ESSEX Corporation

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Research Institute for the Behavioral and Social Sciences

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This report develops a conceptual scheme for the consideration of human resources in weapon systems development. The area of personnel affordability is defined and related to the design and development process, to the establishment of manpower requirements, and to the processes involved in developing personnel inventory to match requirements. Examples of recent and ongoing research efforts are described and discussed.

Data collection for this project was completed in August 1979.

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PREFACE

This document was developed under Contract MDA903-79-M-3975 with the Army Research Institute. The objective of the project was "to assess the state-of-the-art in the area of personnel affordability" where personnel affordability was defined in the Scope of Work as:

> The area of inquiry dealing with the identification and analysis of the discrepancy between personnel requirements determined by materiel system design and personnel resources available to operate and maintain the materiel system at the designed operational capability level. Personnel affordability involves developing and implementing methodology for forecasting personnel requirements and personnel resources, assessing the impact of discrepancies between personnel requirements and personnel resources, and reducing discrepancies between personnel requirements and personnel resources early in the materiel Life Cycle Management process. Personnel affordability involves integration of, and trade-off among, the processes affecting personnel requirements and the processes affecting personnel resources. Specifically, existing knowledge and advancements in the areas of human engineering, human factors, and manning criteria affecting personnel requirements must be integrated with existing knowledge and advancements in the areas of personnel recruitment, selection, assignment, utilization, and training affecting personnel resources. Procedures for evaluating trade-offs among the above areas as they impact on the operational capability of materiel systems and procedures for inputting the findings into the materiel Life Cycle Management process at an early stage must be developed.

The level of effort provided in the contract did not permit either an extensive or an intensive review and analysis of the wide-ranging concerns contained in the Scope of Work. Therefore, the state-of-the-art is represented as an organizational structure to provide a perspective on what is known about personnel affordability and as a collection of examples of current work that are intended to denote the state-of-the-art in the several areas that comprise the focus of the study. Although written primarily for an Army reader, it is hoped that others may read the report with profit.

In gathering material for this report interviews were conducted with a number of individuals in several locations. Visits were made to the Navy Personnel Research and Development Center in San Diego, to Air Force Human Resources Laboratory facilities at Wright-Patterson AFB, Ohio, and Brooks Field, Texas, to the Navy Training Analysis and Evaluation Group at Orlando, Florida, to the Air Force Office of Scientific Research at Anacostia, D.C., the Office of Naval Research at Arlington, Virginia, to the U.S. Army Missile Materiel and Readiness Command at Redstone Arsenal, Alabama, and the U.S. Army Communications Materiel and Readiness Command at Fort Monmouth, New Jersey. Additional phone interviews were conducted

with personnel of the Center for Naval Analysis, and the Institute for Defense Analysis, both in Arlington, Virginia. Followup telephone calls were made to many of these facilities to obtain additional materials or information. Those individuals who were so generous of their time, information, and materials contributed greatly to the scope of the report.

Data collection for this project was completed in August 1979.

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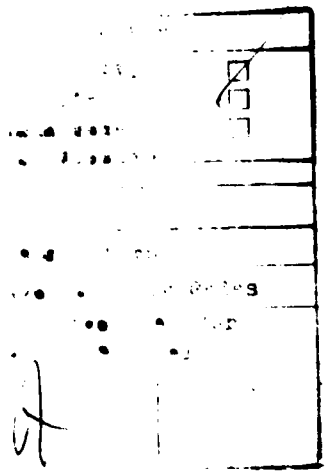


1.0 INTRODUCTION

As defined in the Preface, Personnel Affordability deals on the one hand with the impacts that new equipment will tend to have upon doctrine, upon organizational structures, and upon personnel-related concerns. On the other hand, Personnel Affordability is concerned with the impacts that the available supplies of personnel will have upon equipment utilization. New personnel considerations and requirements, projected into the future, affect or should affect the design of new equipment. These personnel-related projections will impact upon the potential readiness and effectiveness of the equipment being designed. This interrelated set of concerns can be discussed in the framework of supply and demand as applied to military personnel. Demand is implied in terms of manpower requirements by the weapons systems deployed and the organizational structures that have been or will be established to operate, maintain, and support those systems. Supply is a product of the recruiting, training, and retention efforts that are employed to create a personnel inventory.

In order for equipment to be effectively utilized, the jobs required by weapon systems must be matched by personnel available in terms of quantity and in terms of skills and skill levels. When operating in the present or short range future, the problem of matching personnel inventory and manpower requirements are relatively straightforward, albeit not simple. On the demand side — manpower requirements — the equipment exists and determinations of the number of operators, maintainers and support personnel that are required to interact with that equipment in order to maintain a stated level of effectiveness can usually be made by observation or by trial and error.

On the supply side, data is continually collected that describes levels and the characteristics of recruits, recruiting, attrition, and training times. These data form the basis for planning a personnel inventory to match the manpower requirements in quality and quantity. Even in the short range time frame, however, mismatches can occur, for example, as a result of recruiting shortfalls or when larger than anticipated numbers of some types of skilled personnel fail to renew their service contracts.

Over a somewhat longer time frame, say that of the Five-Year Defense Plan (FYDP) mismatches may threaten to become chronic when, as is now the case, the available supply of new recruits from the civilian manpower pool is threatened by the demographic reality of diminishing numbers. This problem is exacerbated by recent increases in the sophistication of weapon systems requiring higher skill levels for operation and mainte-nance. Moreover, these skills, largely in the computer and electronic fields, are also in demand in the civilian sector thus increasing the pressure for migration from the military to the civilian sector. This fact, of course, aggravates the difficulties of the personnel inventory development system.

In the FYDP time frame, little can be done about manpower requirements. The equipment has already been designed and the operation and maintenance concepts have been made reasonably firm. It may be possible to transfer some maintenance tasks to contractors, which may alleviate the military personnel problem but have little overall effect in the Total Force sense. The overall requirements, however, are fairly firmly fixed, and although operations may be undertaken with reduced manning in some areas, the result is likely to be a reduction in performance or effectiveness.

Although manpower requirements are firm, in the short range some changes can be made in the personnel inventory development system. These changes are of two kinds:

- Modification in procedures or methods
- Changes in policies

Examples of the first kind are improvements in training technology that may make it possible to assist recruits with lesser potential develop complex skills in short supply. Examples of the second kind are changes in compensation policies, in rotation policies, in accession policies, and the like, all of which may provide for a greater number of desired personnel in the short run, but in the long run these changes may ramify throughout the system in unpredictable ways.

From a longer run point of view, say that of the Extended Planning Annex (EPA), the problems become somewhat different. Since this time frame includes

all the events in the development cycle for new weapon systems, it should be possible from this perspective to have a design process that is sensitive to manpower and personnel considerations. Questions of personnel costs and availability could, therefore, be used as design constraints. Weapon systems, therefore, could be designed not be so reliant upon quantities of high-priced, highly skilled and relatively scarce human resources. From the supply side, the time frame of the EPA is sufficiently long that major improvements in such areas as training technology could be anticipated to supply quantities of needed skills at lower cost. The longer time frame could also make possible the evolution of solutions to those persistent policy issues that prevent a direct approach to problem resolution.

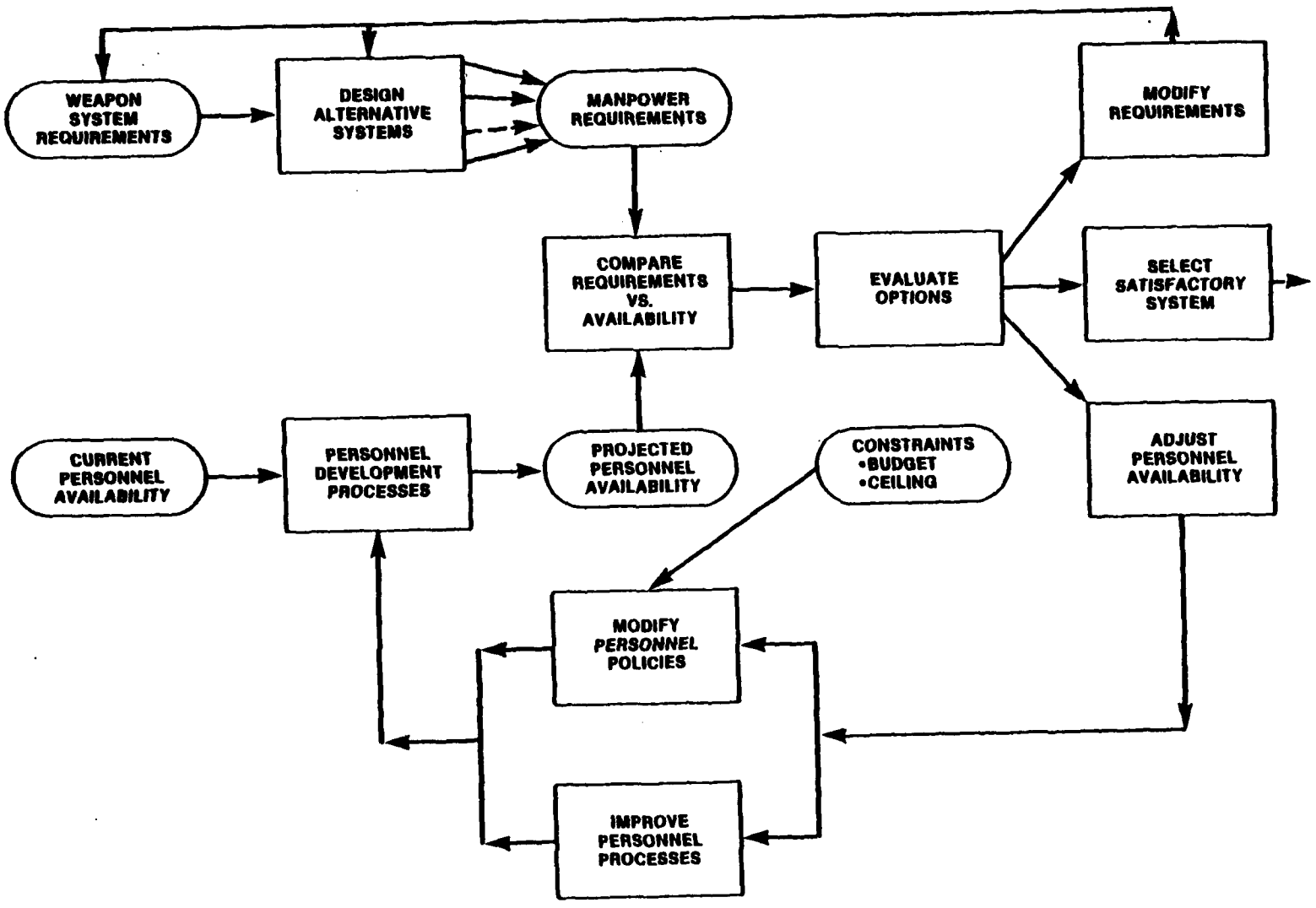
In terms of this overview, several large clusters of problems emerge. From the point of view of equipment design there are a number of consequences in addition to those related to manpower requirements. A more comprehensive list might include the following:

- Costs
  - hardware
  - personnel
  - logistics
  - training
  - support
- Performance
  - personnel effectiveness
  - personnel productivity
  - mission effectiveness
  - equipment reliability
  - ease of maintenance
- Safety
- Personnel characteristics required
- Number of personnel required

There exist a large number of trade-offs possible among these design consequences. It is not clear whether designers should bear the responsibility of producing manpower-sensitive designs that meet preordained specification, or of designing with a spectrum of considerations in view, with decision makers having the final say in making trade-offs.

To put this discussion into perspective, let us consider a model of the way in which human resource considerations can be made an integral part of the weapon system design process. Exhibit 1 presents such a model. In this model design criteria are established as an initial stage and one or more alternative realizations of these criteria are developed by the designers. These alternatives are then evaluated in terms of several criteria, one of which is the set of human resource requirements that are implied by the design. A separate availability analysis is performed in order to estimate the personnel availability given the requirements of the specific system and other requirements associated with other long-range Army plans. There may be discrepancies between requirements and personnel availability. Other analyses can be performed to identify the cause of the discrepancies and to determine whether or not they can be overcome, perhaps by changes in personnel policies or improvements in personnel processes. The best solution to the problem of human resource availability is then determined, as well as the steps to reach that state. This information is then fed back into the model along with other consequences of the design alternatives. The various trade-offs are examined in detail in view of total service and DOD commitments and strategies. At this point if a satisfactory alternative emerges it is given a go- ahead for further development. Otherwise it is rejected or returned for further elaboration or refinement so that new design criteria can be established to achieve a satisfactory solution to the conceptual and pragmatic demands of the system components.

To focus still further on this problem, it is helpful to look at the factors that affect or are related to personnel availability. To sharpen up this perspective let us consider an overall model of the manpower, personnel, and training concerns as



MANPOWER REQUIREMENTS AND PERSONNEL AVAILABILITY IN THE WEAPON SYSTEM ACQUISITION PROCESS

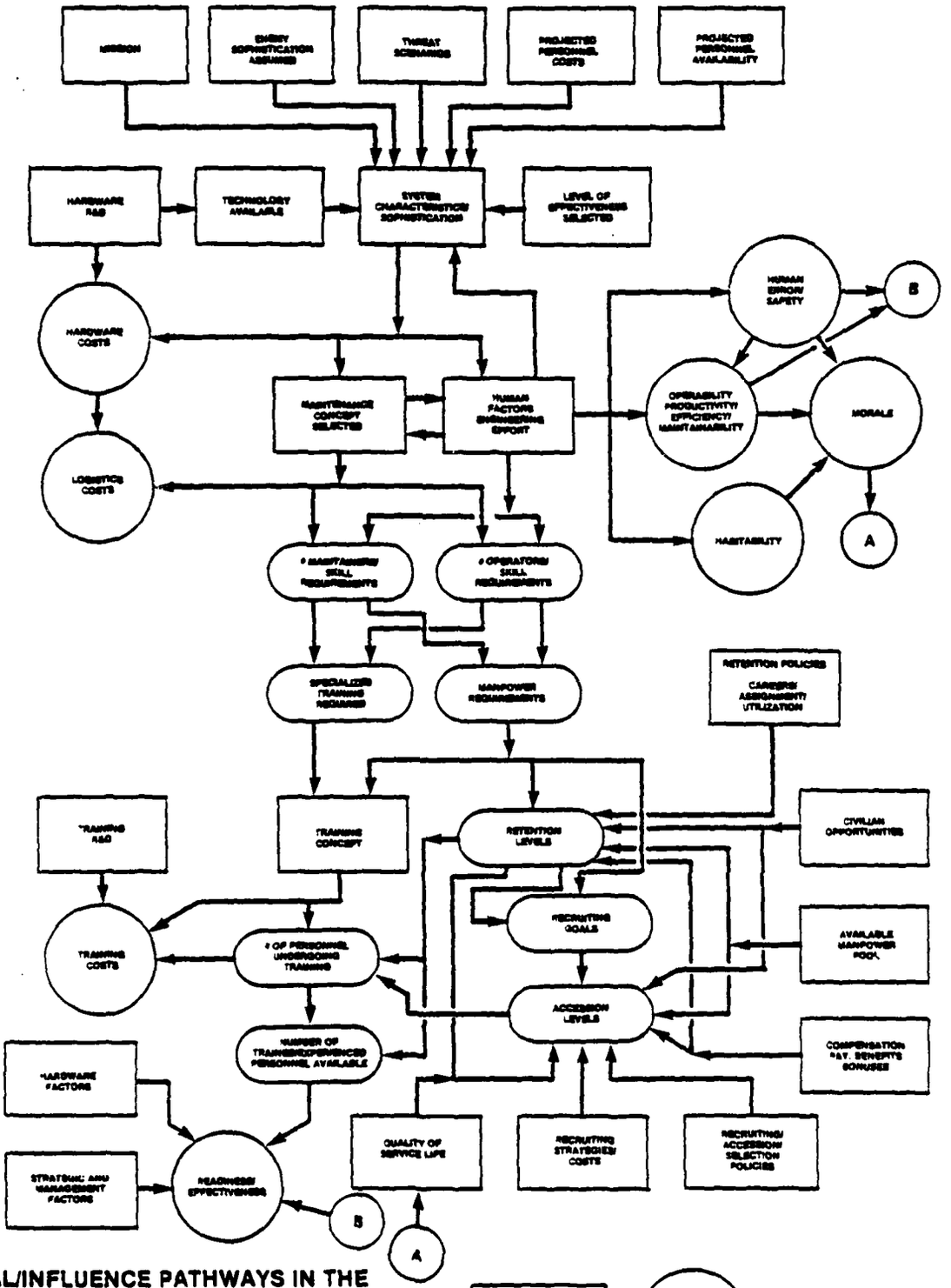
EXHIBIT 1

in Exhibit 2 entitled "Causal/Influence Pathways in the Manpower/Personnel/Training System." This Exhibit makes clear that the MPT system is indeed complex and that multiple causes and multiple consequences are the order of the day.

The upper portion of the Exhibit deals with influences on the characteristics of the system design. These in turn affect decisions about maintenance concepts and personnel utilization which have ramifications for hardware and logistics and utlimately, in the lower left hand corner, in training costs and readiness. The lower right corner encompasses a number of variables involved in the personnel system including those that influence that system as well as those reflecting the dynamics of that system and their effects on training and readiness.

The top half of Exhibit 2 is concerned with human resource requirements. All the constraints and influences on system design and characteristics, including personnel considerations to the extent that they are represented, go to establish human resource requirements along with other factors such as maintenance concept decisions and human factors engineering efforts. From the point of view of concerns about personnel availability, the complete bottom half of Exhibit 2 is involved. All of the personnel and training variables impact on availability.

The two exhibits highlight the complementary relationships that exist among manpower requirements determination and personnel development. Personnel Affordability is seen to be affected by both of these systems. Both systems in turn are impacted by considerations of Personnel Affordability when decisions must be made about proper courses of action if estimated manpower requirements and projected personnel availability are discrepant.



CAUSAL/INFLUENCE PATHWAYS IN THE MANPOWER/PERSONNEL/TRAINING SYSTEM

EXHIBIT 2

Various formulations have been made of the issues and interrelationships that are represented in the complex of factors as described above. One useful approach taken by Eckstrand, et al[1] is in terms of a new discipline to be called "Human Resources Engineering." In their summary, the concept is described:

> The concept of human resources engineering is introduced, which is the process of using human skill resources as factors in design trade-off studies. The development of the military's response to human resources needs in systems is traced from the reacting phase, through the current predicting phase, to a possible future phase involving some degree of control. The implementation of the control phase will require a human resources engineering technology. The establishing of such a technology will require research in the areas of data structuring, methods for relating data to design and life cycle costing, and computerized banks of human resources data.

By any name, be it "personnel affordability" or "human resources engineering," the fields and factors that are encompassed in the concept are complex and only beginning to be understood. The remainder of this report is an attempt to impose some order on this complexity.

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[1] Eckstrand, G.A., Askren, W.B., & Snyder, M.T. Human Resources Engineering: A new challenge. Human Factors, 1967, 9, 517-520.

2.0 SPECIFIC RESEARCH AREAS

The foregoing section has provided a perspective for analyzing the need for R&D activities within the context of a concern for Personnel Affordability. In this section we will identify specific activities related to Personnel Affordability and characterize them in more detail. We will also look at the research initiatives within the armed forces that have been directed at these activities, and, in the process, we will establish a baseline state-of-the-art. This paper makes no attempt to deal with all aspects of the Personnel Affordability in detail. Rather we will point out the way that Personnel Affordability concerns ramify throughout the manpower, personnel, and training efforts of the services, and we will provide specific interesting examples of current work being done. This discussion will be organized into two major areas: manpower requirements determination and personnel inventory development. These, as we have seen, constitute the demand and supply sides of the manpower, personnel, and training area.

We will also make a distinction between short-term and long-term considerations. We can assume in the DOD Program, Planning, and Budgeting System (PPBS) that the budgeting process for the upcoming fiscal years is dealing with problems and issues that are reasonably well established and defined. Beyond the POM cycle, planning for the Five-Year Defense Plan (FYDP) considerations, while dealing with some unknowns, is still for our purposes dealing with reasonably well known system characteristics. Weapon systems that will be coming on-line in the time frame of the FYDP are developed to a point at which their human resource implications are reasonably firmly determined. Training, logistics, and doctrine will be in a relatively final state as will Tables of Organization[2]. The net result is

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[2] A good description of the total process can be found in:

Betaque, N.A., Kennelly, D.M., Nanta, F., and White, T.A. Manpower Planning for New Weapons Systems. Logistics Management Institute, 1978.

Case studies comparing manpower requirements estimates made at various stages in the development cycle with actual manning figures are found in supplements to that study.

Kennelly, D.M. Manpower Planning of the Army PATRIOT Air Defense Missile System. Logistics Management Institute. WN ML801-7, 1978.

Kennelly, D.M. Manpower Planning for the Army Tactical Fire Direction System (TACFIRE). Logistics Management Institute. WNML 801-5, 1978.

that little can be done at this stage to affect manpower requirements to a significant degree without, at the same time, affecting system performance and effectiveness. On the supply side, known and projected shortfalls in some specialties can be recognized in the FYDP and attempts made to counter them by such measures as increased recruiting goals and expanded training programs for those specialties.

To deal with the problems in the FYDP, entailed reasonably straightforward procedures for planning and making projections have been developed and are operational. For the most part these procedures and the problems they deal with are not the subject of this report except to the extent that they provide a baseline for the tougher problems in the Extended Planning Annex (EPA). This report is primarily concerned with longer range planning, the EPA and beyond. It is in this time frame that the need for new major weapon systems is foreseen, concepts are developed to contend with long range threats, and good solutions to the process of compromise that faces decision makers are given their initial nudge toward realization. It is in these early stages of the long range time frame that human resources consideration can achieve significance. Design can be tailored to human resource constraints, and the human resource implications of design characteristics can be entered into the decision process as factors in the evaluation of potential systems.

2.1 Manpower Requirements in the Systems Design

The utilization of human resources data early in the design stage poses a number of problems that can be summarized into two main groupings.

- Translating new technology into manpower specifics
- Considering human resources issues during the design process

The first of these problems comes about because the use of new technologies injects many unknowns into the process of estimation. Little may be known about the way that human operators will be required to interact with a system that is based upon the new technologies. The second problem involves the identification of useful human resources data and the problem of providing it in a format that

promotes utilization. The manner in which the task is to be structured to the designer is also at issue. Should the designer be asked to design within specific limits for specific variables? If so, what is the leeway for trade-offs at the designer's level? In the sections that follow these issues will be discussed in more detail.

2.1.1 Translating New Technology Into Manpower Specifics

This problem represents a continuum of problems. At one end are weapon systems that are created by combining a number of subsystems already in existence. The characteristics of these subsystems are known as are their human resources implications. What must be determined for these subsystems are the personnel inventory requirements of the particular combination of subsystems given the conditions in which they are to be deployed as well as the organizational modifications that must be made to accommodate these systems. Powerful methods are now in existence that can define manning level requirements under these conditions, for example, the Logistics Composite Model (LCOM)[3] of the Air Force, and Ships II[4] of the Navy.

Using LCOM, it is possible to establish a number of initial conditions such as number and type of aircraft, types of subsystems employed, spare parts inventories, sortie requirements and the like. The model will then determine the number of maintenance specialists of various kinds required for this level of performance. Or, using LCOM, restrictions of various kinds can be placed on manpower to determine the degradation of mission performance that results.

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[3] Drake, W.F., et al. Logistics Composite Model Users Reference Guide. Air Force Logistics Command Report 70-1, AD-703 328. Headquarters Air Force Logistics Command. January 1970.

[4] Bowser, S.E., Robinson, E.R., and Harris, R.N. SHIP II: A description of a computer simulation program for manpower allocation. Navy Personnel Research and Development Center. August 1979 (In press).

Ships II performs a similar modeling function for a Navy ship with its associated subsystems. Ships II considers operation and maintenance requirements as well as such factors as watch standing requirements and skill substitutability to determine the ship's complement required for various conditions of readiness. The degradation implied by reduced manning can also be determined. In order to simulate real contingencies, both models employ empirical distributions of such variables as time before failure of subsystems and of time to repair.

Given that such subsystem information is available, the requirements implied for training resources and costs for training and other associated personnel functions can be established. It is possible, for example, to collate life-cycle personnel costs based upon the Ships II manpower requirement determination by use of the Navy's billet cost information. Koehler[5] gives an example of a Navy system that requires three OS-E-4's and one OS-E-6 (OS - Operations Specialist rating). He shows how the basic operating 10-year life cycle costs obtained from his billet cost tables, are accumulated for the four operators, are multiplied by three to accommodate three watches for 24-hour/day operation, and then life-cycle billet costs are accumulated for the estimated number of maintenance personnel by rating required to keep the system running. Since the Ships II model provides a listing of all personnel by rating that are required for a particular state of readiness of the ship, including watch standing and maintenance requirements, the total life-cycle personnel costs for the entire number of billets may be obtained by summation after referral to the billet cost tables.

The computations above can only be applied, of course, when the manpower requirements and other characteristics of systems are known. At the other end of the spectrum of technology are weapon systems composed, at least in part, of

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[5] Koehler, E.A. Life Cycle Navy Enlisted Billet Costs -- FY79. Navy Personnel Research and Development Center Special Report 79-13. NPRDC, San Diego, March 1979.

subsystems involving technological advances that provide no basis of experience for estimating system operating characteristics or human resource requirements. Many of the systems that are conceptually evolving now have this kind of uncertainty associated with them. This uncertainty makes for extreme difficulty in establishing reliable estimates of manpower requirements at early stages of development, and these requirements only gradually begin to solidify in the later stages of development as experience with prototypes becomes possible.

This particular problem has been recognized for some time and has been the focus of a large number of research efforts that have by no means solved the problem. Blanco and Chernowitz,[6] for example, review a number of preliminary results that have utilized analytic techniques to forecast maintenance man-hour/skill requirements for aircraft and find these techniques to be "very encouraging." Using curve-fitting procedure, they note, for example, that avionic system reliability has been shown to be inversely proportional to aircraft weight and to avionic system cost, that total maintenance man-hours are proportional to aircraft empty weight, and that the operating tempo is predictive of maintenance man-hours. These relationships can be further refined to predict airframe and engine skill groupings. Although these procedures seem gross, they have been demonstrated to predict manning requirements better than the procedures that have been in standard use to provide estimates by the manufacturer. According to Blanco and Chernowitz,[7] "the real military operating environment, including quality of maintenance, is rarely, if ever, anticipated by the manufacturer," and thus discrepancies occur between manufacturer estimates and empirical data on maintenance requirements.

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[6] Blanco, T.A. and Chernowitz, G. Forecasting Manpower Requirements for a New Weapon System. Paper presented at the XXIV International Meeting, The Institute of Management Sciences, June 1979.

[7] Gates, H.P., et al. Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability. Volume II: Complete Report. Institute for Defense Analysis. Prepared for Defense Advanced Research Projects Agency, Washington, D.C., January 1974.

The procedures cited by Blanco and Chernowitz might be termed "macro" approaches, to borrow a concept from economics. "Micro" approaches on the other hand might consist of procedures that look at human resource characteristics as a function of fine design detail. Two such approaches will be cited. One involves the use of regression procedures, or correlational modeling to predict performance from specified design characteristics. The other approach utilizes the judgments of experts to make performance predictions.

An example of the first kind of approach is a study by Potempa, et al.,[8] which attempts to demonstrate the feasibility of developing a methodology for predicting job performance in maintenance tasks from data describing system design and personnel characteristics. Ten avionics subsystems were rated in terms of 49 design characteristics. Regression equations were developed to account for task time and error data on trouble shooting and repair. The findings indicated that task time and errors could be predicted quite well from a small number of variables. The experiment tended to support a conclusion of Smith and Westland[9] that the correlational approach appears to be "the only possible empirical approach for use in early design, short of providing subjective estimates."

The feasibility of subjective estimates, however, has been examined by a number of investigations including those of Whalen and Askren[10] (1974) and Sauer and Askren[11] (1978). In the Whalen and Askren study, maintenance technicians

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8 Potempa, K.W., et al. Impact of avionic design characteristics on technical training requirements and job performance. Human Factors, 1975, 17, 13-24.

9 Smith, R.L. and Westland, R.A. Status of maintainability models: A critical review. USAF:AMRL-TR-70-97. Wright-Patterson AFB, Ohio, 1971.

10 Whalen, G. and Askren, W.B. Impact of design trade studies on system human resources. Wright-Patterson AFB, Ohio, USAF:AFHRL-TR-74-89 (AD-A009 639), December 1974.

11 Sauer, D.W. and Askren, W.B. Validation of an expert estimate technique for predicting manpower, maintenance, and training for proposed Air Force systems. Wright-Patterson AFB, Ohio, USAF:AFHRL-TR-78-19. May 1978.

were required to estimate time for repair as well as crew size, skill level and career field for a number of Air Force avionics systems. These estimates were only based upon conceptual-phase engineering descriptions of the equipment. The investigators reported that the technicians underestimated maintenance times but produced accurate estimates of crew size, skill level, and Air Force Specialty Code required. Sauer and Askren expanded upon the Whalen and Askren study, using the same retrospective procedure that based judgments upon information available only in the early design stages. The Sauer and Askren study, additionally obtained estimates of the time and facilities required to train maintenance personnel for the tasks involved and also assessed the qualities and quantities of raters needed to provide useful estimates. They reported that the estimates of training times and training facilities/equipment were not accurate or productive. As a result of this study a prototype user's guide is available for implementing the expert estimate method (AFHRL-TR-78-19-Supplement 1).

Koehler[12] has utilized the expert estimation technique to develop a package of design information intended for use by engineers designing electronics equipment. Several approaches are presented. In one, based upon estimates by experts, a matrix of relationships was established between various maintenance and operational design concepts on the one hand and requirements for manpower, skills, and training on the other. It is then possible to identify the effects of adopting specific concepts; or, approached from the other direction, it is possible to identify the design concepts needed to maximize or minimize specific human resources variables. In another approach, skill levels in selected Navy specialty ratings for various performance levels in specific tasks were estimated. Other information provided includes data on specialty ratings projected to be in short supply and on billet cost for the various ratings.

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[12] Koehler, E. An Engineer's Guide to the Use of Human Resources in Electronics Systems Design (Working Draft). Navy Personnel Research and Development Center, San Diego, NPRD (STN-79-8) June, 1979.

2.1.1.1 Research Implications. The development of procedures for determining the human resource implications of design specifications is critical both for the decision maker and the designer. The decision maker must balance human resource implications in the context of a variety of conflicting system and resource criteria. To have an impact, the human resource indications must be stated in forthright terms that can be readily compared to the hard engineering cost and performance data that are part of the decision context. The designer must be able to select design approaches that will yield specified manpower requirements.

Given the importance of the problem, we must be struck by the primitive state of research aimed at developing of these assessment methodologies. The recently completed research that has been reviewed is only the beginning of the development of operational procedures that can routinely be used to provide human resource data for comparing alternative system concepts. At this stage it can be said that potentially useful methodologies have been demonstrated but only in very limited areas. The methodologies require considerable refinement and the range of applicability must be expanded if they are to prove generally useful in the early design stage.

At the basic research level, critical dimensions of the design process must be identified and quantified. The critical criterial dimensions of human resources as consequences of design must also be identified and quantified. Currently only empirical approaches have been used to relate these two kinds of variables. Further work must be undertaken to create a theory that relates design characteristics to human resource variables by means of which a general solution to the problem can emerge. The design process itself should be explored.

At more applied levels, the empirical relationships among specifiable design characteristics and human resource criteria should be explored for a wide range of systems *in order to determine* the possibility of developing a data base for predicting human resource variables. Undoubtedly such a program could lead to greater understanding of the dynamics of the design process as it relates to human resources, and to a refinement of the empirical methodologies employed.

2.1.2 How are Human Resources Concerns to be Considered in the Design Process?

The ability to relate human resources data to design features only solves part of the problem. How can that data become part of the design process? This question suggests other questions. What kinds of data should be available. How should the data be presented? What procedures exist or should be developed for making use of human resources data in design? When should such data be employed?

One important form of data is that discussed in the last section — data that relates design features to human resource characteristics, particularly the quantity and quality of the operator, maintenance and other personnel associated with the deployed system. Although no specific procedures are described here to effect trade-offs, the availability of such data could be useful to designers and decision makers for evaluating and selecting among alternative system concepts and configurations.

Could and would designers make use of human resources data? Askren and Lintz[13] answered in the affirmative after studying the Air Force system-design trade study process in which an analysis and evaluation is made of two or more design approaches to a design requirement. Using simulated design problems, these investigators determined that designers could and did use human resource data in trade studies, using personnel cost data most frequently and skill levels data the least. The study analyzed the data needs of designers and provides several recommendations for data content and format. The Air Force Human Resources Laboratory at Wright Patterson AFB is currently developing a human resources data base that will utilize the trade study results.[14]

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[13] Askren, W.B. and Lintz, L.M. Human resources data in system design trade studies. Human Factors, 1975, 17, 4-12.

[14] Askren, W.B. Personal communication. July 1979.

2.2 Personnel Inventory Development as a Design Concern

Design has three main types of human resource consequences. It establishes requirements for personnel, both quantitative and qualitative; it creates requirements for organizational structures to operate and maintain the system being designed; and it affects the potential performance of the personnel who will utilize the system being designed. Personnel affordability or availability in part represents a concern about the ability of the personnel inventory development system to provide the personnel levels to operate the system. The concern is not simply with providing sufficient lead time so that sufficient quantities of individuals may be recruited and trained. Rather, the concern is that the personnel system may be unable to provide the required force structure at an affordable price under any conditions. The increasing use of high technology in new weapon systems brings with it the concomitant requirement for individuals who can master that technology. Thus operator and technician recruits must be individuals with the aptitude to profit from demanding training programs. The services must be able to attract such individuals and keep them if the requirements for personnel are to be met.

As was obvious from the large number of interacting variables depicted in Exhibit 2, personnel inventory development involves a complex system. From the perspective here, the main functions entail:

- Bringing individuals into the military
- Training them
- Retaining them

These functions are affected by a large number of conditions both internal and external to the military and to the civilian establishment — Department of Defense and the White Houseas well as Congress — that govern it. Some of these conditions are readily manipulable by system procedures in effect. Other conditions may be changed by decisions affecting personnel policies. Others may change if personnel methodologies and technologies are improved. Still other conditions are essentially intractable.

Thus, it is not easy to predict whether or not a particular manpower requirement is feasible, particularly from the perspective of the conceptual phase of weapon system design. At the conceptual phase, the requirements imply a personnel inventory that will not be needed until the system is deployed in some future time. The major unknowns that arise involve the kinds of changes that must be made in the personnel system in order to initiate and maintain an evolutionary process that causes an existing personnel inventory to adapt to future requirements. Are those requirements easily attainable, or are major modifications needed in personnel technology or personnel policy? What costs are associated with meeting the requirements, in recruiting, in compensation and benefits, as well as in training and other factors?

The potential availability of a required personnel inventory, the feasibility of achieving it, and the costs of that force structure, or at least that segment of those costs attributable to the life cycle costs of a system under consideration, should enter into the decision to adopt that system or one of its options. But unless methodologies exist for making these evaluations, the necessary data will not be available in a usable form. Some approaches are now available for estimating how personnel inventory structures will be influenced by their controlling variables. These are considered in the next section.

2.2.1 Models for Projecting Personnel Inventories

Projections of the personnel inventory for future points in time can be based upon numerical extrapolation of existing hands under the assumption that the factors influencing these trends will remain constant. Frequently such an assumption is unwarranted by events. First, it may be known that changes in relevant controlling factors are anticipated, for example, the supply of youths in the 17-20 age range. It then becomes necessary to determine the impact on the personnel structure of such a change, and this impact cannot be calculated simply by extrapolation processes. To determine such an impact, there must be a means

of assessing the effects of change in the controlling variables in a causal framework.

Second, an assumption of constant conditions may be undesirable. A straightforward extrapolation under constant conditions may yield a personnel inventory structure that has undesirable properties. Consequently it may become necessary to make changes in the controlling variables in order to move toward the desired personnel inventory structure. Then, the question arises as to which controlling variables should be changed and by how much. To answer this question, a means is again necessary to assess the effects of changes and combinations of changes.

These problems have been dealt with by the design of computerized simulation models. At the present time there exist a number of models of varying levels of sophistication that enable manpower and personnel managers to make predictions about the characteristics of future personnel inventory structures.

The most ambitious of these models is the Integrated Simulation Evaluation Model (ISEM)[15] which is currently in an advanced stage of development by the Air Force. ISEM contains several interacting components that work together to simulate a number of important controlling influences on the personnel development process. These major subsystems are the following:

- Policy-Information Control System (PIC)
- The Personnel Force Structure (PFS)
- The Training and Transportation Pipeline (TTP)
- The National Labor Market (NLM)
- System Evaluation Package

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[15] Knight, J.M., Pope, W.H., & Polk, S.B. Integrated Simulation Evaluation Model (ISEM) of the Air Force Manpower and Personnel System: Requirements and Concepts. USAF. AFHRL- TR-77-63. Brooks AFB, Texas.

The Personnel Force Structure subsection models attrition and skill perishability as impacted by supply and demand factors contained within the National Labor Market. The Training and Transportation Pipeline models flow rates through training programs and from one job to another. The Policy-Information Control System is a management module that detects discrepancies and selects methods for eliminating them, given policy and other constraints, all built into the model. Finally, the System Evaluation Package monitors the process and provides as output the set of status indicators. A layout of the system is presented here as Figure 3.

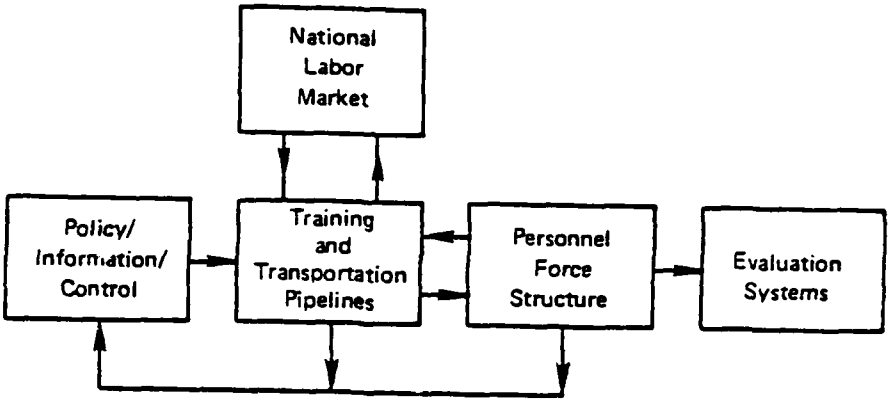

Figure 3. Basic elements of ISEM

The ISEM model has only recently been developed and is not yet fully meeting the planning need for which it was intended. The fact that this model is so new attests to the relative lack of concern for personnel availability that has existed in the past. As has been noted elsewhere, this concern is based upon a number of

recent developments including the institution of the All-Volunteer Force, the projected decrease in the number of youths reaching the age eighteen, and other social and economic factors that have escalated personnel costs and decreased the ability of the services to attract and retain the kinds of personnel they need. Included among these factors are inflation, of course, but also the increasing sophistication of weapon systems that places a premium on skills, for operation and maintenance, that are highly valued in the civilian sector and thus subject to the call of the marketplace. Models such as ISEM represent an attempt to evaluate the magnitude of the impacts of these developments on manpower planning activities and to assess the degree to which coping responses will be able to compensate for those impacts.

Classification in Manpower Requirements Determination. A major problem in defining manpower requirements is the establishment of a system that relates the tasks required to operate and maintain the equipment to the people who will be performing those functions. Certain combinations of skills and skill levels are implied for effective performance of the man-machine systems. It is convenient to combine tasks utilizing these skill combinations as jobs and to relate these jobs to individuals by means of such devices as billet descriptions and occupational specialty codes. A set of tasks implied by equipment can thus be translated into persons with appropriate skills and skill levels.

From the perspective of manpower requirements determination, classification systems make it possible to identify ratings and rates required to perform the tasks mandated by equipment design and associated maintenance requirements. From the perspective of personnel supply, such classification programs serve to identify skills that
form the content of training programs and that define the rungs of the career ladder. The same identifying code can thus be used to describe either a job with its task requirements or an individual with his or her skills.

Projecting future manpower requirements take on additional uncertainty because the metric being used to scale requirements, the classification system, is not a static thing. For the Army, for example, some MOSs will disappear over time, new ones will be added, all will be modified as a result of changes in

equipment, in skills, and in doctrine. The classification system, which accommodates itself to those developments thus becomes an important aspect of manpower requirement projections.

The Air Force was the lead service in developing a service-wide classification program, the Comprehensive Occupational Data Analysis Program (CODAP). The CODAP data base utilized by the Air Force contains estimations of percent of time spent in a very detailed set of tasks covering over 150 occupations. These data are used, for example, to identify jobs that involve clusters of tasks, to determine training requirements, and to scale job difficulty and to relate that to aptitude.[16] Current work entails refinements, updating, and further analyses. The Navy has adopted the CODAP program and calls its version the Navy Occupational Task Analysis Program (NOTAP).[17]

2.2.1.1 Research Implications. The implications of the foregoing for research need little elaboration. Models are only as good as the assumptions built into them. Important variables must be identified, and their effects verified. Means must be determined to control those variables effectively. The interactions of changes in these variables must be determined, either by means of a model, which must be developed and its properties verified, or by means of experimental changes on the system itself. Any of these constitute the basis for a research program which must first be articulated and planned with respect to goals and to means for achieving those goals.

For example, because of the policy assessment feature of ISEM, it is possible to model the effects of changes in policies under a variety of conditions. It thus becomes possible to identify both policy changes that will lead to severe

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16 The CODAP system and its use is discussed in Christal, R.E. The United States Air Force Occupational Research Project. USAF, Wright-Patterson AFB. AFHRL-TR-73-75, 1974.

17 Bureau of Naval Personnel. Development of Job Descriptions and grouping of jobs. Washington, D.C., Bupers NOTAP Dept. 1977.

degradation as well as policy changes that represent strategies for achieving desired goals. Presently it does not seem possible to evaluate such strategies against an optimality criterion simply because the data and methodologies do not exist.

That fact provides a major area for research and development activities. It should be possible, for example, using an ISEM-like model to identify several alternative processes that would lead to a desired goal. Continuing the example, it might emerge that a given personnel structure is predicted to be attainable if training time were to be reduced by 25% or if military salaries were increased by 10%, or perhaps some combination of the two. Data, or a theoretical understanding of the underlying processes sufficient to generate good estimates, should be available that would allow an economic analysis to determine the costs of these options or a least-cost combination of them.

The possibility of performing such analyses presumes a basic understanding of the costs of making improvements or changes of various magnitudes in the outputs of a wide variety of personnel processes. The understanding required depends upon a broad base of knowledge about the personnel development system achieved through an integrated research and development program. In the next section, personnel processes will be discussed further.

2.3 Personnel Processes in Personnel Affordability

Personnel processes are the mechanisms that enable the services to effect changes in individuals so that they are prepared to perform the activities that are mandated by the slots they occupy. Individuals must be recruited, evaluated and selected, trained, classified, assigned, compensated and finally separated. Each of these processes involves a number of activities and people who perform those activities. Collateral efforts involve developing and evaluating the processes as well as the technologies that underlie them, managing the process, and planning for and integrating the processes to meet overall service goals. As a net result of these activities, recruits enter the service, develop skills and experience and are utilized in positions that make use of those skills and experience.

Personnel processes enter into a consideration of personnel affordability because they govern the overall force structure, placing constraints on the composition of the force and on the rates of change of that composition. In addition to the processes themselves, which can be described in statistical terms, there are additional general indices that describe the quality or excellence of the personnel process. Examples of such measures are force effectiveness, readiness, productivity, retention, and so on. Some of these indices are performance measures. Although personnel affordability as defined in this paper is concerned primarily with personnel inventory variables, namely the number available in various skills and skill levels, such variables are intertwined with performance variables. The quality of the people selected into the services affects performance. Since the services are competing with the civilian sector for high quality personnel and these are numerically limited, it is often difficult to recruit desired numbers of individuals at the higher quality levels. Conversely by lowering quality levels for selection, the quantity requirements can be more readily met, but skills and performance may suffer. Various other social and economic factors also conform to these relationships. Training costs go up as attempts are made to achieve required skill levels using personnel with less aptitude, and so on.

From the perspective of design, these considerations should be and are reflected in design efforts to match the skill requirements of the force presumed to be available by demands for those skills. Equipment should be designed to be utilized effectively by the quality of personnel that will be available to use it. Plans should be made to magnify the effectiveness of the high quality personnel available. How this should be done is also a matter of research. How are design characteristics to be related to personnel characteristics to optimize the interactions? A concern with personnel affordability, thus, becomes, in part, a concern with personnel processes because the effectiveness of those processes determines whether projected manpower requirements are feasible. Personnel processes are subject to improvement through research and development efforts. Consequently personnel affordability estimates must be continually reassessed to determine the extent to which technological advance has modified previous assessments.

In the following discussion, we will deal with personnel processes and provide examples of the problems that are current and the kinds of approaches that are being taken to solve those problems. A vast amount of research effort is directed at personnel process improvement, and there is no attempt made here to be exhaustive. As mentioned earlier, the primary personnel processes are involved in recruiting, training and retaining the individuals needed to maintain the personnel inventory required at any point in time. The processes include:

- Recruiting
- Selection
- Training
- Classification
- Assignment
- Compensation
- Separation

This sequence suggests the temporal sequence of the processes as they are applied to an individual who flows through the personnel system in a Navy career. They will be considered below.

All the services found it necessary to undertake special recruiting programs as a result of the end of the draft and the initiation of the All-Volunteer Force (AVF) concept. One example of a service response to the issues surrounding the AVF is the set of manpower R&D programs administered by the Office of Naval Research.[18] These programs are concerned with such recruiting problems as:

- Effect of local economic conditions on Navy enlistment
- Optimal combination of advertising and recruiter efforts
- Enlistment in the Navy as a case of career choice
- Effects of recruiting personnel and advertising on accessions.

[18] Office of Naval Research. Psychological Sciences Division: FY 1978 Programs. Arlington, VA. ONR-450-10. 1978.

No reports are available for the projects covering these topics as yet. This effort represents an attempt to find ways to fine tune the recruiting process by reaching a firmer understanding of conditions that affect recruiting success and utilizing the augmented understanding to plan a more effective recruiting effort.

The services do not choose to select all individuals who are attracted by recruiting efforts. Selection criteria are determined by such factors as the aptitudes necesary to achieve proficiency in military tasks as well as health and physical standards. The problem of selection is that of evaluating selected characteristics of individuals at the time of recruiting and of predicting from these characteristics the potential of the individual for absorbing training and for performing military functions. Traditional paper-and-pencil tests have long served the services as tools for evaluation and prediction, but recent research is aimed at more esoteric indicators such as brain waves. Research and development efforts are required, however, even with traditional approaches. The principal instrument for measuring aptitude for selection and assignment purposes in the military is the Armed Services Vocational Aptitude Battery (ASVAB). Developed by the Air Force as the lead service, ASVAB is periodically updated and reassessed.[19]

Initial assignment of new recruits into a specialty area is based upon aptitudes and desires of the recruits and the needs of the services. In order to refine the job placement procedure the Air Force has developed the Vocational Interest-Career Examination (VOICE) that measures relative vocational interests.[20] Further development and validation is now in progress, and the other services are considering adopting it or constructing their own versions. These approaches represent attempts to deal with the problem both of evaluating military specialties in which a recruit is likely to be successful as well as be compatible in terms of interest. Obviously, these efforts will be furthered by advances in the

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[19] See Air Force Human Resources Laboratory. AFHRS Annual Program Report: 1978. Brooks AFB, Texas, 1979.

[20] Air Force Human Resources Laboratory. Development and Validity of a Vocational and Occupational Interest Inventory. AFHRL-TR-73-28. 1973.

theoretical underpinnings of intelligent behavior, skill learning, and motivation, on the one hand, and task analysis and job design on the other.

Following selection, a recruit ordinarily undergoes the first of what may be a series of training programs, that are interspersed throughout a military career. The training area is so extensive that no attempt will be made to deal with it here except in passing. Current developments in the training area include an increased utilization and refinement of simulation devices, of self-paced instructional techniques, of on-the-job training, and of job performance aids.

Training is usually the first step in a Navy career. The choice of a training program is a complex science. Classification involves the assignment of an individual to a career ladder and the establishment of an identification code and a rank to indicate the occupational specialties and skills for that individual as he or she proceeds up the ladder or, as is sometimes the case, transfers into new specialty areas. Work done in classification, such as CODAP research as well as and selection and classification testing, mark the state-of-the-art in this area.

Once the individual is in the service, there exist a number of programmatic efforts to maintain that individual's interest in pursuing a service career. Many of these are concerned with the "quality of life," involving tangible and intangible factors that contribute to the satisfaction of the serviceman. In part, quality of service life involves leadership and management. To improve these factors, all services have research programs that are intended to understand the motivation of individuals and groups in the military and the factors that determine and control motivation. As a result of this work, procedures are implemented for conducting training to improve leadership and management skills.

One very important aspect of service quality of life consists of compensation in terms of pay and benefits. Research in this area involves such topics as schedules of reinforcement and such prosaic but difficult subjects as the comparability of pay of the military versus the civilian factors. [21]

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[21] For example, Holt, C.C. and Toikka, R.S. The economic and labor market environment of military manpower: Annual summary report. Urban Institute, August 1977. (AD A043 514).

Finally, the last process undergone by an individual in the military is separation from the service. Often this is scheduled, or for the convenience of the service. Frequently, however, the separation is inconvenient for the service and expensive. Particularly with the advent of the All-Volunteer Force, retention of desirable individuals and the untimely attrition of those who have not completed training have become major problems. Much research in this area seeks to identify and rectify problems of early separation.

2.3.1 Other Problems and Issues

Projected or potential discrepancies between manpower requirements and the force structure available may be attacked in other ways. Additional sources of input may be sought, for example, women; or attempts may be made to increase the productivity of the force available. All of the services have studied extensively the impact of the utilization of women in greater numbers and in non-traditional roles, and this area of research continue to attract a considerable amount of funding and effort.

Productivity has been approached from a number of directions. For example, at the organizational level, a procedure for identifying organizational problem areas impeding effectiveness has been developed for the Air Force Leadership and Management Development Center.[22]

At the individual level productivity may be approached, for example, by creating stimulating jobs and providing a context in which the individual's efforts are appreciated and rewarded.[23] Specific productivity problems may be analyzed via questionnaire.[24]

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[22] Air Force Human Resources Laboratory. Organization Survey Assessment Package for Air Force Organizations. Brooks AFB, Texas. AFHRL-TR-78-93. 1979.

[23] For example, Pritchard, R.D., et al. Productivity through feedback and job design. Brooks AFB, Texas. AFHRL-TR-79-44. 1978.

[24] For example, Edwards, J.O. Comparative analyses of enlisted job satisfactions measured by the occupational attitude inventory. Brooks AFB, Texas. AFHRL-TR-78-61. 1978.

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The above brief description of the personnel processes by no means covers the wide range of problems and issues that currently are under attack by the services. In the next section we shall take a look at the research organizations concerned with manpower and personnel research for the Navy and the Air Force. The gamut of R&D areas, even there, however, will only be hinted at in a presentation of research goals and objectives of the various organizational units concerned with manpower and personnel R&D. To be topical, it is necessary to review the annual program plans of the several organizations and observe the specific work units that are contributing to the achievement of goals identified.

3.0 NAVY AND AIR FORCE RESEARCH AND DEVELOPMENT ORGANIZATIONS

This report is intended to supply an Army reader with a conceptualization that pulls together the diverse activities that may be considered under the rubric "Personnel Affordability." Examples of recent or ongoing studies or reports have been presented to convey the flavor and the content of state-of-the-art R&D being conducted in Navy and Air Force settings. In this section is discussed the organization of the principal Navy and Air Force research units performing research related to personnel affordability.

3.1 Navy Research and Development

Navy 6.1 efforts in personnel-affordability areas are monitored and/or coordinated by the Psychological Sciences Division of the Office of Naval Research (ONR), whose programs, for the most part, are carried out under contracts with universities. According to a recent publication,[25] "The bulk of the program is basic in nature, but there is a selected augmentation of advanced research and exploratory development efforts." The research programs are shaped by staff-determined "scientific and technical gaps in the Defense Research Sciences" and by guideline statements promulgated by the Naval Research Requirements in the Behavioral and Social Sciences established by the Chief of Naval Research and the Science and Technology Objectives on Personnel/Medical Support (STO/PN) promulgated by the Chief of Naval Operations. These directives, however, are quite broadly stated and do not provide specific guidance for R&D target selection.

The ONR program of MPT-related research is organized into 18 research-area clusters that are considered under four main headings. These areas, with brief descriptions of each, are as follows:

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[25] Office of Naval Research. Psychological Sciences Division:1978. PSD/ONR, Publication 450-10, September 1978.

Personnel and Training Research Programs

- Theory-based Personnel Assessment. This research should lead to more efficient and valid psychological assessments for selection, classification, training, and advancement.
- Information Processing Abilities. Exploration of individual differences in the basic parameters of information processing is aimed at a clearer understanding of aptitudes and other abilities important in Navy jobs.
- Representing Knowledge for Training. Ways of representing knowledge and instructional strategies are being explored with a view to their incorporation in generative, knowledge-based computer-based instruction.
- Cognitive Processes. This research is aimed at models of the cognitive processes and structures underlying skilled performance in real-world tasks with complex information-processing demands.
- Analyzing Job Demands. This research, as an attempt to increase our knowledge of the complex interaction among abilities, job performance, and other aspects of the world of work.

Manpower Research and Development Programs

- Personnel Recruiting. This research examines factors that affect recruiting success.
- Personnel Attrition. These projects deal with the causes of attrition, its costs, and procedures to enable recruits to cope with military life.
- Manpower Supply. This research focuses upon forecasting of supply and demand for personnel and for predicting occupational choice.
- Manpower Management. Research in this area examines possibilities for streamlining personnel operations, for estimating the value of current personnel resources, for identifying factors associated with retention, and for devising better methods of obtaining needed information from active duty personnel.

Organizational Effectiveness Research Programs

- Leadership and Management. Theoretical and empirical research with the ultimate aim of improving programs of leader and manager development.
- Adaptation in Organizations. Research on the factors that determine how individuals adapt to work in organizations and the ways in which organizations can be changed to enhance work performance and satisfaction.
- Intergroup Relations. Aims at improving our understanding of how individuals with diverse ethnic and cultural backgrounds can be merged effective teams, crews, and units.

- Personnel Turnover and Retention. Research and development on the determinants and impact of personnel turnover.
- National Security Crisis Management. A program of the Defense Advanced Research Projects Agency designed to increase the effectiveness of crisis decision-making.

Engineering Psychology Programs

- Visual and Auditory Perception. This program currently focuses on broadening the data base and extending theory to cover more complex patterns of behavior than previously, including perception of three-dimensional imagery.
- Information Processing and Decision-Making. These research efforts seek to understand how people assimilate information, assess situations, and choose actions under uncertainty and risk; this research also investigates computer programmer performance.
- Man-Machine System Interfaces. This research, involving operator performance in man-machine systems, focuses on advanced concepts for computer-aided control and the effective utilization of new and emerging display technologies in naval environments.
- Decision Aid Development. These efforts are intended to develop techniques and displays to support decision-making in command and control systems; current focus is on Navy surface, Navy air ASW, and Marine Corps command and control functions.

By and large, these programs are not identified in terms of personnel system procedures and functions, although it is obvious that they all pertain to the system somewhere. They do, however, deal at a basic level with processes that could be employed as part of a methodological approach to personnel or manpower problems. A major exception is the cluster of specific research topics in the Manpower R&D Program. These deal with particular problems related to recruiting; and they came into being in support of the management of the All-Volunteer Force program.

Navy efforts beyond the 6-1 level tend to be sponsored by or coordinated through the Navy Personnel Research and Development Center (NPRDC) located on Point Loma in San Diego. NPRDC is the principal Navy activity for human resources research and development for the areas of manpower, personnel, education, and training. It also supports human factors efforts in systems design, development, and acquisition. Thus, NPRDC conducts and manages research across the total spectrum of manpower and personnel concerns.

NPRDC breaks its programs into eleven major areas as follows:[26]

- Personnel Acquisition and Initial Assignment. Program emphasis involves (1) improving recruiter selection andperformance, (2) assessing advertising, program options, and incentives, (3) improving selection and classification, and reducing attrition, and (4) developing computer-based occupational decision systems.
- Applied Psychobiology. The program goals are to improve personnel selection and classification, and to enhance personnel performance through the application of psychobiological findings and procedures.
- Attitude and Motivation. The domain of the program is behavior in the organization context that affects the motivations, work attitudes, productivity, job satisfaction, personnel utilization, and overall effectiveness of Navy units. The general goal of the program is to help the Navy achieve its objective of maximum readiness through R&D to improve organizational functioning
  by maximizing the contribution of individuals to the organization.
- Performance Enhancement. The major thrust of this program is to identify, appraise, test, and exploit specific applications of available human resources technology to produce cost-effective improvements in on-the-job personnel performance and system effectivenes measures and to realize cost benefits in personnel and training systems.
- Design of Manned Systems. The overall aim of the program is to achieve improved manpower and personnel utilization through (1) enhanced individual and team job design for operator/maintainer positions, (2) development of innovative man-machine system design and training procedures for optimum integration of the human element in Navy systems, and (3) quantitative measurement and evaluation of job performance in Navy occupational contexts.
- Measurement of Job Performance. Its major purpose is to address the problem of measuring job performance capabilities of the Navy's military and civilian personnel, which capabilities are critical to the effective and efficient accomplishment of the Navy's assigned missions. This program is essential to the assessment of personnel readiness and is a direct link to assessing fleet readiness and is a basis for criterion development for assessing and validating major R&D efforts of the center.

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[26] Navy Personnel Research and Development Center. Five-year plan (FY78 - FY82) NPRDC, San Diego. 1977.

- Development of Training Technology. This program seeks answers to four major questions:
  - How can training be provided in the most efficient manner?
  - How can training be made job relevant?
  - How can complex skills be developed where training capabilities are currently deficient?
  - How can flexibility in a training program be provided to improve the efficiency of the system?
- Test and Application of Training Systems. The program's primary focus is on practical problems of applying training technology to the task of maintaining and enhancing Navy operational readiness. The general mission of the program is to provide a bridge between developers of training technology and the Navy organizations which use this technology. The program stresses technology assessment, technology adaptation, and operational problem analyses.
- Management of People and Organizations. The program seeks (1) to identify alternative ways people and organizations can be used—given certain material resources— to accomplish organizational goals or missions, (2) to develop and evaluate measures of effectiveness, (3) to develop methods and models to represent "people-organizational-materials systems," and (4) to develop information systems to provide inputs for management decisions related to organization function and structure.
- Management Systems. At least three long-range R&D objectives can be delineated: (1) computer-based systems for the training and development of managers, (2) development of design parameters for management information subsystems, and (3) quantification of manpower and personnel system behavior. All three are closely related.
- Information and Decision Processing. Program goals are (1) to determine how people integrate information, (2) to investigate variables affecting information seeking, (3) to determine the diagnostic impact of information on the decision-maker, and (4) to identify and develop valid performance measues in the context of optimization models and decision-aiding systems.

To relate these program areas to manpower and personnel system needs, NPRDC has established a prioritized list of Navy problems and determined which programs are germane to each problem. The NPRDC budget of about $16 million is allocated in accordance with these priorities.

Additional Navy R&D functions are widely distributed. The Navy Training Equipment Center at Orlando, for example, is responsible for the development of simulators and other equipment for training.

3.2 Air Force Research and Development

The organization for research and development in the Air Force is similar to that for the Navy. Basic research is conducted under the auspices of the Air Force Office of Scientific Research, with manpower and personnel research located in the Division of Human Resources of the Directorate of Life Sciences. Both university-based and intramural research are monitored, supported, and coordinated at this level in four areas. These areas and their current emphases are described below:

- Human Factors Engineering. In this area, the focus is upon visual processes, primarily as related to visual displays; upon workload methodology measuring stress, information processing; upon crew systems technology developing mathematical models of human operators; and information and decision processes.
- Personnel Systems Technology. Main foci in this area are psychological test construction, studies of social forces in the military, and physical criteria for assigning personnel to Air Force jobs.
- Manpower Utilization and Management. Much research in this area is concerned with productivity: individual and organizational productivity and methods for measurement of productivity, the role of communications, feedback, social actions, leadership, and job design and enrichment.
- Education and Training. This research centers upon the acquisition and retention of complex skills, such as motor skills and visual learning of complex flight scenarios.

Beyond the 6.1 funding level in the Air Force, research is conducted and coordinated by laboratories. The laboratory with responsibility for personnel affordability research is the Air Force Human Resources Laboratory (AFHRL). AFHRL is divided into several branches, each with a number of branches including the following:

- Advanced Systems Division (ASD)
  - Personnel and Training Requirements Branch (ASR)
  - Simulation Techniques Branch (ASM)
  - Resources and Instrumentation Branch (ASI)
- Occupational and Manpower Research Division (OR)
  - Career Development and Job Evaluation Branch (ORE)
  - Job Analysis and Job Requirements Branch (ORA)
  - Personnel and Manpower Systems Branch (ORS)

- Personnel Research Division (PE)
  - Selection and Classification Systems Branch (PES)
  - Demographic and Attitudinal Research Branch (PEM)
  - Manpower Development and Evaluation Branch (PEP)

The above divisions are involved in research critical to the personnel affordability area. Other Divisions consist of the Technical Training Division (TT), the Flying Training Division (FT) and the Computational Sciences Division (SM).

Of the Divisions to be considered, ASD is located at Wright-Patterson Air Force Base, Ohio, while OR and PE are at Brooks Field, San Antonio, Texas. The programs of these three divisions are focussed on a series of goals.[27] For the ASD, these goals are as follows:

1. Develop methods and data which will assist system designers and operational planners to incorporate human resources considerations into the development and utilization of advanced weapon systems so as to achieve and maintain optimum mission readiness and effectiveness at the lowest life cycle costs.

2. Determine the maintenance manpower requirements of new weapon systems. Expand the computer-based maintenance manpower model (using LCOM, Logistics Composite Model) so that the model considers the maintenance rate required by each type of equipment.

3. Develop methods and data which can be used to obtain weapon system life cycle costs, particularly the human element, so that such information can impact on planning.

4. Improve the productivity of maintenance personnel, especially through better data on-the-job, matching job-oriented training and better job environment. Support the development of an automated technical data system and develop improved techniques to evaluate on-the-job performance of maintenance technicians.

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[27] Plans and Programs Office. Fiscal Year 1980 - Air Force Technical Objective Document. Air Force Human Resources Laboratory, Brooks Field, Texas. (AFHRL-TR-78-79) November 1978.

5. Develop and consolidate human factors information bearing on the design and use of major items of training devices.

6. Integrate, demonstrate, and evaluate on one weapon system all the separate technologies involved in planning and developing the human element in a weapon system.

7. Develop methods and techniques to provide crew/unit/team training programs for operators of complex weapons and command control and communication (C^3) systems.

The goals of the Advanced Systems Division seem to closely approximate definitions of personnel affordability. The goals of the two other divisions under consideration – Personnel Research and Occupational and Manpower Research – are focused on the two major areas: personnel inventory development and manpower requirements determination. The goals of PE are as follows:

General Objective:

The objective is to develop measuring devices and associated technologies which are predictive of the subsequent conduct and performance of persons in military service. The results provide a substantive basis for personnel decisions in the initial selection, assignments, and retention of Air Force personnel. Resources are allocated to maximize the return on personnel investment.

Specific Goals and Technical Approach:

1. Selection techniques for a quality force. Match career and special assignment with individual skills, interests, and needs; reduce student attrition from training programs and decrease undesired turnover during initial tours and at subsequent career decision points.

2. Classification and Assignment Technologies. Optimize the match between an individual's abilities and interests and his assignment to an occupational speciality.

   a. Develop and evaluate mental tests to improve predictive efficiency for success in Air Force personnel and training programs.

   b. Develop and evaluate composite batteries of cognitive and non-cognitive tests to maximize the opportunity for person/job match at the time of initial assignment.

   c. Develop prototype selection and classification batteries implementing research results which can be used operationally and can be transitioned into the Air Force Personnel Testing System.

3. Armed Services Vocational Aptitude Battery. To provide research and development support for the Armed Services Vocational Aptitude Battery as the lead service laboratory. This joint service program works toward achievement of DOD-wide economies in the personnel selection and initial assignment systems of the services through a single system rather than duplicative separate systems.

4. Perceptual/Motor and Computer-Managed Measurement. Increase the effectiveness of personnel selection and assignment systems. All services have implemented computer-based recruit job assignment systems at the Air Force Entrance and Examining Station (AFEES). Tailored testing should improve individual assessments at the AFEES, permit direct integration of these individual measurements into the assignment systems, and provide more efficient AFEES processing.

5. Performance Measurement/Criterion Development. To develop prototype measures of technical job performance to provide an evaluation of the abilities required on the job which can serve as criteria for on-the-job validation of selection and classification devices. Such data are essential to the development of selection and classification instruments which best match human abilities with job requirements.

In the OR division, a number of interesting programs germane to personnel affordability considerations are in progress, an observation that can be validated by reference to the goals of this division.

General Objective and Investment Strategy:

Develop technologies and management tools to determine optimum force structures under specified mission requirements and establish force mix and utilization strategies that will enhance individual and unit effectiveness. Work in this technical area will establish data bases and computer simulation techniques to determine the effect of personnel management policies on force composition and productivity.

Specific Goals and Technical Approach:

1. Provide manpower planners with information for forecasting personnel requirements as a function of mission workload. During FY 80/81 studies will be conducted to evaluate the validity of civilian job data, to further the development of an Air Force occupational information center and to perform research on improved methods for the collection and analysis of occupational data. In addition to furthering the application of this research within the Air Force, modification of survey and data analysis techniques for use by other agencies will continue as well as AFHRL assistance to the Federal Acquisition Institute.

2. Provide cost effective utilization of personnel and manpower resources by adapting force management decisions to specific job and mission requirements. During FY 80/81 work will be essentially completed on determining relative aptitude requirements for Air Force specialties. Changes will be proposed for selected specialties. Studies will be conducted on task level training priorities, training decision systems, safety training priorities, and strength and stamina requirements for Air Force jobs.

3. Enhance personnel utilization, productivity, satisfaction and retention by developing and fully utilizing individual capabilities through a progression of planned assignments and by restructing job characteristics. In FY 80/81, basic research initiatives will be transitioned to the exploratory development program. These include further exploration of intrinsic reward systems as a means of improving worker productivity, the development and application of a functional taxonomy of productivity criteria, an investigation of the impact of organizational characteristics on individual and unit effectiveness and the design of procedures for identifying high cost tasks.

4. Provide management with methods and technologies to structure a force with the appropriate grade, skill, and compensation levels to accomplish the Air Force mission within current manpower and budget constraints. During FY 80/81 quantified job evaluation techniques will be developed for determining grade and skill level requirements and equivalency among military/civilian jobs. Requirements and characteristics will be identified, which must be considered in an optimal person-job-match system and to evaluate their contribution to career development and improved occupational structures.

5. Establish a comprehensive program for utilizing skills and experience data to improve management decisions particularly in the areas of job classification, personnel assignment, and training. Technology will be developed during FY 80/81 to identify and measure skills and knowledge required in Air Force specialties, to assess individual capabilities for successful on-the-job performance, to investigate the extent of skill perishability over time, to determine remedial training strategies and finally to explore the area of skill transferability between specialties with particular emphasis on the AF retraining program.

6. Provide techniques and procedures for use in personnel and manpower management that will forecast the probable outcomes of alternative policy decisions and reduce the cost of operating the Air Force Personnel and Manpower Systems. During FY 80/81, work will be completed on the Air Force

personnel force structure and the national labor market components of the ISEM. Studies will also be performed viewing the Air Force as an internal labor market; various forms of compensation will be evaluated.

7. Collect and organize personnel and training research data and conduct longitudinal and cross-sectional analyses of these data in support of studies on the effective utilization, assignment, and training of military personnel. In FY 80, the personnel and training research data bases will be updated to include FY 79 and FY 80 data. Work on the data base to cross-reference data elements and file layouts will be continued in-house. During FY 81, additional software will be developed which will further improve the retrieval of data from multiple file sources.

8. Develop the mathematical and statistical tools that will facilitate the analysis of human resources data for research programs. In FY 80/81, a comparison will be made of statistical methods of predicting graduation/elimination rates in basic military training, technical training, and undergraduate pilot training. Mathematical and computational procedures to quantify management policies through the use of policy-capturing techniques will be implemented with the objective of developing a methodology supporting the direct interaction of the policy maker with the computer. Computer-based mathematical algorithms for sample survey techniques will be developed and tested in support of the variety of Air Force wide surveys.

9. Develop systems for use in personnel assignments which identify optimum matches of persons to jobs. A person-job-match system for applicants for enlistmene tbecame operational in FY 77. Enhancements and modifications are continuing to be made to this system, such as refinements to the job match payoff system and improved forecasting techniques for the applicant pool. A post-enlistment system for enlistees requiring assignments during basic training will become operational during FY 79. Future research will result in a compatible, unified total person-job-match system for applicants and enlistees. The person-job-match technology will be adapted for other assignment/reassignment requirements within the AFMPS management system.

10. Develop techniques and models which will enable Air Force manpower and personnel planners to make better informed, and therefore more effective, resource allocation decisions. One specific area of research will be to provide for Air Force Recruiting Service a recruiting resource and goal allocation design model which will assist them in their decision processes. This model should be operational in FY 79/80. Enhancements to this model to provide for improved recruiter productivity feedback and incentive systems will be made in the FY 80/81 period.

This overview of manpower and personnel research areas in the Navy and Air Force has not dealt in any significant way with the vast training area which constitutes the bulk of the funding for the two services in this general area. All of the organizational units described here have large training R&D programs, and training R&D is carried on at other commands. The short shrift given to training in this report is not intended to minimize this most important area for military services, which as a policy matter are committed to developing military skills internally. Rather, this report recognizes the futility of attempting to describe training R&D in all of its ramifications in the short space and time allotted to this project. In this regard, attention is called to the Research and Development Information (RDIS) that is being developed at NPRDC. According to reports, this system will provide for the collection, review, organization, update, analysis, and dissemination of Navy, Marine Corps, Army and Air Force people-related R&D efforts. RDIS should provide the definitive data base for training as well as other manpower and personnel research efforts.

The report has attempted to provide a conceptual framework within which training R&D, as well as manpower and personnel R&D in general, may be considered. This framework has been garnished with examples of relevant research efforts and with statements about the major R&D organizations and their objectives with respect to the framework. The outlines of the state of the art in personnel affordability can be detected within this organized approach and presentation.

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