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OFFICER DUAL SPECIALTY ALLOCATION SYSTEM (ODSAS).(U)
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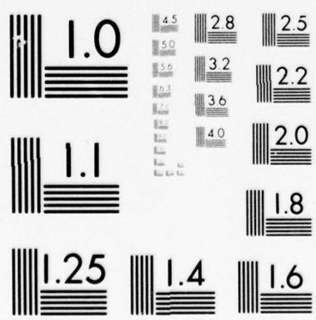

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STUDY REPORT
CAA-SR-76-6

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OFFICER DUAL SPECIALTY ALLOCATION SYSTEM

(ODSAS)

APRIL 1976

PREPARED BY
METHODOLOGY AND RESOURCES DIRECTORATE

US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20014

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8120 Woodmont Avenue
Bethesda, MD 20014

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Officer Personnel Management System, Dual Specialty Allocation, Dual-qualified Officers, Basic Entry Specialty, Alternate Specialty, Personnel Management

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In 1974 the Army adopted the Officer Personnel Management System (OPMS), replacing the earlier "career branch" system under which the officer corps had been managed. Under OPMS each officer is assigned two specialties--a basic entry specialty (BES) and an alternate. Goals of OPMS include improving the match between the officer's qualifications and the Army's requirements and providing discrete career development patterns for the individual officer in both his BES and alternate specialty. The US Army Concepts Analysis Agency (CAA), at the

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request of the Office of the Deputy Chief of Staff for Personnel (ODCSPER), Headquarters Department of the Army, developed the Officer Dual Specialty Allocation System (ODSAS), a computer-based system, to assist OPMS managers in satisfying Army officer personnel requirements. The ODSAS-derived solution is driven by requirements associated with any force structure specified by the user. The methodology employed computes the optimum number of officers for allocation to specific OPMS specialty pairings, consistent with the specified force structure requirements. The system treats officer grades from lieutenant through colonel, inclusively, over a period of time (up to 9 years).

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

APRIL 1976

PREPARED BY
METHODOLOGY AND RESOURCES DIRECTORATE

US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20014

FOREWORD

DEPARTMENT OF THE ARMY
US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20014

IN REPLY REFER TO

MOCA-MRC 12 APR 1976

SUBJECT: Officer Dual Specialty Allocation System (ODSAS)

Deputy Chief of Staff for Personnel
Department of the Army
Washington, DC 20310

1. The US Army Concepts Analysis Agency (CAA) has completed the attached study in response to your letter, DAPE-MPO-S, 14 February 1975, subject: Study Directive: Officer Dual Specialty Allocation System (ODSAS). The study directive requested that CAA:

a. determine the feasibility of developing a methodology to analyze any given force structure and project, by grade level, an officer inventory requirement with the proper composition of primary and alternate OPMS specialties to meet the force level, and if feasible,

b. develop a computer-based model to implement the methodology.

2. Following an investigative and problem analysis period in which several approaches were considered, a network flow design was used to formulate the dual specialty allocation problem; linear programing techniques were employed for solution. The methodology was implemented in an automated information system which features on-line user interaction to facilitate review and analysis of intermediate and final results. The automated ODSAS methodology was designed for operation on computing system hardware and software existing at the US Army Military Personnel Center (MILPERCEN). In this regard, full-scale system testing was conducted with data provided by the ODCSPER to validate results in the user's operational environment. Throughout the study, close contact has been maintained with officer personnel managers at MILPERCEN to insure understanding and acceptance of ODSAS by its intended users.

3. The attached CAA report describes the ODSAS methodology, the automated information system, and results of testing the system. The ODSAS is a planning tool for use by officer personnel managers to evaluate quantitatively the composition of the officer corps based upon Army force structure

1 2 APR 1976

MOCA-MRC
SUBJECT: Officer Dual Specialty Allocation System (ODSAS)

requirements; alternative officer management policies prior to implementation; and the impact of projected force structure changes. An additional document, designed specifically for ODSAS automated system users will be forwarded directly to MILPERCEN.

1 Incl
as

JOHN T. NEWMAN
Technical Director

DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF FOR PERSONNEL
WASHINGTON, D.C. 20310

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DAPE-MPO-S

SUBJECT: Study Directive: Officer Dual Specialty Allocation System (ODAS)

THRU: Deputy Chief of Staff for
Operations & Plans
Washington, DC 20310

25 FEB 1975

TO: Commander
US Army Concepts Analysis Agency
8120 Woodmont Avenue
Bethesda, MD 20014

1. Attached directive for subject study (Inclosure 1) is forwarded for action in accordance with paragraph 4, AR 10-38, US Army Concepts Analysis Agency.

2. Tasking has been undertaken in accordance with procedures contained in AR 18-38. Informal coordination was accomplished with LTC David Harpman, Resources Constraints Group, USACAA (ext. 295-0390).

3. Request subject study be accomplished by USCAA in accordance with study directive at Inclosure 1.

FOR THE DEPUTY CHIEF OF STAFF FOR PERSONNEL:

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R. O. VITERNA
Colonel, CS
Chief, Research Office

STUDY DIRECTIVE
FOR
STUDY: OFFICER DUAL SPECIALTY ALLOCATION SYSTEM (ODSAS)

1. Purpose. To provide a system which assists in the management of Army officer assets by Officer Personnel Management System (OPMS) specialty and grade.

2. References.

a. AR 10-38, US Army Concept Analysis Agency.

b. AR 5-5, The Army Study System.

c. DF, DAPE-PBR, 2 Oct 74, subject: Proposed Study: Officer Specialty Designation Under OPMS.

d. DA Pamphlet 600-3, 1 Mar 74.

3. Study Sponsor. DCSPER (DAPE-MPO). DCSPER point of contact - MAJ Terence Henry, DAPE-MPO-S, ext. 695-2457.

4. Study Agency. US Army Concepts Analysis Agency.

5. Terms of Reference.

a. Problem. Under OPMS, the current system of managing officers by career branch and grade is being replaced by a system of managing officers by primary/alternate OPMS specialty and grade. Each officer will be designated a basic entry specialty as the primary specialty upon entry to active duty. An alternate specialty will be formally designated at the eighth year of Active Federal Commissioned Service although tentative identification may be made at any time prior to the formal designation. A requirement exists to provide a system for the procurement, training, and specialty designation of adequate numbers of dual qualified officers at all grade levels to meet projected force requirements. The system must have the capability to accept and analyze various future force structures and generate the appropriate personnel procurement and training requirements. The system must consider specialty requirements for officers with less than eight years of Active Federal Commissioned Service (AFCS). For officers with more than eight years of AFCS, the system must insure the optimal mix of specialty pairings needed to meet OPMS assignment criteria.

b. Objectives.

(1) Determine by June 1975 the feasibility of developing a methodology to analyze any given force structure and project by grade level an officer inventory with the proper composition of primary and alternate OPMS specialties to meet the force level.

(2) If a feasible methodology can be derived, develop this computer-based model by February 1976.

c. Scope.

(1) The study entails deriving a method of allocating authorized Army commissioned officers controlled by the Officer Personnel Directorate (OPD).

(2) The study will deal with combinations of all 45 OPMS specialties less those pairings judged mutually exclusive in DA Pamphlet 600-3. Any dual specialty pairings for which there are five or less requirements in all grades will be treated as if the dual requirement did not exist.

(3) The system designed will address all requirements derived from the TO&Es, MTO&Es and TDAs normally found in any force structure analyzed.

d. Assumptions.

(1) Optimal represents the satisfaction of minimum levels of designated pairings of selected specialties, and minimization of the officers that alternate their assignments outside the limits of the OPMS utilization ratios.

(2) The Structure and Composition System (SACS) will be used for specification of specialty requirements.

(3) The Defense Officer Personnel Management System (DOPMS) will be used for promotion opportunity and phase points.

(4) Continuation rates, to be furnished by DCSPER, will be used to age the force.

(5) Specialties delineated in DA Pamphlet 600-3 as being incompatible with certain others will be excluded from consideration as a possible pairing of primary and alternate specialties - all other specialties are feasible.

(6) All authorized positions will be filled by officers of the required grade, or 1 grade lower.

(7) Specific schooling incident to skill acquisition as well as the TPS account, are included in the requirements.

(8) The subjects of "short tour equity" and "space imbalance" vis-a-vis CONUS and Overseas will not be addressed.

(9) The concept of average tour length will be used instead of tour lengths associated with specific requirements.

(10) OPMS assignment criteria has as its goal a utilization ratio whereby an officer alternates assignments between his two specialties on a 1:1 basis. An acceptable ratio should fall between the limits of 1:2 or 2:1. However, provisions should be made to allow for sensitivity analysis beyond these limits.

e. Essential Elements of Analysis (EEA).

(1) In any given year, based upon the requirements generated by a given force structure, can the number of officers to be allocated specific specialty pairings at each grade level not to exceed the utilization ratio limits be determined?

(2) In any given year based upon the requirements generated by a given force structure, can the total procurement of officers by basic entry specialty be determined?

(3) In any given year based upon the requirements generated by a given force structure, can the training requirements for basic entry and alternate specialties to support the force be determined?

f. Time Frame. The system will address force requirements for a stated point in time.

g. Models. System developed must be capable of being run on the MILPERCEN UNIVAC Computers.

6. Support and Resource Requirements.

a. Support Requirements. ODCSPER, ODCSOPS and USA MILPERCEN will provide support as required by the study agency.

b. Resource Requirements. Four (4) CAA programmer analyst technical manyears.

7. Administration.

a. Study Title. Officer Dual Specialty Allocation System (ODSAS).

b. Study Leader. David Harpman, LTC US Army Concepts Analysis Agency, 295-0390.

c. Work Schedule. See Inclosure 1.

d. Transfer of Model. To be accomplished after completion of the study.

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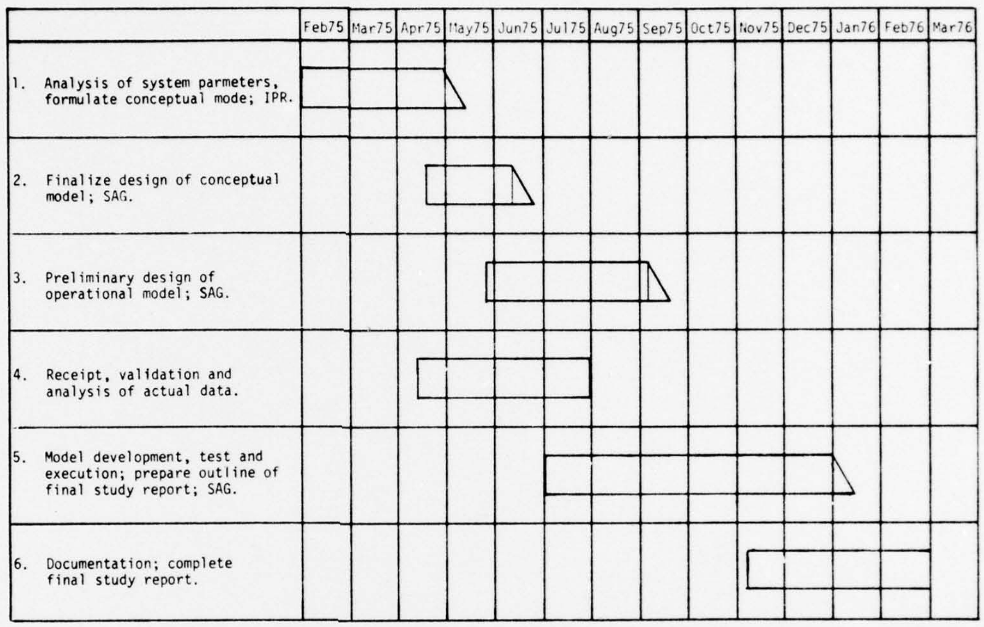
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1. Analysis of system parmeters, formulate conceptual mode; IPR.
2. Finalize design of conceptual model; SAG.
3. Preliminary design of operational model; SAG.
4. Receipt, validation and analysis of actual data.
5. Model development, test and execution; prepare outline of final study report; SAG.
6. Documentation; complete final study report.

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OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

SUMMARY

1. Background

a. Under the Army Officer Personnel Management System (OPMS) established in 1974, members of the officer corps are managed and assigned according to their primary and alternate specialties as well as by grade. Associated with each specialty pair are utilization criteria designed to balance the pattern of assignments between specialties--consistent with the requirements of the force structure. To realize the full potential of OPMS, new officer management techniques must maintain an officer's skills in each of his dual specialties and, concurrently, meet specific position requirements within the Army force structure.

b. A large number of possible specialty pairings result from the OPMS dual specialty concept. Additionally, time-varying force structure requirements, by grade and specialty, and the explicit utilization criteria combine to extend the dimensions and complexity of managing Army officer personnel.

c. The growing complexity of officer resource management signaled the need for decision-assisting tools to aid Army personnel managers. Specifically, a systematic approach was needed to determine how many officers should be designated in each possible pair of specialties. Consequently, the Office, Deputy Chief of Staff for Personnel (ODCSPER) requested the US Army Concepts Analysis Agency (CAA) to provide analytic support in studying the new officer dual specialty allocation concept under OPMS.

2. Purpose and Scope. - In the major support requirements outlined jointly by ODCSPER and CAA, the following study elements were considered.

a. Investigate and define the scope and structure of the problem posed by officer dual specialty allocation.

b. Explore and develop alternative methodological approaches to address the dual specialty assignment problem--with particular emphasis on future Army force requirements.

c. Specify a methodology and associated data requirements for development and application to the dual specialty assignment problem.

d. Formulate and implement an automated information system incorporating the specified methodology.

e. Provide a documented operational system to the US Army Military Personnel Center to be applied by ODCSPER analysts and managers in addressing key issues in dual specialty assignment.

3. Objectives. - CAA was tasked to conduct this study in two sequential phases:

a. To determine the feasibility of developing a methodology to analyze any given force structure and project an officer requirement by grade level, with a proper composition of primary and alternate OPMS specialties.

b. If a feasible methodology could be derived, to develop a computer-based model that would assist OPMS managers in satisfying Army officer personnel requirements.

4. Essential Elements of Analysis (EEA). - Examination of key personnel management issues and related problem variables led to definition of the following study EEA.

a. In any given year, based upon the requirements generated by a given force structure, can the number of officers to be allocated specific specialty pairings at each grade level not to exceed the utilization ratio limits be determined?

b. In any given year, based upon the requirements generated by a given force structure, can the total procurement of officers by basic entry specialty (BES) be determined?

c. In any given year, based upon the requirements generated by a given force structure, can the training requirements for basic entry and alternate specialties to support the force be determined?

(Response to each EEA is derivable from the study methodology. EEA responses are included later in this summary).

5. Methodology

a. Problem Analysis. - The series of assignments which an officer receives during his career form a complex path; assignments can alternate between the officer's specialties, the length of the assignments can vary, and the officer is subject to the influences of attrition and promotion policies which further affect his assignments. The number of assignments available to an officer is dependent upon his OPMS specialties, grade, and the requirements of the Army force structure. Force structure requirements can be satisfied in many different ways, creating, in effect, competition among officers for assignments. Considering the entire officer corps, a very large number of options can be postulated by which officers alternate assignments between specialties, either leave the service, become promoted, or remain in grade and still meet the requirements of the projected Army force structure.

b. Approaches - ODSAS Model

(1) The movement of officers along the multitude of paths defined by assignments against the time-phased force structure requirements is similar in nature to flows in the paths of a large network, e.g., communications or transportation. For example, the patterns of message channels in a communications network are analogous to paths followed by officers alternating between assignments in dual specialties. Further, communications channel capacity is analogous to force structure requirements--precautions must be taken to insure that message capacity is not exceeded, or correspondingly, that the number of required officers does not exceed authorized strengths.

(2) In view of the foregoing analogy drawn between officer flow and communications flow, it was reasoned that mathematical techniques applied to optimize transmission efficiencies in a communications network may be applied to the flow of officers within a time-varying force structure. Pursuit of this course of analysis led to the following approaches:

(a) The officer dual specialty allocation problem could be formulated as a network flow process.

(b) The network formulation yielded a mathematical representation of the OPMS dual specialty allocation problem which could be solved using advanced analytic techniques.

c. Solution Technique. - The solution of the officer network problem involved applying techniques for directing the flow of officers between specialties in order to observe how projected demands for dual qualified officers can be satisfied without exceeding total authorized strength. In the ODSAS methodology, the network solution technique is embodied in linear programing (LP)--a systematic, mathematical approach which facilitates solution of the conceptual network flow problem. Linear programing involves an objective function and a set of restrictions or constraints expressed as simultaneous linear equations. LP is suited to the dual specialty flow problem because force structure objectives direct and constrain officer flows. Significantly, LP was chosen over other network solution methods because, to answer the EEA, flows from any point within the network must be directed to specific subsequent points. Because of its capability to handle this necessary directional condition, LP is uniquely suited for ODSAS methodology.

d. Implementation - Operational Considerations

(1) In addition to the methodological considerations discussed above, other technical and managerial factors influenced the development effort, particularly with regard to implementation of the solution technique. Problem size--based on the number of mathematical equations in the linear programing formulation required to represent the officer network--is a key consideration in assessing resource requirements and operational procedures for solution. In this regard, ODSAS resources involve computer hardware and software facilities available at the US Army Military Personnel Center (MILPERCEN) where the automated system is to be operated. MILPERCEN employs UNIVAC 1108 large-scale, third generation computing systems.

(2) The UNIVAC Functional Mathematical Programing System (FMPS)--a mathematical software utility package operating on the Model 1108--is used to solve the network flow problems. Problem size associated with the dual specialty allocation for the officer corps entails automated LP processing requirements exceeding available computing capacity. This condition required problem segmentation by individual officer grade. The segmentation approach resulted in several smaller linear programing problems being solved rather than one prohibitively large one. Further segmentation (within grade) was established as a user option for operational convenience.

e. Application. - The ODSAS solution is driven by requirements associated with a force structure specified by the user. The methodology is employed to compute the optimum number of officers for allocation to specific OPMS specialty pairings--consistent with the specified force structure requirements. The system treats officer grades from Lieutenant through Colonel, inclusively, for annual time increments (up to 9 years). The solution for each officer grade is computed in sequence, starting with the grade of Colonel. Attrition and promotion rates are applied to represent quantitatively the changes in the composition of the officer corps expected to occur over time.

f. Solution Levels. - ODSAS is designed to address allocation of dual specialties at macro or aggregate levels. Application of ODSAS results in requirements for the total numbers of officers with specific dual specialties. The assignment of individual officers to dual specialties remains the function of Army officer personnel managers.

6. Automated Information System

a. The second objective of the study required that the ODSAS methodology be incorporated into a computer-based model. To achieve this objective, an automated information system was developed to implement the methodology and include data handling, computational and report generation facilities in support of officer personnel managers. Information system design criteria were established to take maximum advantage of ADP capability to perform rapidly and accurately the large number of computations required to solve the ODSAS network through linear programing techniques.

b. The system provides for solution data to be stored in readily accessible automated form. To enhance user utility and facilitate interpretation of results, a direct access (man-machine) information retrieval and display capability is incorporated as an integral part of the automated system. Operating at a terminal device connected to the MILPERCEN computing sytem, the ODSAS user can selectively retrieve, aggregate, re-sequence and display data in desired report format. This computer-assisted access and retrieval capability reduces the need for manual data extraction from voluminous hard copy printouts. This special feature is furnished to assist the user in selective analysis, interpretation and evaluation of solutions to problems encompassing thousands of variables.

c. In sum, the ODSAS automated information system is an organized collection of data files and handling routines, computational models and user-oriented access and retrieval facilities which work in concert to aid the personnel manager in the dual specialty allocation process.

7. Quality Assurance. - As indicated, the officer dual specialty allocation process posed an analytical problem of extensive size and technical complexity. Consequently, intensive critical reviews of methodology development, automated system implementation, data, and testing were conducted throughout the study. Summarized at Table 1 are major constituents of the overall quality assurance activities associated with the ODSAS Study.

TABLE 1, Quality Assurance

Study Activity	Solution Technique	Quality Assurance Contribution/Utility
Problem Analysis	Network Formulation	Provides highly structured descriptive means to illuminate and assess problem variables and interactions.
Solution Derivation	Linear Programing	Establishes rigorous, proven and mature solution method.
Automated Information System Development	Modular Architecture	Enhances design validity and operational flexibility by creation of five separate but interrelated processing modules: - Linear equation generation - Linear program solution - Data base creation - Data access and retrieval - Officer grade segment linkage.
Automated Information System Testing	Modular and Integrated Approaches	Insures system validity, reliability and accuracy through methodical testing procedures: - Single module testing with validated set of input data. - Integrated testing to confirm proper interaction among modules.
Data Analysis	Edit and Validation	Assures validity of data set for computation by use of: - Automatic edits/checks, error detection performed by the system on force structure requirements data. - Special printouts generated automatically for data sampling, audit, and historical files.
Validation	Base Case Testing	Establishes operational capability and output validity predicated on user-provided base case data.
Acceptance Testing	Sensitivity Testing	Enhances output validity, stability and user understanding of system responsiveness.

8. Essential Elements of Analysis (EEA) Response

a. EEA 1

(1) Element. - In any given year, based upon the requirements generated by a given force structure, can the number of officers to be allocated specific specialty pairings at each grade level not to exceed the utilization ratio limits be determined?

(2) Response. - The number of officers allocated to specialty pairings is obtained from the ODSAS solution values calculated for the grades of CPT through COL.

b. EEA 2

(1) Element. - In any given year, based upon the requirements generated by a given force structure, can the total procurement of officers by basic entry specialty (BES) be determined?

(2) Response. - The total procurement of officers by BES is obtained from the ODSAS solution for the LT grade.

c. EEA 3

(1) Element. - In any given year, based upon the requirements generated by a given force structure, can the training requirements for basic entry and alternate specialties to support the force be determined?

(2) Response. - The training requirements for BES and alternate specialties can be derived by comparing the actual officer asset position to the optimum position determined in the ODSAS solution.

9. Observations. - This study describes the ODSAS methodology, the automated information system, and results of testing the system. Based upon the work reported, the following observations are presented.

a. The ODSAS can be used as a viable planning tool by officer personnel managers at MILPERCEN and ODCSPER to evaluate the following:

(1) The optimum composition of the officer corps based upon perceived force structure requirements.

(2) Alternate officer personnel management policies prior to implementation.

(3) The impact of projected force structure changes.

b. The use of ODSAS provides information to assist officer personnel managers in determining the following:

(1) The number of officers, by grade, to be allocated specific specialty pairings (answers EEA 1).

(2) The total procurement of officers by basic entry specialty (answers EEA 2).

(3) The training requirements to support the optimum composition of the officer corps (answers EEA 3).

c. The solutions for allocation of dual specialties to officers are driven by whatever force structure requirements the user specifies.

d. The large size of the linear programing (LP) program was recognized early in the formulation of the ODSAS methodology. Any attempt to solve the LP problem without segmenting the processing would exceed the UNIVAC hardware and software capabilities at MILPERCEN.

(1) For a 5-year projection period, the LTC and MAJ segments approach the capacity of the UNIVAC computer and LP software.

(2) The ODSAS contains options to employ additional segmentation-within-grade. These procedures provide for processing the grades in two parts and mitigate the hardware and software limitations but impose burdens on the interpretation of the solution. Therefore, the additional segmentation-within-grade option is generally not preferred.

(3) Experience gained through operational testing with user supplied input data indicates that solution times are very long. The time required to obtain solutions of a grade segment ranges from 1 to 8 hours. Consequently, processing of all grade segments is likely to occur during non-prime time over a 1-week period.

e. The ODSAS solutions are sensitive to changes in the input data. The impact of input changes on the solutions is affected by the 4,000 to 6,000 constraints which act upon the LP problem for each grade segment. Therefore, it is difficult to predict the changes to the ODSAS solution resulting from changes in the input.

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

CHAPTER I
INTRODUCTION

1. Background

a. Officer Personnel Management. - Increasing manpower and materiel costs have made it imperative that the Army manage its personnel resources more efficiently. Within the officer corps, the Army adopted the Officer Personnel Management System (OPMS) in 1974, replacing the earlier "career branch" system under which the corps had been managed for many years. General Creighton W. Abrams, in referring to OPMS, wrote, ". . . This system will provide officers with the opportunity to develop the professional skills that the leaders of tomorrow's Army will need . . . " (reference 1). Under OPMS, each officer is assigned two specialties--a basic entry specialty (BES) and an alternate. The BES is designated when the officer enters on active duty, and normally constitutes the officer's primary skill/specialty throughout his Army career. After the eighth year of active federal commissioned service the second, or alternate, specialty is designated. This dual specialty concept is a fundamental element of the OPMS, and influences the personnel management function from procurement to separation.

b. OPMS Goals. - The OPMS will provide officers with defined specialties in which to concentrate and develop professionally. Goals of OPMS include improving the match between the officer's qualifications and the Army's requirements, and providing discrete career development patterns for individual officers in both the primary and alternate specialties. These goals can be obtained only with considerable management effort; management of the officer corps is now significantly more complex than under the career branch management system because the number of specialties (currently 46) represents more than a threefold increase from the 14 career branches. This increase, coupled with the possible specialty combinations an officer might have under OPMS, influenced a reorganization of the Officer Personnel Directorate (OPD) in May 1975. This reorganization not only segmented management by grade, but also established procedures for monitoring specialties across all grades.

c. Study Origin. - To insure that goals are realized, the OPMS must provide the correct composition of dual qualified officers to meet Army positional requirements. Officer personnel managers need a system, based on requirements, which provides information on a proper composition of the officer corps. Toward that end, the US Army Concepts Analysis Agency (CAA) was tasked by the Office, Deputy Chief of Staff for Personnel (ODCSPER) to determine the feasibility of developing such a requirements-driven system.

2. Purpose. - The purpose of this study was to explore methodologies to assist in the management of Army officer assets by OPMS specialty and grade; select a methodology; and then design and develop an automated information system incorporating that methodology.

3. Objectives

a. Sequential Objectives. - CAA was tasked to perform this study in two sequential phases:

(1) To determine the feasibility of developing a methodology to analyze any given force structure and project officer requirements, by grade level, with a proper composition of primary and alternate OPMS specialties.

(2) If a feasible methodology could be derived, to develop a computer-based model that would assist OPMS managers in satisfying Army officer personnel requirements.

b. Accomplishment of Objectives

(1) The series of assignments which an officer receives during his career forms a complex path; assignments can alternate between the officer's specialties, the length of assignments can vary and the officer is subject to the influences of attrition and promotion policies which further affect his assignments. The number of assignments available to an officer is dependent upon his OPMS specialties, grade, and the requirements of the Army force structure. Those force structure requirements can be satisfied many different ways, creating, in effect, competition among officers for assignments. Considering the entire officer corps, a very large number of options can be postulated by which officers alternate assignments between specialties, become promoted, remain in grade, or leave the service, and still meet the requirements of the projected Army force structure. The movement of officers along the multitude of possible paths through the projected force structure can be likened to the paths through a vast communications network. The patterns of the communication channels are analogous to paths followed by officers alternating between assignments in their dual specialties. The capacity of a communication channel is

analogous to a force structure requirement--precautions must be taken to insure that capacity is not exceeded (or that the number of available officers does not exceed requirements).

(2) Because of the analogy between officer flow and communication flow, it was reasoned that methodologies applied to optimize transmission efficiencies in a communication network may be applied to optimize the flow of officers within a force structure. The solution to this officer network problem involved applying techniques for directing the flow of officers between specialties in order to observe how projected demands for dual qualified officers can be satisfied without exceeding total authorized strength.

(3) Several alternative approaches for solving the officer dual specialty problem were investigated and evaluated. Techniques involving network flow algorithms, linear programing, and simulation were tested to determine if they yielded solutions which were requirements-driven reflecting promotion and attrition rates, variable tour lengths and utilization policies for the specialty pairs. In addition, the desired solution technique had to assist in the designation of alternate specialties for captains at their eighth year of service (YOS).

(4) Following the period of methodology research and evaluation, a network formulation utilizing linear programing (LP) was selected. Linear programing was the only technique that could represent the necessary control and direction of the flow throughout the network. A prototype model using the LP methodology was demonstrated to the satisfaction of the Study Advisory Group (SAG) in August 1975.

4. Scope. - This study entailed deriving an automated system to assist in managing the allocation of authorized Army commissioned officers controlled by OPD. Combinations of all 46 OPMS specialties are addressed except those dual specialty pairings judged mutually exclusive (listed in DA Pamphlet 600-3) or those for which the total Army requirement in all grades is five officers or less. The automated system was designed to address officer personnel requirements which may derive from tables of organization and equipment (TOE), Modification Table of Organization and Equipment (MTOE), and tables of distribution and allowances (TDA) normally found in any force structure.

5. Assumptions. - Four assumptions were used in formulation of the problem and solution technique.

a. Attrition/Promotion. - All officers within a given grade and year of service (YOS) population have an equal opportunity for promotion and are equally susceptible to attrition, without regard to their specialties; i.e., for a given grade, attrition and promotion are functions of the YOS distribution only. This implies that all YOS are represented proportionately in each specialty.

b. Applicability of Attrition/Promotion Rates. - Annual attrition and promotion rates (percentages) are used to "age" the population of a given grade across the time span being analyzed. In calculating the annual rates, the attrition and promotion rates for a YOS within a given grade are assumed to be valid for any population which attains that grade and YOS. For example, if an attrition rate of 20 percent per year applies for COLs with 22 YOS in the first year, that rate also applies 3 years later for COLs who attain 22 YOS.

c. Assignment Policy. - The population serving in a given specialty is assumed to be uniformly distributed according to the length of time served in the specialty; i.e., if the normal assignment period is 3 years, one-third of the population will complete the assignment in the first year, one-third in the second year, and one-third in the third year.

d. Real Versus Integer-Valued Variables. - The numbers of officers can be approximated within acceptable limits by an algorithm which computes real numbered values.

6. Essential Elements of Analysis (EEA). - The essential elements of analysis, as included in the study directive, are as follows:

a. In any given year, based upon the requirements generated by a given force structure, can the number of officers to be allocated specific specialty pairings at each grade level not to exceed the utilization ratio limits be determined?

b. In any given year, based upon the requirements generated by a given force structure, can the total procurement of officers by basic entry specialty be determined?

c. In any given year, based upon the requirements generated by a given force structure, can the training requirements for basic entry and alternate specialties to support the force be determined?

7. Contents of the Report. - The remainder of this report presents a detailed explanation of the Officer Dual Specialty Allocation System (ODSAS), its functioning, and use. A discussion of the methodology and the rationale underlying the development and structuring

of that methodology is presented in Chapter II. In Chapters III, IV, and V, respectively, the automated information system is described, the interpretation of ODSAS solutions is explained, and sensitivity analyses are discussed. Certain unique aspects that merit additional explanation, such as continuation and designation of alternate specialties for company grade officers, are set forth in appendixes.

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

CHAPTER II
SYSTEM METHODOLOGY

1. Development of the Methodology

a. General. To determine the allocation of officers to various OPMS specialties, a methodology was selected for the ODSAS involving the application of a linear programing (LP) solution technique to a conceptual network flow problem. For reader convenience a brief summary of the key network and LP terms is provided in subparagraphs (1) through (4) below.

(1) A simplified network is illuatrated at Figure II-1. In this network there are three sources of a commodity denoted S_1, S_2, and S_3 with three destinations D_1, D_2, and D_3. (Both sources and destinations are called nodes.) The quantities of the commodity available at S_1, S_2, and S_3 are 10, 20, and 20, respectively, while 30 are required at D_1, 10 and D_2, and 10 at D_3. The lines connecting sources and destinations are the only permitted flows (these lines are called arcs). In this example, S_1 can only supply D_1, S_2 can supply either D_2 or D_3, and S_3 can accommodate any destination. The optimum flow in the example is shown by double lines with the amount shipped shown by the number above the line--no other flow can meet the requirements.

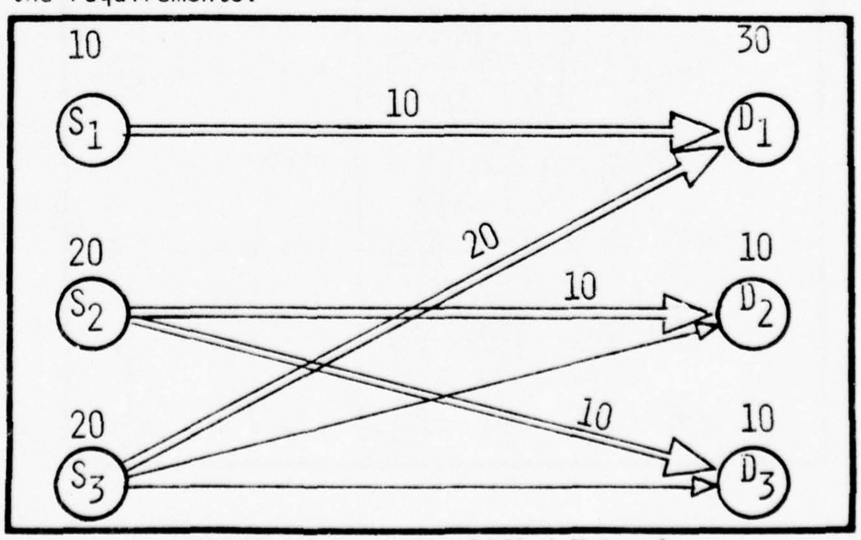

FIGURE II-1, A Simplified Network

(2) The preceding example can be expanded to include intermediate destinations and different types of commodities. The ODSAS network is such an expansion. In ODSAS, intermediate destinations are created representing OPMS specialty requirements over time. Figure II-2 shows a network constructed to represent a span of time. In the figure T_0 is a base year, T_1 is 1 year later, and T_N is some arbitrary year N years in the future. The OPMS specialty numbers are shown in the nodes and the permissible flows are shown by the lines or arcs connecting the nodes. Node requirements exist, but are not shown. For example, the requirements of specialty 14 at T_1 would represent the requirement for officers to be serving in specialty 14, 1 year from T_0. In ODSAS, officers are the commodities; they can represent multiple types of commodities because officers can have dual specialties. The dual specialties add a complication to the network because an officer with dual specialties 11 and 49 can be applied to fill a specialty 49 requirement and thus move along an arc from 11 to 49; an officer with specialties 11 and 97 cannot fill a specialty 49 requirement. The ODSAS methodology (linear programing applied to a network flow problem) is designed to find the number of officers, by specialty pair, which represents the maximum flow of officers through the network.

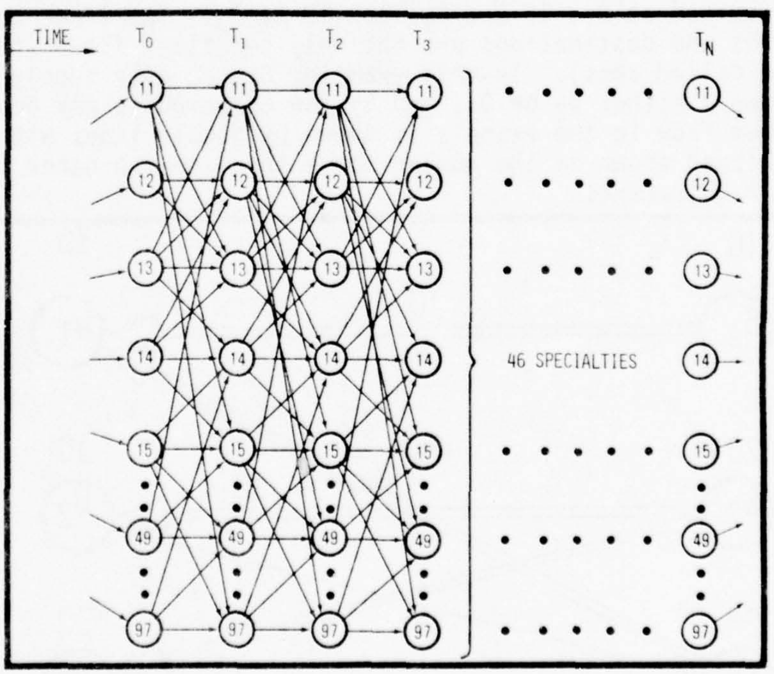

FIGURE II-2, Multi-time Period Network

(3) Linear programing* is a mathematical technique wherein one linear equation (called an objective function) is maximized (or minimized) subject to a set of linear functions (called rows or constraints) which constrain the range of values for the objective function. An LP problem with m rows and n variables is typically written in the following manner:

Objective Function:

$$\text{Maximize or minimize} \quad \sum_{j=1}^{n} c_j X_j = Z$$

Subject to the following constraints:

$$\sum_{j=1}^{n} a_{ij} X_j \begin{matrix} \leq \\ = \\ \geq \end{matrix} b_i \qquad i = 1, 2, \ldots m$$

$$X_j \geq 0 \qquad j = 1, 2, \ldots n$$

where c_j, a_{ij}, and b_i are coefficients and X_j and Z are variables.

The rows are of two types: an objective function and constraints. Both types contain variables (e.g., X_1, X_2) with coefficients (e.g., c_j, b_i, a_{ij}). The variables in ODSAS are comprised of the flow in each arc. The constraint rows have a constant on the right side which represents a limitation on the variables (e.g., $X_1 + X_2 = 10$). The objective function has a unique variable ("Z" is commonly used) on the right side of the equation (e.g., $2X_1 + X_2 = Z$). In solving the linear program, the solution must optimize the value of "Z". In the ODSAS methodology, the objective function was maximized subject to constraints representing the node capacities, and necessary controls on the movement of flows within the network.

(4) Thus, through the LP technique, the ODSAS methodology will find the maximum flow in the network, while satisfying a user-defined force structure.

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*For a detailed explanation of linear programing, see standard texts such as Gass, <u>Linear Programing</u> (see Appendix B, Additional References).

b. Considerations in Selecting the Network Flow Algorithm. - To answer the EEA it was necessary to determine how many dual qualified officers are needed to meet projected annual requirements for up to N years into the future. Several network flow algorithms were investigated for suitability as solution techniques. The governing factor in selecting a LP solution technique rather than alternative network flow algorithms (i.e., trans-shipment, or maximum flow) was that flows from any point within the network had to be directed because of dual specialty requirements. That direction was determined by the arcs along which the flows had traveled before reaching those points. In other words, since officers in a dual specialty pair could only alternate between the two specialties, directing the flow representing the pair out of a node required knowledge of the constraints on both specialties. For example, officers with specialties 11 and 49 would rotate between assignments in 11 and assignments in 49. No other possibilities exist for officers with this specialty pairing. Upon leaving specialty 49, officers with specialties 11 and 49 return to specialty 11, whereas officers with specialties 12 and 49 return to specialty 12. The only technique examined that could meet these requirements involved linear programing.

c. Problem Size Considerations. - While LP was a feasible approach, problem size required special consideration. With 46 specialties, six grades (second lieutenant (2LT) through colonel (COL)), and a time span of up to 9 years to consider, an LP formulation exceeded the capacity of the Functional Mathematical Programing System (FMPS) (reference 2) LP package*. The FMPS has a stated capacity of 8,162 rows but the problem, as described thus far, exceeds this size limitation. In addition, there was no certainty of the computer's ability to handle problems at or near the FMPS stated capacity. In this respect, the ability to solve the LP formulation was problem-dependent and therefore not totally predictable.

d. Problem Segmentation. - For the above reasons, the problem was segmented into logical components, first by grade, and then within grade by subgroups of specialties. Segmentation in this manner reduced the problem to smaller, more reasonable levels (paragraph 2, below) and improved the quality assurance of the model. An important MILPERCEN policy decision that significantly reduced the size of the problem required personnel planners to specify preferred specialty pairings (thereby excluding all

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*FMPS is the LP package used at the US Army Military Personnel Center (MILPERCEN) on the UNIVAC 1108 computers on which the ODSAS Model must run.

unspecified pairings from ODSAS). This policy decreased the total number of possible permutations, and reduced the number of constraints needed to control specialty pairs. The mathematical solution of the LP then more closely conformed to the planner's guidance on logical (or preferred) pairings.

e. Modifications to General Form of the Network. - To determine how to meet the Army's officer personnel requirements, the simple network described thus far and illustrated in Figure II- was modified. That modification is shown in Figure II-3. At the far left, an interval from T_0' to T_0 has been added. The flow in the arcs in this leftmost interval represents numbers of officers with two specialties (identified by the node numbers at both ends of the arc) who enter the solution at the true beginning of the system--T_0'. The model solution for the flow associated with the arcs in the T_0' to T_0 interval represents the number of officers that should be allocated to the specialty pairs at T_0. Figure III-3 illustrates this important concept. For instance, the flow in the arc connecting node 11 at T_0' and node 15 at T_0 is the number of officers of a particular grade who should have a primary specialty 11 and alternate specialty 15 at T_0.

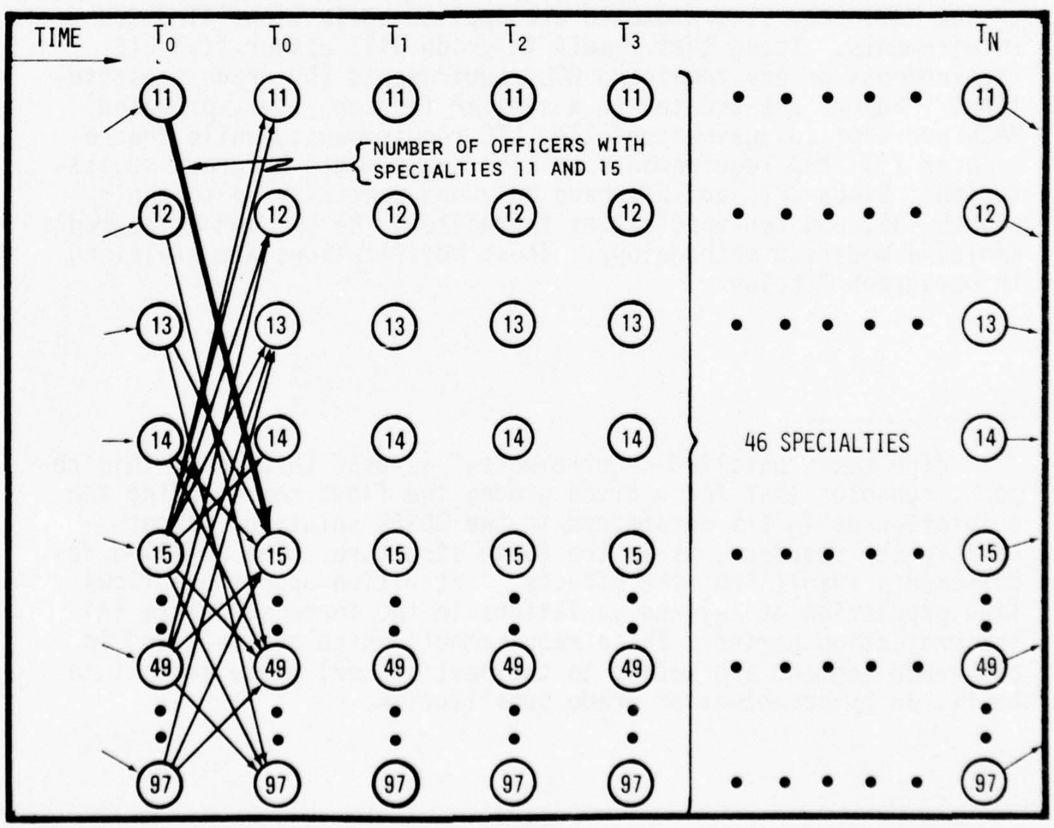

FIGURE II-3, Multi-time Period Network with T_0' Interval Added

f. Sequential Processing of System Segments. - As shown at Figure II-4, ODSAS considers the allocation of officers, defined by grade and YOS, to the authorized OPMS specialties. Each officer grade is a segment of ODSAS. The system considers all officer grades in sequence starting with colonel (COL), followed by lieutenant colonel (LTC), major (MAJ), captain (CPT), and lieutenant (LT). First lieutenants (1LT) and second lieutenants (2LT) comprise a single segment for purposes of this system. No two segments are completely alike; however, all segments do assume officers as being distributed according to number of YOS. Attrition and promotion rate data (furnished by the user) for each YOS and grade are used to compute weighted average promotion and attrition rates needed as input to the system. These averages are computed for each year in the projection period and reflect the aging of the officer population (Appendix D). During processing of the COL segment, the number of COLs required to have particular specialties will be computed for that grade; the number of COLs that will leave the network via attrition or promotion will also be computed. Promotions to COL are computed in the LTC segment. If there are any unfilled COL requirements* after the COL segment is processed by ODSAS, these requirements are passed to the LTC segment. Annually, starting at T_0, LTCs can either be promoted to COL or remain in grade; in either event, they will be attrited as a function of the YOS. Any LTCs promoted are applied against unfilled COL requirements. Those that remain in grade will either fill LTC requirements or any remaining COL requirements (by grade substitution). Majors are treated in a similar fashion, i.e., promoted MAJs are applied against unfilled LTC requirements, while the remainder fill MAJ requirements or LTC requirements by grade substitution. Since CPTs and LTs have only one specialty up to their eighth YOS, and two specialties thereafter, the CPT and LT segments employ a modified methodology. These modifications are explained in paragraph 3 below.

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*The term "unfilled requirements," as used throughout this report, connotes that for a given grade, the flows representing the population at T_0 (as determined in the ODSAS solution) cannot satisfy the requirements in the force structure. The unfilled requirements result from the effects of attrition upon those flows (the population at T_0) and variations in the force structure in the projection period. Those requirements which are unfilled in one grade segment are passed to the next (lower) grade segment to be filled by promotees or grade substitution.

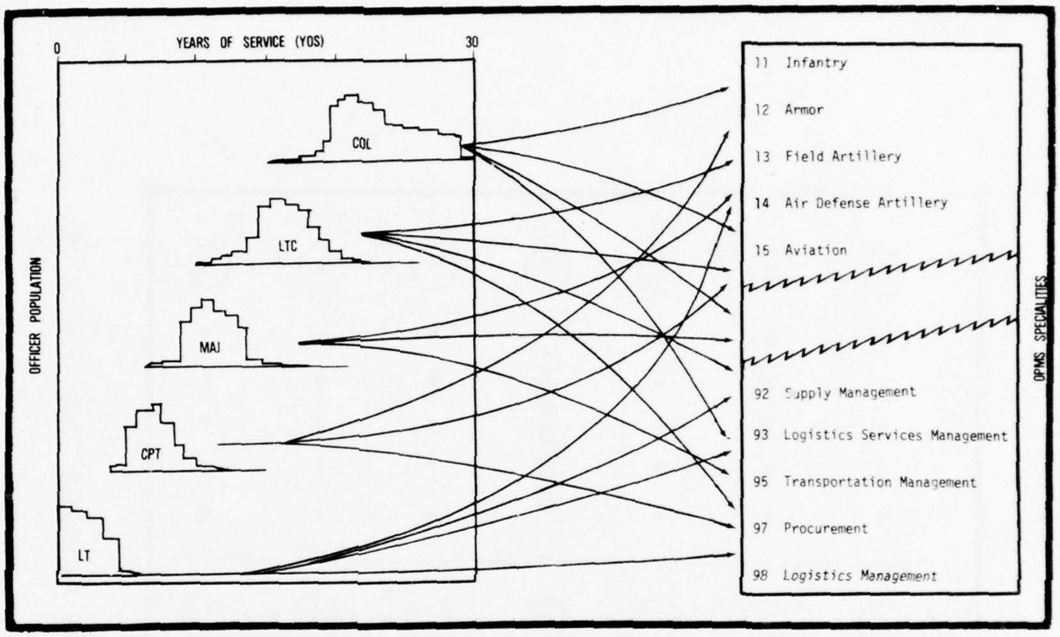

FIGURE II-4, Overview of Officer Representation in ODSAS

g. Required Input Data. - The methodology requires quantitative input reflecting management policy on utilization ratios (ratios of the number of tours in the primary specialty to the number in the alternate specialty) and length of tours for each preferred specialty pair. In addition, attrition rates (stated as percent of officers in a particular grade and YOS) for a reference population and the number within the population (by grade and YOS) must be specified by the user. The YOS distribution of the current officers on active duty and the attrition rates that would apply to them would normally be used as the reference population to derive the promotion and attrition rates used in ODSAS; however, the current officers on active duty do not have to be used as the reference population. Some other reference population and rates may be used as input.

h. Linear Programing Problem Formulation. - The LP problem for each segment is formulated as a multitude of paths (a series of arcs connected at the nodes which depict assignments for specialty pairs) starting at T_0 and proceeding through the network according to the utilization ratios and tour lengths specified. At Figure II-5 are examples of two of the many possible paths. The paths are determined by the utilization ratios, and the tour lengths

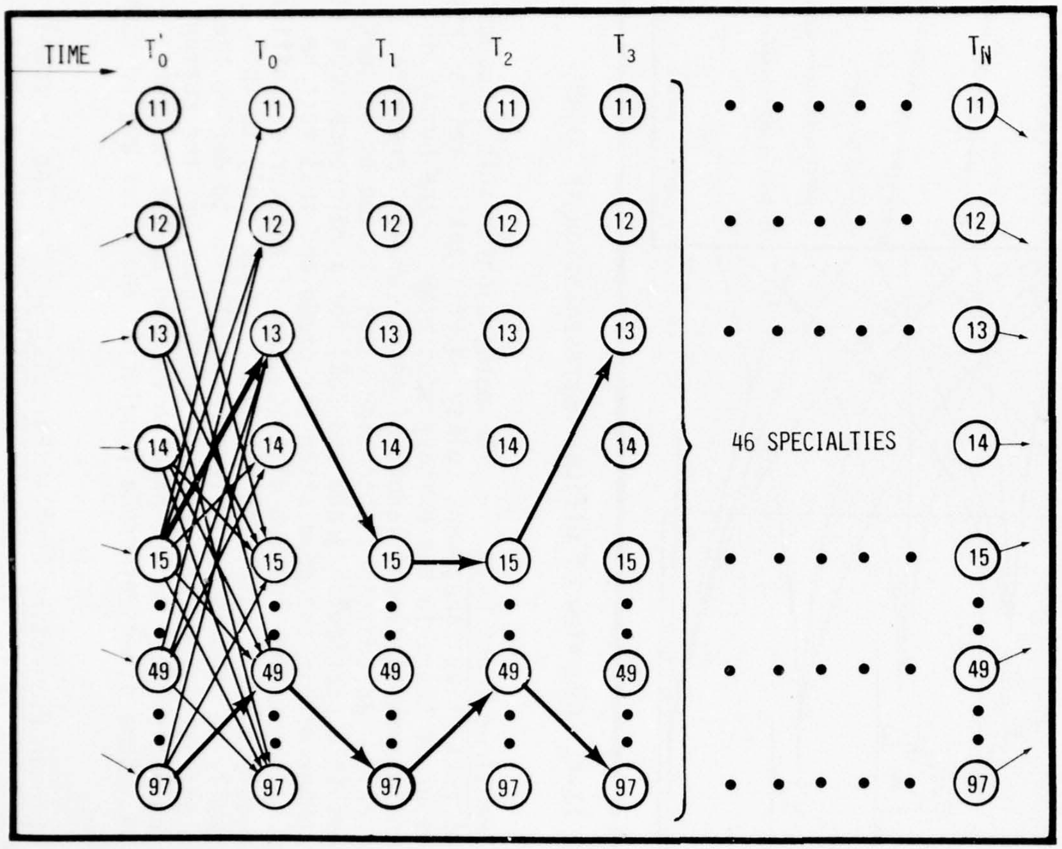

FIGURE II-5, Examples of Possible Paths for Specialty Pairs of the specialty pairs. For instance, the path beginning at node 15 at T_0 in Figure II-5 is constructed using a 1:1 ratio with a 2-year tour length in each specialty. The tour in specialty 15 begins with node number 13 at T_0 and is completed 2 years later at T_2 (node number 15 at T_2). At T_2, the arc connecting node 15 to node 13 at T_3 represents the first of 2 years in a specialty 13 assignment. The path would continue in this assignment pattern to T_N. The lower path (specialty pair 49/97) illustrates a 1:1 ratio with 1-year tour lengths in each specialty. First assignment begins with node 49, at T_0, is completed at node 97, at T_1, followed by another 1-year assignment in specialty 49 and continuing in this pattern to T_N. A refinement, not shown, is the capability to phase the assignment of officers such that some are assigned to their primary specialty and others are assigned to their alternate at T_0; others are assigned at T_1, or T_2, and so on. The paths delineate ways that the preferred specialty pairings would traverse the network. For a given specialty pair, the path of officers promoted may differ from the path for those remaining in grade. Such differences would reflect alternative utilization ratios and/or tour lengths for the higher grade.

i. Types of Constraints. - The algorithm considers all allowable paths through the network and, subject to constraints, determines how many officers can move along each path. The five types of constraints are:

(1) Flow conservation

(2) Node capacities

(3) Control of flows for dual specialties

(4) Control of input to the network

(5) Key arc relationships

These five types of constraints are explained in detail in subparagraphs k through o, below, respectively.

j. Name Convention for Variables. - A naming convention was devised so that the variables in the constraints used in each grade segment could be uniquely identified with arcs and have an intrinsic meaning. That naming convention for the variables consists of four fields, one alphabetic followed by three numeric subscripts, i.e., the general form is A_{yfg}. Each term is explained as follows:

A	y	f	g
Alphabetic identifier	Year coming from	Specialty number coming from	Specialty number going to

where A = W - identifier for arcs in the T_0' to T_0 interval only

X - identifier for officers remaining in grade

Y - identifier for officers promoted to higher grade

y = 0 - 9

f = 01 - 99*

g = 01 - 99*

For example, an arc connecting the specialty 25 node at T_0, and the specialty 36 node at T_1, for a LTC in the LTC segment, would be X_{02536}; for a LTC promoted to COL in the same segment and year, and the same "from" and "to" nodes as the previous example, the arc would be Y_{02536}.

k. Flow Conservation Constraints. - This constraint specifies that all flow entering a node must leave that node.

(1) The general form of the flow conservation constraint upon each node is:

(Node Input - Node Output) = 0

For each node, a, in year k, node input consists of all officers newly assigned from all other specialties to specialty a at year k-1, plus those remaining in specialty a at year k-1, and who will remain in that assignment at least until the following year (k).

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*Includes only the currently authorized OPMS specialty numbers (see Appendix F).

Output consists of all officers in specialty a reassigned from specialty a to another specialty at year k as well as those who remain in specialty a in year k.

(2) This type constraint for specialty a, in year k, is

$$(\gamma_1 \times \sum_{f=\alpha}^{\omega} X_{(k-1)fa}) + (\gamma_2 \times \sum_{f=\alpha}^{\omega} Y_{(k-1)fa}) - \sum_{g=\alpha}^{\omega} (X_{kag} + Y_{kag}) = 0$$

where γ_1 and γ_2 are the survival factors (1.0 - attrition rate) that are applied to the nonpromoted and promoted populations, respectively. The survival factors are derived from input data and vary with time since the assumed starting population distribution ages. The terms in the summation, (α and ω) are, respectively, the first and last members in the set of preferences of the primary specialty. For example, all officers with specialty 15 as one of the specialty pair, e.g., 41/15 or 15/41, who were assigned to specialty 15 at year T_1 and who have not been attrited by year T_2, must be reassigned at T_2 to their alternate specialty. Substituting this example into the flow conservation equation above yields the following:

$$(\gamma_1 \times \sum_{f=\alpha}^{\omega} X_{1f15}) + (\gamma_2 \times \sum_{f=\alpha}^{\omega} Y_{1f15}) - \sum_{g=\alpha}^{\omega} (X_{215g} + Y_{215g}) = 0$$

1. Node Capacity Constraints. - The flow conservation constraints require equality of node input and output, whereas the node capacity constraints place limits on the amount of input. The node capacities are the requirements for specialties by grade and year. A node's capabitics are represented in two constraints. One constraint restricts the arcs representing the number of officers promoted to a higher grade (Y arcs) to no more than the unfilled higher grade requirements (computed from the solution to the previous segment, if any). The other constraint limits the sum of the arcs representing the number of officers promoted plus those remaining in grade (Y + X arcs) to the sum of the unfilled higher grade requirements, if any, plus the requirements for the grade of that segment. The constraints for any specialty, a, are expressed mathematically as follows:

$$\sum_{f=\alpha}^{\omega} Y_{yfa} \leq C_{ta}$$

where C_{ta} equals the unfilled requirements for specialty a of the next higher grade at year $t = y+1$; α and ω are, respectively, the first and last members in the set of preferences of the primary specialty. The constraints on Y + X arcs are given as follows:

$$\sum_{f=\alpha}^{\omega} Y_{yfa} + \sum_{f=\alpha}^{\omega} X_{yfa} \leq C_{ta} + C'_{ta}$$

where C_{ta} is as defined above, and C'_{ta} is equal to the requirements for the segment grade at year $t = y+1$, in specialty a.

For instance, the Y arc constraint limits the number of officers who will be promoted to the unfilled requirements of the higher grade. Should the flows in the Y arcs not be sufficient to satisfy all the unfilled higher grade requirements, the Y + X arc constraint provides that flows in the X arcs can satisfy the remaining unfilled higher grade requirements. Those flows in the X arcs that satisfy the remaining unfilled higher grade requirements are an example of filling positions by grade substitution. The remaining flows in the X arcs are used to satisfy the requirements for the segment grade; if the X arc flows do not fulfill all segment requirements, the remaining requirements are passed to the next lower segment.

m. Flow Control Constraints

(1) These constraints restrict the flow in an arc to flows representing officers with both specialties of the "from" and "to" specialty numbers in the arc name. For example, at year y, officers with specialties 37 and 49 can only be represented by the flow in arcs named X_{y3749}, X_{y4937}, X_{y3737}, or X_{y4949}.* By the methodology of this study, the flow in an arc is dependent on the flow in antecedent arcs along the paths of the specialty pair. The mathematical notation for an X arc flow control constraint for specialty pair d/e is:

$$X_{yde} = f(X_{rde}, X_{red})$$

where r is some year before y. The flow control constraint for a Y arc with the same specialty pair is:

$$Y_{yde} = f(X_{sde}, X_{sed}, Y_{rde}, Y_{red})$$

---

*The latter two arcs (i.e., X_{y3737} and X_{y4949}) represent officers who remain in one specialty for consecutive tours.

In this latter equation the X terms refer to those officers assigned at year s = y-1 and promoted at year y, and the Y terms refer to those promoted before year y.

(2) Figure II-6 illustrates the flow control imposed upon an X arc. In this illustration, X_{32536} (the flow leaving specialty 25 at T_3 and going to specialty 36) is a function of X_{22525} and X_{23625}. These latter two arcs are, in turn, functions of arcs in the T_1 to T_2 interval.

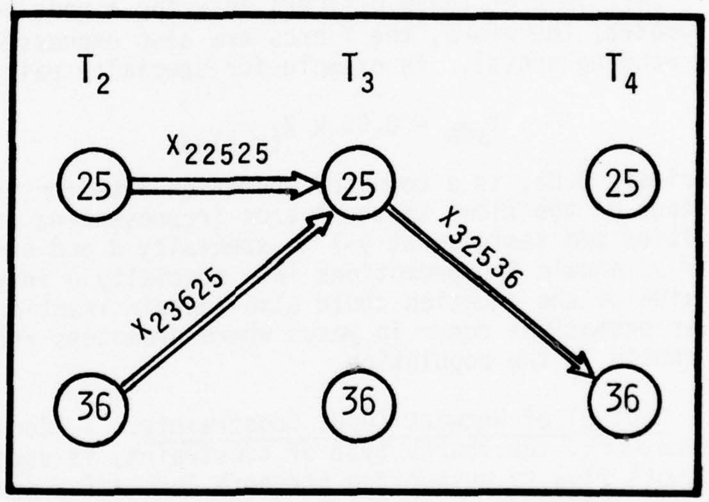

FIGURE II-6, Illustration of Flow Control Constraint

(3) The assignment of officers to an alternate specialty at T_0 can reflect the condition that all officers do not complete an assignment at the same time; some fraction of officers is reassigned at T_0, some at T_1, etc., depending on how long officers would normally remain in a given specialty. The fractions are determined by the utilization ratios and tour lengths. For instance, for a specialty with an associated ratio calling for a tour that is 2 years long, one-half of the officers leave the specialty at T_0 and the remainder at T_1. In this example, the

equations for the flow control constraints for a d/e specialty pair would be:

$X_{0de} = 0.5 \times W_{0ed}$ (half of flow in W arc (from specialty e to d) is reassigned at T_0 from specialty d to e)

$X_{0dd} = 0.5 \times W_{0ed}$ (remaining half of flow in W arc continues in specialty d)

(4) Some of those officers entering a node would get promoted; therefore, the Y arcs are also expressed as a function of a preceding arc(s). An example for specialty pair d/e would be:

$$Y_{yde} = 0.05 \times X_{(y-1)ed}$$

The decimal, 0.05, is a computed promotion rate for year y. That percentage of the flows in the X arcs (representing officers with specialties e/d assigned at y-1 to specialty d and surviving at year y, equals the promotions into specialty e in year y. The right side of the equation could also contain fractions of Y arcs whenever promotions occur in years where promotees from previous years remain in the population.

n. Control of Network Input Constraints. - Control of input to the network, the fourth type of constraint, is used to limit the network flow to authorized strength levels (as specified by the user). These strength levels are the total authorized strengths by grade, and the total authorized strengths for selected specialties within grade.* These constraints are of two forms:

(1) For total authorized strengths by grade:

$$\sum_{f=\alpha}^{\omega} \sum_{g=\alpha}^{\omega} W_{0fg} \leq C_{AUTH}$$

---

*The selected specialties are only those that relate specifically to branch, e.g., specialty 11 is Infantry Branch, specialty 13 is Field Artillery Branch. There are other specialties, such as 49 Operations Research/Systems Analysis (OR/SA), which are not branch related.

Where the double summation of the W arcs (which represent all officers in a grade at T_0) must be equal to or less than the authorized strength level, C_{AUTH}.

(2) For total authorized strength for selected specialties within grade (e.g., specialty 15):

$$\sum_{g=\alpha}^{\omega} W_{015g} + \sum_{f=\alpha}^{\omega} W_{0f15} \leq C'_{AUTH}$$

where the left most summation of W arc flows represents officers with specialty 15 as their primary and the second summation of the W arc flows represents officers with specialty 15 as their alternate. Together, the two summations of the W arc flows equal the number of officers with specialty 15 at T_0. That sum must be equal to or less than the authorized strength for the selected specialties within that grade, C'_{AUTH}.

o. Key Arc Relationships Constraints. - The last type of constraint, key arc relationships, is used to relate the flow in one W arc to that in another W arc. Specifically, these constraints relate the flows in the two W arcs representing officers with particular specialty pairs (i.e., the flows in W_{01235} and W_{03512} both represent officers with specialties 12 and 35). The utilization ratio is used to relate the two flows. For instance, if the utilization ratio of specialty pair 12/35 were 1:2, then that implies that those officers will serve one tour in specialty 12 to two tours in specialty 35; furthermore, for each year in the projection period, the ratio implies that there should be twice as many 12/35 officers serving in 35 as there are 12/35 officers serving in specialty 12. The key arc relationship constraints specify this type of relationship for each preferred specialty pair at T_0 (if this relationship is established at T_0 the flow control constraints will insure that the relationship will hold throughout the projection period). The mathematical notation of the key arc relationship for any specialty pair a/b with a utilization ratio of $r_1:r_2$ is:

$$(r_1 \times W_{0ab}) - (r_2 \times W_{0ba}) = 0$$

The following equation illustrates the application of this type constraint for specialty pair 12/35 with a utilization ratio of 1:2:

$$(1 \times W_{01235}) - (2 \times W_{03512}) = 0$$

Actually, a modification of this relationship is implemented in the methodology. Rather than specify that the left side of the equation be equal to zero, the constraint is defined as less than or equal, and the coefficient on the right side is not zero, but a positive number derived from the requirements for both specialties. As presently implemented, the right hand side coefficient is 5 percent of the arithmetic average of the requirements for the two specialties at T_0. The basic concept is to provide a tolerance for the difference in the two flows to allow for force structure variation. Through the use of an LP procedure (called ranging on a constraint), the right side coefficient is doubled, and that amount subtracted from the original coefficient value becomes a lower limit for the tolerance. For example, using specialty pair 12/35 again, with a utilization ratio of 1:2, and the T_0 requirements for specialties 12 and 35 are 122 and 102 officers, respectively, then the following constraint would apply:

$$(1 \times W_{01235} - (2 \times W_{03512}) \leq 0.05 \times \frac{(122+102)}{2}$$

or

$$(1 \times W_{01235}) - (2 \times W_{03512}) \leq 5.85$$

with the range specifying, in effect, that the left side be greater than or equal to 5.85 - (2 x 5.85) or -5.85.

p. Solution Technique. - Once the constraints are established the LP algorithm is used to compute a maximum value for the flow in each possible path in the network. The algorithm considers all the possible alternatives to satisfy each node capacity (i.e., requirements for a specialty) while not exceeding the capacities of subsequent nodes along the path. Thus, the allocation of officers to the specialty pairs is requirements-driven because all specialty requirements within the projection period are considered. Referring back to Figure II-5, the sum of the flows in the arcs at the far right side of the network (those exiting the nodes at T_N) is the objective function to be maximized. The value of the objective function does not directly answer any of the EEA; the function is a mechanism by which the maximum flow through the network is determined. The answers to the question, "How many officers do we need to meet the Army's requirements?" are found in the values of the path segments (arcs). The determination of these answers, as well as answers to the other EEA-related questions, are explained in Chapter IV, Interpretation of Solution.

2. System Segmentation

a. General. - As originally conceived, ODSAS was to consider all permutations of specialties in six grades (2LT through COL) for 9 years. Simple calculations indicated that the number of constraints would easily exceed 100,000 (46 specialties x 45 theoretically possible alternate specialty designations x 9 years x 6 grades = 111,780 constraints). If the flow conservation and node capacity constraints were included, another thousand constraints would be added. Presently available computer hardware and software cannot handle a problem of such a size and this computational limitation logically led to segmenting the problem. Another consideration was the implicit constraint that computer run time increases as the number of rows, or equations, increases; the computer run time increases exponentially with problem size.* Thus, run time became another important consideration in the decision to segment the problem.

b. Problem Size Reduction. - With the objectives of reducing computer run time and defining a feasible range of problem parameters, several approaches were explored. Procedures for modifying the parameters which contribute to the problem size were developed. These procedures included modifying the number of grades, years, specialties and specialty permutations to be evaluated.

(1) The LP problem was initially segmented by grade; that is, only one grade was run at a time. That grade segment considered all the officers of that grade at T_0 and their subsequent utilization in the projection period, whether they were promoted to the next higher grade or remained in grade. Unfilled requirements were passed down to the next lower grade to be filled by promotees or by grade substitution during processing of the next grade segment.

(2) A 5-6 year projection could be used instead of the 9-year projection in order to further limit the size of the problem. A 5-6 year planning cycle was deemed acceptable and conveniently corresponded with other Department of the Army (DA) staff planning cycles. This decrease in projection time lowered the maximum size of the original LP problem and therefore reduced the degree of segmentation which would be required.

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*While software with more than twice the row capacity of UNIVAC's FMPS exists, this alternate package (IBM's Mathematical Programing System-Extended (MPS-X), which has a stated capacity of 16,374 constraints, is most efficient when solving problems of less than 8,000 rows. The MPS-X is slower than FMPS in terms of computer run times needed to solve large problems. The UNIVAC possesses several specialized routines within its FMPS package that provide accelerated solution times (e.g., SPRINT).

(3) The concept of logical preferences for specialty pairings was also introduced to further reduce the problem size. Logical preferences limit the theoretically possible alternate specialty designations to those which should be considered in the solution, e.g., if specialty 49, OR/SA, had historically been chosen by many artillery officers, then 49 would be a logical preference, whereas if artillery (specialty 13) officers had never wanted specialty 82, Food Management, then the combination 13/82, might be excluded from the solution set.

(4) Finally, the LP problem was reduced through provisions for segmenting within a grade. That is, solutions could be sequentially derived for two subsets of specialties. The first subset could include the combat arms specialties and combat arms-related specialties, and the second subset would consider the rest of the specialties. A solution could be obtained in the first subset for preferred pairings of only the specialties specified for that subset. The specialty pairings specified in the first subset would then be excluded when processing the second subset. In effect, such segmentation divided the preferences into two groups to allow processing of smaller LP problems. When segmenting within a grade, the user may specify additional constraints on the solution. These additional constraints specify upper limits on the amount of a specialty's requirements that can be satisfied in the first subset. Without this constraint, a subset 2 specialty's requirements (e.g., specialty 49) could be filled entirely by officers with primary specialties included in the first subset, and therefore, no officers with primary specialties in the second subset could have specialty 49 as a primary or an alternate. Thus the optional constraint capability can preclude totally filling a specialty's requirements in the first subset. No additional constraints are required since segmentation within a grade is a modification which uses the constraints previously described. The second subset requires no additional constraints and considers only those specialties not specified in the first subset.

c. Segmentation Options for the User. - Segmentation-within-grade is an optional procedure for the COL, LTC, and MAJ segments. Utilization of the segmentation procedure depends upon individual problem size; problem size is a function of the officer grade being evaluated, the number of years and specialties being considered, and the number of preferred pairings. If the problem segment would exceed the stated or actual capacity of FMPS, or too much computer time would be required, then segmentation-within-grade would be required in order to reduce problem size and computer run time.

d. Problem Size Estimation. - At Appendix E a procedure is presented for estimating a problem's size from known parameters. This estimating procedure is used to determine whether the optional segmentation discussed above is required. In addition, the procedure assists in evaluating the impact of certain parameter values, such as the number of years being played, on the time needed to solve the LP problem.

3. Description of Segments by Grade

a. General. - As mentioned in the methodology description (paragraph 1i), there are five types of constraints that can be used to define and limit the problem being addressed (flow conservation, node capacities, flow control, control of input and key arc relationships). Each grade segment considers the same time span, number of specialties and preferred specialty pairings. However, the logic used within each segment employs the different constraint types selectively. The control of input and flow conservation constraints are common to all grade segments, and the key arc relationship constraints apply in all but the LT segment (paragraph 3e(1)(a)). However, there is some variation introduced when segmenting a field grade into two subsets. Without segmenting a grade into two subsets of specialties, there is one flow conservation constraint per node, constraints for total authorized strength by grade and selected specialties within grade, and one key arc relationship constraint for each preferred specialty pair. By selecting segmentation-within-grade, the preferences and specialties are divided into two groups for processing separately. That separation causes the control of input and key arc relationships to be applied to two LP problems, and flow conservation constraints are imposed for only those specialties (nodes) represented in each subsegment. The application of the other constraint types (node capacity and flow control) varies with the logic of the grade segments and is explained in subparagraphs b through e below.

b. Colonel Segment. - The primary difference between the COLs segment and other field grade segments is that promotion to the next higher grade is not explicitly considered; rather, it is considered along with normal attrition as a loss from the grade of COL. This is because utilization of general officers is not within the scope of ODSAS. In other words, a COL promoted to general officer, or retired, would no longer fill a COL requirement. This implies two unique facets of the logic used in this segment: only the X arcs (representing COLs on active duty) need to be considered and controlled; and, the nodes have only one capacity--COL requirements. Thus, from T_0 up to, but not including T_N, there is one capacity constraint per specialty. At T_N, a logical upper bound on the value of the single arc leaving a specialty replaces the capacity constraint, thus minimizing the number of rows required for the problem. Finally, since the percentage of COLs promoted is included in the annual attrition rate for COLs, only the preferred specialty pairs for arcs representing COLs remaining in grade (X arc) are controlled.

c. Lieutenant Colonel and Major Segments. - Both of these segments use the same logic. The two segments differ only in the Personnel Structure and Composition System (PERSACS) requirements data values, the attrition and promotion rates used, and the paths, all of which are grade dependent. In these two field grade segments, promotions to the next higher grade are explicitly considered. Furthermore, once promotion is effected, the flows of promotees are treated according to different rules than the flows of those not promoted (as explained in subparagraph (3) below). Whereas in the COL segment only one attrition rate per year is used, the LTC and MAJ segments each need two attrition rates and one promotion rate per year. Figure II-7 illustrates the application of these three rates. The promotion rate is used at each node to determine how many officers will move from one grade's path to a path for the next higher grade. Then one attrition rate is used for promotee flows in the higher grade's path (Y arcs) and the other attrition rate is used for flows of those not promoted (X arcs). Promotion introduces three additional considerations.

(1) First, the unfilled requirements from the next higher grade segment restrict the sum of the flows into a node from all incoming Y arcs. In other words, the number of officers promoted to the next higher grade must be less than, or equal to the unfilled requirements for that grade (which were computed in the previous segment).

(2) Second, the sum of all incoming arcs (Y + X) to a node cannot exceed the sum of the unfilled higher grade requirements plus the requirements for the lower grade. For example, if for specialty 46 in the LTC segment, there are 10 unfilled COL requirements (as determined from processing the COL segment) and 40 LTC requirements, at year 3, those requirements must be satisfied by assignments in year 2. The node capacity constraints are therefore:

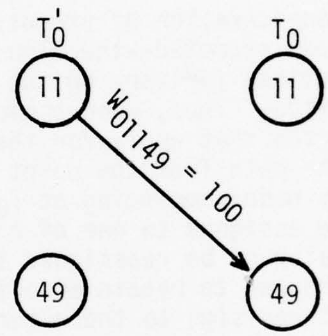
$$\sum_{f=\alpha}^{\omega} Y_{2f46} \leq 10$$

$$\sum_{f=\alpha}^{\omega} Y_{2f46} + \sum_{f=\alpha}^{\omega} X_{2f46} \leq (40 + 10)$$

If the following rates are applied:

Promotion rate for promotion to COL - 0.05
Attrition rate for COLs from $T_0 - T_1$ - 0.10
Attriton rate for LTCs from $T_0 - T_1$ - 0.15

and if 100 LTCs with specialties 11 and 49 were serving in specialty 49 at T_0



then the following occurs:

0.05 x 100 are promoted to COL ($Y_{04911} = 5$)

(1 - 0.05) x 100 remain LTCs ($X_{04949} + X_{04911} = 95$)

Y_{04911} will attrit at the 0.10 rate and ($X_{04949} + X_{04911}$) will attrit at the 0.15 rate

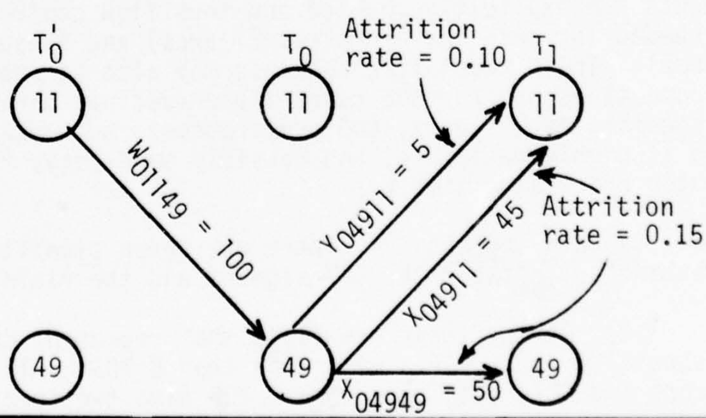


FIGURE II-7, Example of Application of Promotion and Attrition Rates

The two equations provide for the grade substitution effect. Since the first equation specifies that the sum of the Y arcs can be less than 10, then the flow in the X arcs (officers not promoted) can fill by grade substitution any of those 10 higher grade positions not filled by Y arc input. In this example, the 10 positions to be filled are also included in the 50 requirements composed of 40 LTC and 10 COL positions. In other words, if the flow in the Y arcs does not satisfy the COL requirements, then flow in the X arcs is applied toward the unfilled requirements through grade substitution.

(3) The third consideration of promotions is the different treatment accorded to those promoted--the flows in the Y arcs. The ODSAS methodology provides for varying the utilization ratio of a specialty pair by grade. Thus, upon promotion, the utilization ratios and tour lengths that apply for the next higher grade will be used to define the path from the point of promotion. Promotion is effected at every node commencing at T_0 and ending at T_{N-1}. An officer promoted while assigned to one of his dual specialties can remain in that specialty or be reassigned to his other specialty. In ODSAS, the decision whether to retain an officer in a specialty at the higher grade or to reassign to the alternate specialty is determined in the following way:

(a) If at the time of promotion, one tour length of the specialty has not been completed, then promotion is made in the same specialty.

(b) If at least one tour length has been completed, then promotion results in reassignment to the other specialty.

Unlike the COL segment, promotions within both the LTC and MAJ segments are explicitly modeled and thus flow control constraints are needed for both the promotees (Y arcs) and those not promoted (X arcs). These two latter segments may also be processed in two subsegments each. For the current user-defined parameter values (46 specialties, 5 years, 600 preferences), segmentation-within-grade is highly desirable, and possibly mandatory, for reasonable computer processing time.

d. Captain Segment. - There are seven significant differences in methodology between the CPT segment and the field grade segments.

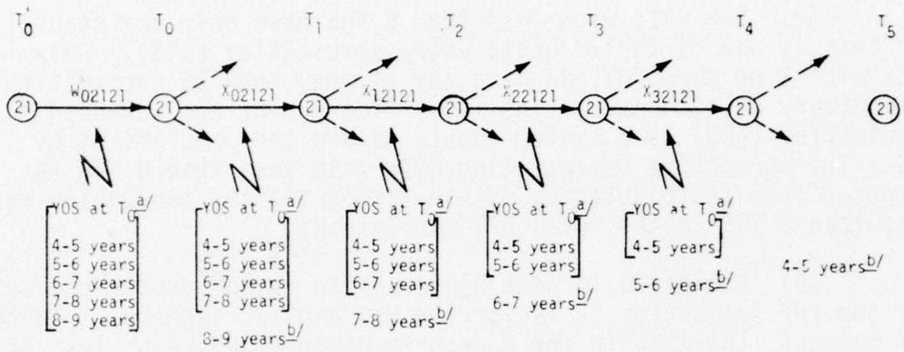
(1) At T_0, there are flows that represent CPTs with only one specialty, i.e., CPTs with less than 8 YOS. All field grade officers and CPTs with more than 8 YOS have two specialties. The CPTs with one specialty at T_0 are represented by W arcs which have

the same specialty number in the "from" and "to" specialty positions, e.g., W_{02121}. This is the only segment where W arcs with identical "from" and "to" node identifications appear.

(2) The CPTs with less than 8 YOS have only one specialty and that is one of the 30 basic entry specialties (BES). Only CPTs with 8 or more YOS can have any of the other 16 specialties for primary or alternate. The identification of the advanced entry specialties (AES) is a system input, as are the populations by YOS. The percentage representing CPTs with less than 8 YOS is computed from the population data by comparing the population with less than 8 YOS to the total CPT population.

(3) Promotion to next higher grade is not explicitly treated for the CPT segment as it is for the MAJ and LTC segments. In the CPT segment, the flow in the X arcs represents CPTs with less than 8 YOS, whereas the Y arcs represent the CPTs that either started at T_0 with more than 8 YOS, or attained 8 YOS since that time. The computation of the attrition rates for the two categories of CPTs (less than 8, and 8 or more YOS) considers that some CPTs are promoted within the projection period. Thus, the flow in the Y arcs is attrited at a rate that is derived by explicitly considering promotion to the next higher grade (see Appendix D for details).

(4) For CPTs, the transition of flows from the X arcs to the Y arcs (caused by designation of the alternate specialty for CPTs attaining 8 YOS) is treated as a residual, rather than being computed for either of two specialties as is done for promotions in the field grades. CPTs in the eighth YOS are required to have an alternate specialty designated during that year, and that alternate specialty should meet future specialty requirements. Such a designation is assured by explicitly controlling the flow of the entire CPT population except the percentage that is due for alternate specialty designation. The percentage of CPTs with 8 YOS must be uniquely identified. This value is computed from variable input data and used in the designation of alternate specialties as shown in Figure II-8. The figure shows that the fraction of CPTs that would remain with only a single specialty from 1 year to the next is specified, as is the reassignment of all CPTs who have two specialties. The number of CPTs due to be designated alternate specialties is the residual of all the flows into a node. The allocation of the residual--designation of alternate specialties--depends upon the computed requirements for the preferred alternates.



a/ Arcs contain the indicated YOS groups associated with the CPT population at T_0 (see paragraph d(6)).

b/ Indicates original YOS group designated alternate specialties in the interval shown. This group travels along Y-arcs (indicated by dashed lines) since the members of the group are now dual qualified.

FIGURE II-8, Representation of Captains with Less Than 8 Years of Service

(5) As in the field grade segments, each of the 46 specialties in the CPT segment has a node capacity constraint based upon total requirements. However, when processing CPTs, all unfilled MAJ requirements, by specialty, are used to specify minimum requirements to be filled by CPTs. This, in effect establishes a mandatory fill of any vacant MAJ requirements. This lower limit will be met in order of priority: first, by flows representing CPTs promoted to MAJ since T_0; second, by dual-qualified CPTs with 8 or more YOS; or third, by CPTs with less than 8 YOS possessing only one specialty.

(6) The X arcs for CPTs are only constructed to the year where all CPTs would reach the eighth year of service. As illustrated in Figure II-8, if the most junior CPTs at T_0 had 4-5 YOS (this would be specified in the user's input), then in 4 years that YOS group would have 8-9 YOS and thus would be due for designation of alternate specialties at T_4. There are no X arcs in the T_4 - T_5 interval (only Y arcs) because the last YOS group is to be designated alternate specialties and, as described in (4) above, those flows move along Y arcs.

(7) The final difference between processing CPTs and processing field grade officers concerns control of the Y arcs. Whereas in the field grade segments, the flow control constraints are equalities (as defined in paragraph 1m above), in the CPT segment some constraints are inequalities in order to provide for the alternate specialty designation methodology described in (4) above. As detailed in that paragraph and in Appendix G, the flow out of a node, along a Y arc, can include an unspecified number of CPTs with 8 YOS due for designation of alternate specialties. Therefore, because the number is unspecified, an inequality is used to allow the flow out of that node to equal, at least, a specified fraction of an earlier flow.

e. Lieutenant Segment. - This segment employs logic similar to that used in the CPT segment, since some of the LT population at T_0 could expect promotions to CPT during the projection period. Additionally, some LTs would reach their eighth YOS, and thus need to receive an alternate specialty. As mentioned in paragraph 1f above, the LT segment considers 2LTs and 1LTs together. The PERSACS requirements data refer to only one LT grade, and the ODSAS methodology was modified according to model flows representing the combined population of 2LTs and 1LTs. The methodology utilized for LTs is explained in subparagraphs (1) through (6) below.

(1) There are fewer arcs in the LT network since, until the eighth YOS, LTs have only one specialty and have repetitive assignments in that specialty. This is modeled in ODSAS as illustrated in Figure II-9.

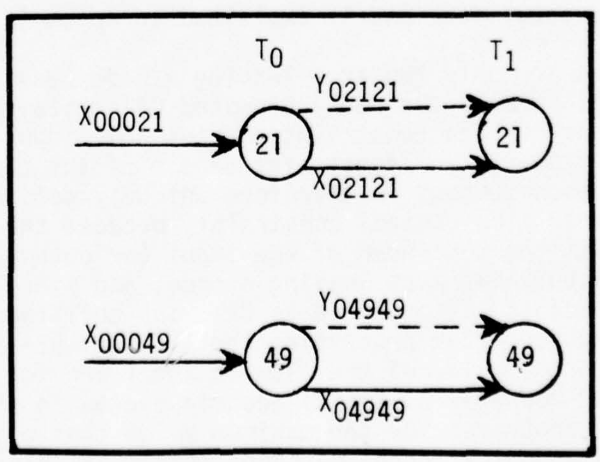


FIGURE II-9, Representation of Lieutenants with Less Than 8 Years of Service

(a) The W arcs (representing dual qualified officers at T_0) and the T_0 - T_0' interval are omitted in Figure II-9. Thus, the arcs at the far left of the figure (e.g., arcs X_{00021} and X_{00049}) terminate at T_0, rather than T_0' as in the other segments. In this segment the X_{000nn} arcs represent LTs with specialty "nn". Thus, the W arcs, and the interval in which they appear, are superfluous. Consequently, the key arc relationship constraints do not apply in the segment due to the absence of W arcs.

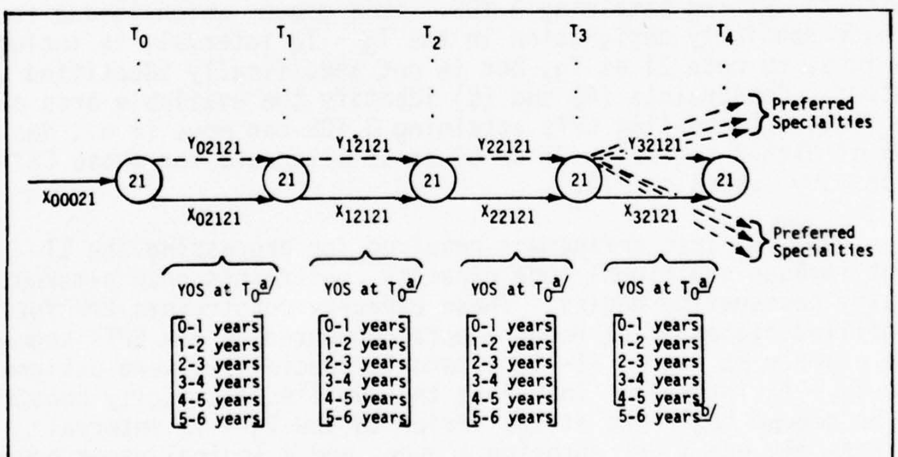
(b) The only X arcs for LTs in the interval after T_0 are the ones in which the "from" specialty number is the same as the "to" specialty number (i.e., arcs X_{02121} and X_{04949} in Figure II-9). This fact reflects the repetitive assignments in a specialty for LTs.

(c) The Y arcs (e.g., arcs Y_{02121} and Y_{04949} in Figure II-9) represent LTs promoted to CPT. This reflects the repetitive assignments of CPTs before they attain 8 YOS. As explained in subparagraph (4) below, when any of these newly promoted CPTs reach the eighth YOS, Y arcs in the LT segment can connect different nodes (specialties). In other words, in the LT segment, promoted officers with at least 8 YOS become dual qualified and can be assigned to their alternate specialty.

(2) Promotion from 2LT to 1LT is not explicitly represented in the network; that promotion is considered in computing the weighted average attrition rates used for the X arcs (which represent all LTs). First lieutenants promoted to CPT are represented in the network by the Y arcs (previous paragraph). An additional calculation is performed to determine when, and what fraction of, the LTs promoted to CPT would reach the eighth YOS. This calculation is derived from user-input data and is explained in Appendix D.

(3) There are only two arcs leaving a node (as shown in Figure II-9) until some of the newly promoted CPTs attain 8 YOS. Since the flow conservation constraint equates node input to node output, only one flow control constraint on one of the two outputs is needed. The second output is therefore uniquely defined without constructing another flow control constraint, because the second output has to equal the remainder of the input (or output). As long as there are only two arcs leaving a node, and since the flow in the Y arc represents LTs promoted to CPT, any unfilled CPT requirements (computed after processing the CPT segment) are specified as upper bounds on the value of the flow in the Y arc for the LT segment. An upper bound is a logical technique used in LP that saves creating a constraint for the maximum value that a variable may attain (e.g., a logical upper bound of 50 on variable Y_{02121} could replace the constraint $Y_{02121} \leq 50$).

(4) Once members of the LT population reached the eighth YOS, then additional Y arcs are introduced to allow utilization in alternate specialties (as mentioned in paragraph (1)(c) above). As an example, if the LT population at T_0 consisted of officers having no more than 5 YOS, then after 2 years the most senior YOS group would complete the seventh YOS, and begin the eighth YOS. Figure II-10 illustrates the example. The first year of alternate specialty designations shown in the example is the T_3 - T_4 interval. The flow into node 21 at T_3 is associated with arcs representing LT and CPT with less than 8 YOS (arcs X_{22121} and Y_{22121}, respectively). The fraction of the former input flow, representing LTs promoted to CPT upon attaining 8 YOS and who are due for alternate specialty designation, is not specified in a constraint. The Y arcs leaving node 21 at T_3, portrayed by dashed lines in Figure II-10, provide paths for the officers to be designated alternate specialties. The requirements for promotable LTs (established in the CPT segment) determine what alternate specialties will be assigned the LTs with 8 YOS and the quantities required.



a/Arcs contain the indicated YOS groups associated with the LT population at T_0 (see subparagraph e(4)).

b/This is the YOS group to be designated alternate specialties. Dividing the number of LTs with 8 YOS by the total LT population gives the percentage due to be designated alternate specialties.

FIGURE II-10, Representation of Lieutenants, and Lieutenants Promoted to Captain, Upon Attaining 8 Years of Service

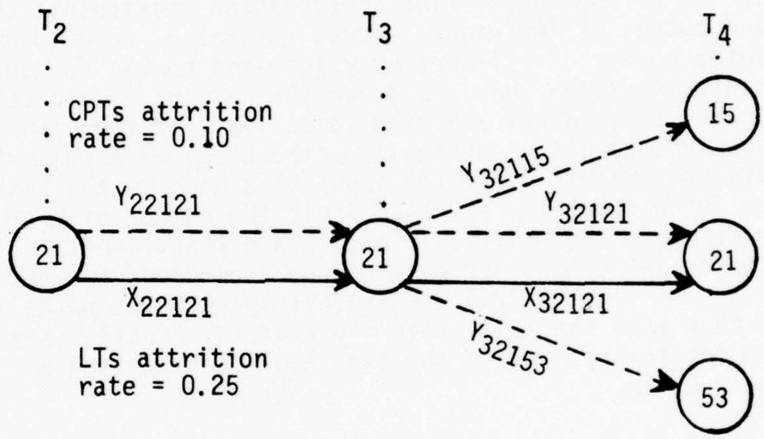
(5) When some of the newly promoted CPTs are due for alternate specialty designation, the flow control constraints are constructed

as inequalities. This is similar to the treatment of flow control in the CPT segment. The inequalities allow LTs with newly designated alternate specialties to be reassigned from their BES to their alternate. Figure II-11 lists the constraints and illustrates their interaction, as a continuation of the example shown at Figure II-10. Constraint (1) specifies that the node input equal the node output (the flow in the two input arcs must equal the flow in the four output arcs). As shown, (1.0 - 0.25), or 0.75, of X_{22121} and (1.0 - 0.10), or 0.90, of Y_{22121} arrives at node 21 at T_3. That input departs node 21 at T_3 along the four arcs named. Equations (2) and (3) specify where a portion of the input flows will depart. In equation (2), a portion of X_{22121} will continue as LT in specialty 21 from T_3 to T_4 (arc X_{32121}). This portion is computed in the model from the tour length and attrition rate data input by the user--0.60 was chosen for this example. The remaining X arc input (0.75 - 0.60 = 0.15) representing LTs promoted to CPT at T_3. This portion will move along arc Y_{32121} in the T_3 - T_4 interval (shown in equation (3)). Similarly, a portion of Y_{22121} will continue as CPTs in specialty 21 from T_3 to T_4 (representing CPTs with less than 8 YOS). The portion of Y_{22121} is also computed in the model from tour length and attrition rate data--0.70 was chosen for this example (in equation (3)). A portion of the Y arc input (0.90 - 0.70 = 0.20) represents LTs promoted to CPT and attaining 8 YOS. This group, which is due for alternate specialty designation in the T_3 - T_4 interval, is included as an input to node 21 at T_3, but is not specifically identified as an output. Constraints (4) and (5) identify the available arcs along which flows representing CPTs attaining 8 YOS can move (i.e., designation of either specialty 21 or 53 as an alternate for those CPTs with primary specialty 21).

(6) The last refinement required for processing the LT segment imposes additional node capacity constraints once alternate specialty designation begins. These capacity constraints are for the unfilled higher grade requirements (computed in the CPTs segment). In the example at Figure II-11, alternate specialties were assigned in the T_3 - T_4 interval. Therefore the additional capacity constraints would be needed beginning at T_4. Prior to the T_3 - T_4 interval there was only one Y arc entering a node, and a logical upper bound was used to limit the flow in that arc. From T_4 on, in this example, there can be more than one Y arc entering a node, and therefore a constraint is needed rather than a logical upper bound.

4. Summary. - After evaluating alternative approaches, the ODSAS study team selected a methodology which applied a LP solution technique to a multi-time period network flow problem. Because of the problem size, the resultant LP formulation required segmentation by grade, and then segmentation-within-grade. The latter segmentation scheme

LT and CPT attrition rates are derived from user-supplied data. The rates in this example are hypothetical. Assume for this example that the preferred specialty pairings for specialty 21 are 21/15 and 21/53.



Flow Conservation:

$$(1.0 - 0.25) \times X_{22121} + (1.0 - 0.10) \times Y_{22121} = X_{32121} + Y_{32115} + Y_{32121} + Y_{32153} \quad (1)$$

Flow Control:

$$0.60 \times X_{22121} = X_{32121} \quad (2)$$

$$0.15 \times X_{22121} + 0.70 \times Y_{22121} = Y_{32121} \quad (3)$$

$$Y_{32115} \geq 0 \quad (4)$$

$$Y_{32153} \geq 0 \quad (5)$$

FIGURE II-11, Illustration of the Interaction of Constraints for Alternate Specialty Designation in the Lieutenant Segment is optional and can be used if the largest grade segments (LTC and MAJ) exceed hardware and/or software limits.

a. The methodology employs five types of constraints: flow conservation, node capacities, flow control, control of input, and key arc relationships. All five types of constraints are used in each grade segment (except key arc relationship constraints do not apply in the LT segment). Flow conservation constraints control the input and output of individual nodes; control of input constraints limit the total number of officers by grade--and number for selected specialties within grade--that can enter the network. Node capacity and flow control constraints are used selectively in the grade segments depending upon the particular methodology of a segment. Node capacity constraints limit the input to a node to the annual requirements for a specialty and also limit the number of promotees to a higher grade to the unfilled higher grade requirements. This important constraint allows for only enough promotions to meet requirements. The flow control constraints specify the paths in the network that each specialty pair may travel. Finally, key arc relationship constraints relate the two flows representing a specialty pair at T_0.

b. For each grade segment, the ODSAS system determines the maximum number of officers that can be utilized in a user-defined set of preferred specialty pairings considering attrition and promotion throughout the time span being analyzed. Unfilled requirements, computed after processing one grade segment, are passed to the next lower grade segment for use as limits on promotions and/or grade substitution. The three field grade segments use similar logic; the CPT and LT segments differ significantly from the field grades because, most CPTs and LTs have only one specialty and, during the projection period, an alternate specialty must be designated to those who attain 8 YOS.

c. In summary, the methodology addresses all three EEA. The number of officers to be allocated specific specialty pairings at each grade level (EEA 1) is the solution value of the W arcs in the CPT through COL segments. Designation of alternate specialties to CPTs attaining 8 YOS is accomplished in the CPT and LT segments. The total procurement of officers by BES (EEA 2) is determined by computing the unfilled LT requirements at the end of the processing for that segment. Finally, the training requirements for BES and alternate specialties (EEA 3) can be derived by comparing the actual officer asset position to what ODSAS computes the asset position should be.

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

CHAPTER III
AUTOMATED INFORMATION SYSTEM

1. System Design

a. General. - In August 1975, the Study Advisory Group approved the methodology described in Chapter II, and directed that work begin on objective 2 of the study. That objective specified that the methodology be incorporated in a computer-based information system consisting of computational and data processing components and associated data elements. The following overall design concepts were used in developing the automated system:

(1) Divide the system functionally. The capability to specify and solve the linear programing problems is separated from other data processing activities (e.g., editing of data).

(2) Utilize high-speed computer disc storage devices for input and output of data.

(3) Retain the solutions in a machine-readable form for analysis--with computer printing to be on a selective basis.

Having established the overall design concepts, the functional divisions were identified and the appropriate computer programs to accommodate the functional divisions were developed. These programs were combined to become the ODSAS system--a system that the user could easily control.

b. Procedural Functions Included. - To implement the ODSAS methodology on the UNIVAC 1108 computer, applications programs were developed, or incorporated, for the following functions:

(1) Computation of attrition and promotion rates for each grade.

(2) Creation of edited input data files for all system segments.

(3) Generation of linear equations for each segment.

(4) Solution of the linear equations--UNIVAC's Functional Mathematical Programming System (FMPS) level 6.R1B, a standard

program product that includes procedures for solving LP problems, was selected for this function.

(5) Specification of FMPS procedures to control the processing while obtaining a solution (e.g., specifying actions to take on encountering error conditions, or identifying information to be output).

(6) Linkage of one segment or subsegment to another (e.g., updating files to reflect solutions of previous segments).

(7) Interpretation of linear program solutions and production of management reports.

c. <u>System Phasing</u>. - The automatic data processing (ADP) system developed for ODSAS is comprised of an initialization phase and a processing phase. In the initialization phase, the functions listed in subparagraphs b(1) and (2) above are accomplished. The initialization phase is executed only once. The processing phase accomplishes the functions in subparagraphs b(3) through (7). The processing phase is repeated for each grade segment or subsegment specified by the user. Segmentation-within-grade, if accomplished, requires modification to one input file containing user-supplied segmentation instructions. Based upon those segmentation instructions, the ODSAS ADP system generates and solves the appropriate linear equations for the grade segment or subsegment specified.

(1) <u>The Initialization Phase</u>. - Figure III-1 is a system flow chart of the initialization phase. As shown, there are four user-supplied input data files needed for the ODSAS file creation, data editing, and rates computation procedures. The resulting output of those procedures are four computer disc files and two printed reports.

(a) <u>Input Files</u>

<u>1</u>. The input data come from three sources. Those sources and identification of all the data contained in the input files are described in paragraph 2 below. The first input file (labeled Input 1) on Figure III-1 contains the policy (official or test) on the utilization ratios and tour lengths (in all grades) for preferred specialty pairs.

<u>2</u>. Input 2 is the Personnel Structure and Composition System (PERSACS) data file of present and future requirements by grade and specialty.

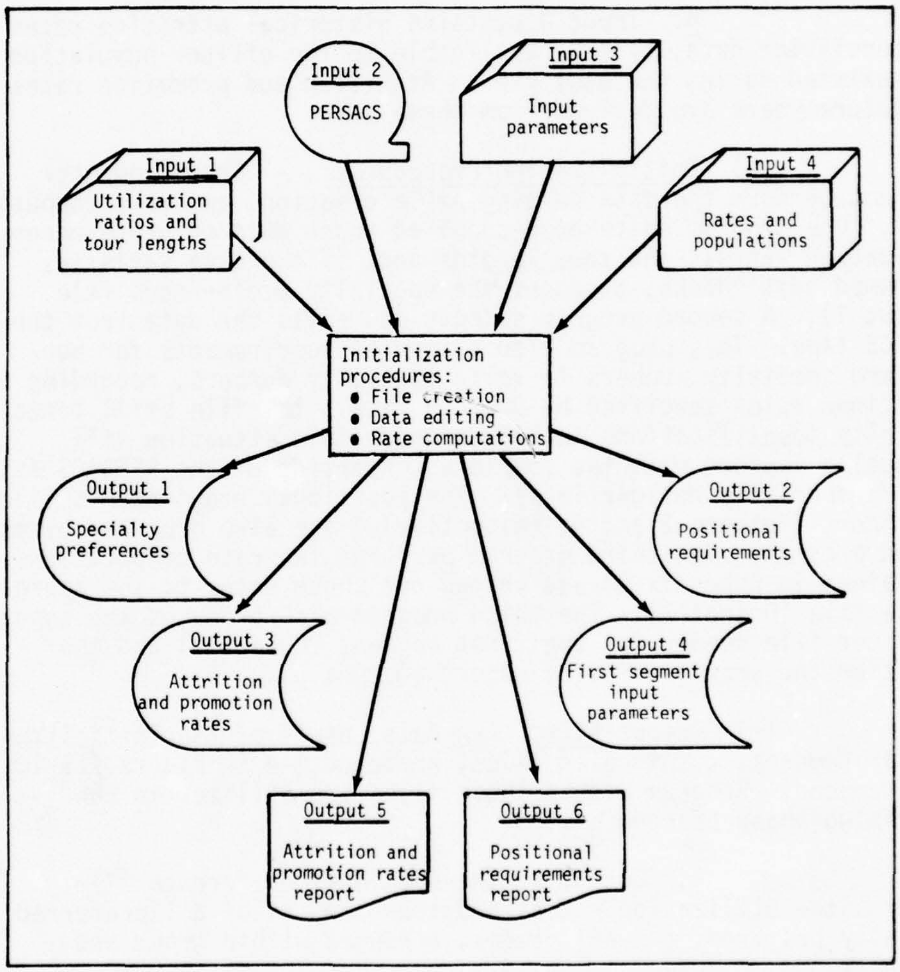


FIGURE III-1, ODSAS Automated Information System, Initialization Phase

3. Input 3 is the specification of system parameters which help determine what size problems will be solved and how they will be solved (e.g., the number of years to project and segmentation instructions). This file also contains the data values needed to control the input to the network (i.e., total number of officers authorized by grade and specialty).

4. Input 4 contains historical attrition rates and population data, by YOS, applicable to the officer population that existed during the past year. Attrition and promotion rates for future years are derived from these data.

(b) Initialization Procedures. - Three computer programs perform the data editing, file creation, and rate computations. One program edits user-supplied input data on preferences, utilization ratios, and tour lengths and, if the data satisfies programed edit checks, produces the specialty preferences file (Output 1). A second program selects and edits the data from the PERSACS tape. This program also allocates requirements for non-standard specialty numbers to valid specialty numbers, according to predefined rules specified by ODCSPER (i.e., the file still contains specialty identifications no longer used--this situation will eventually improve with the complete conversion of the PERSACS file to OPMS specialty designations). The positional requirements file and report (Outputs 2 and 6, respectively) are also produced by the second program. The third program performs the rate computations (explained in Appendix D) and writes out these rates to the appropriate file (Output 3). The third program also produces the input parameter file needed for the first segment (Output 4) and the attrition and promotion rates report (Output 5).

(c) Output Files. - As a result of the initialization procedures, output disc files, numbered 1-4 in Figure III-1, are produced. Records within these files are utilized in the processing phase procedures.

1. Output 1, the specialty preference file, contains the utilization ratios and tour lengths of all preferred specialty pairings, for all grades, arranged within grade and specialty.

2. Output 2 contains the positional requirements (i.e., requirements derived from the PERSACS input for all grades and specialties in the years of the projection period).

3. Output 3 contains the computed attrition and promotion rates for each grade per year of the projection period.

4. Output 4 contains all the parameters and rates needed as input for the processing of the first segment. The input files for the subsequent segments are produced in the processing phase as they are needed.

(d) Reports. - The two printed reports (Outputs 5 and 6 of Figure III-1) are for verification and retention by the user. The reports display the computation of the attrition and promotion rates and the requirements by grade, specialty, and year.

(2) The Processing Phase

(a) General. - Figure III-2 is a system flow chart of the processing phase. The processing phase is comprised of five major activities--the five blocks indicated by the dashed lines in Figure III-2.

1. Major activity 1, the matrix generator, produces the LP equations in FMPS format.

2. Major activity 2, FMPS solution, solves the equations and provides selected solution data for subsequent use.

3. Major activity 3, data base creation, creates the input files and loads them on to the data base.

4. Major activity 4, an on-line inquiry system, permits the user to evaluate system output during processing.

5. Major activity 5, linkage, connects one segment or subsegment to the next, to provide continuity of processing. The processing phase is done at least five times (once for each grade--COL through LT). If the segmentation-within-grade option is selected for any of the field grades, up to three additional iterations of the processing phase would be required (one for each grade segment).

(b) Description of Major Activities

1. Matrix Generator. - The matrix generator, major activity 1, is depicted at Figure III-3. Accessing data on files created in the initialization phase, the matrix generator programs produce an equation file organized according to the standard format of UNIVAC's FMPS. Another file of selected data on the constraints and variables is also produced. Data in the latter file will become part of the records in the data base. A statistical report is the third output, containing information on the network

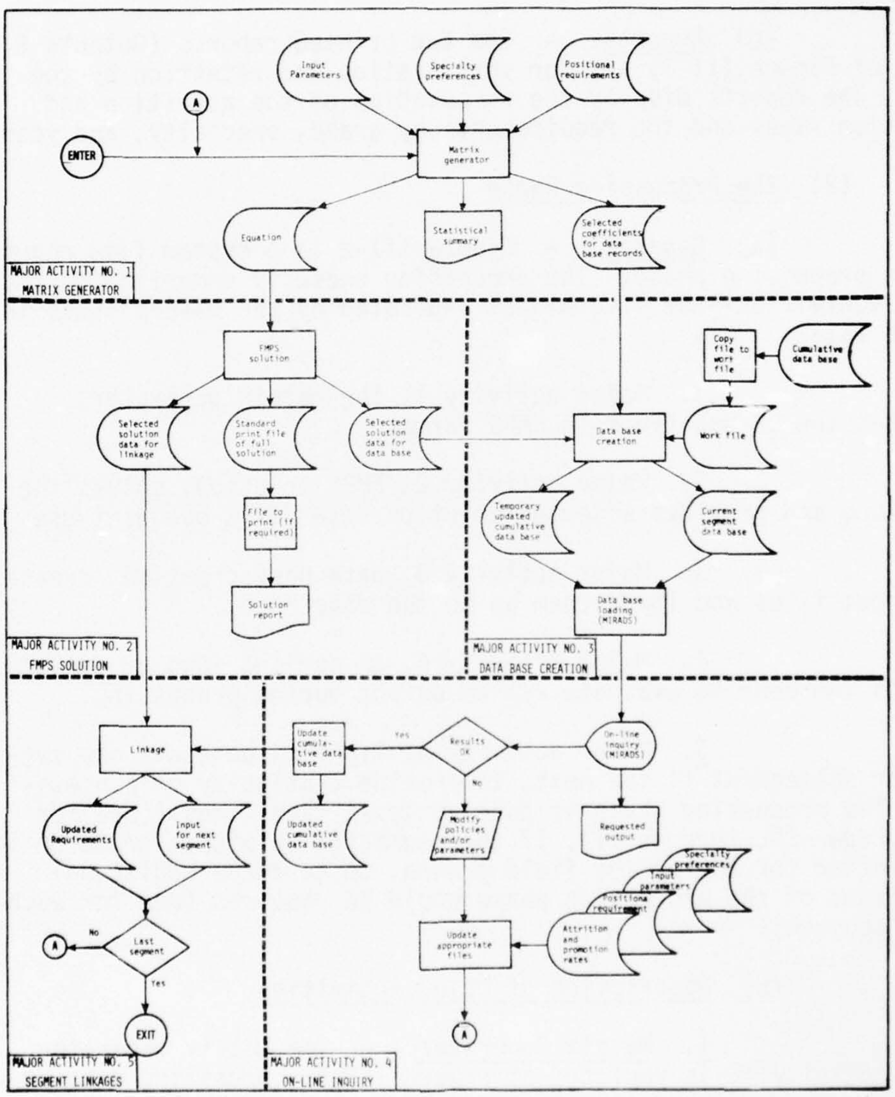


FIGURE III-2, ODSAS Automated Information System, Processing Phase

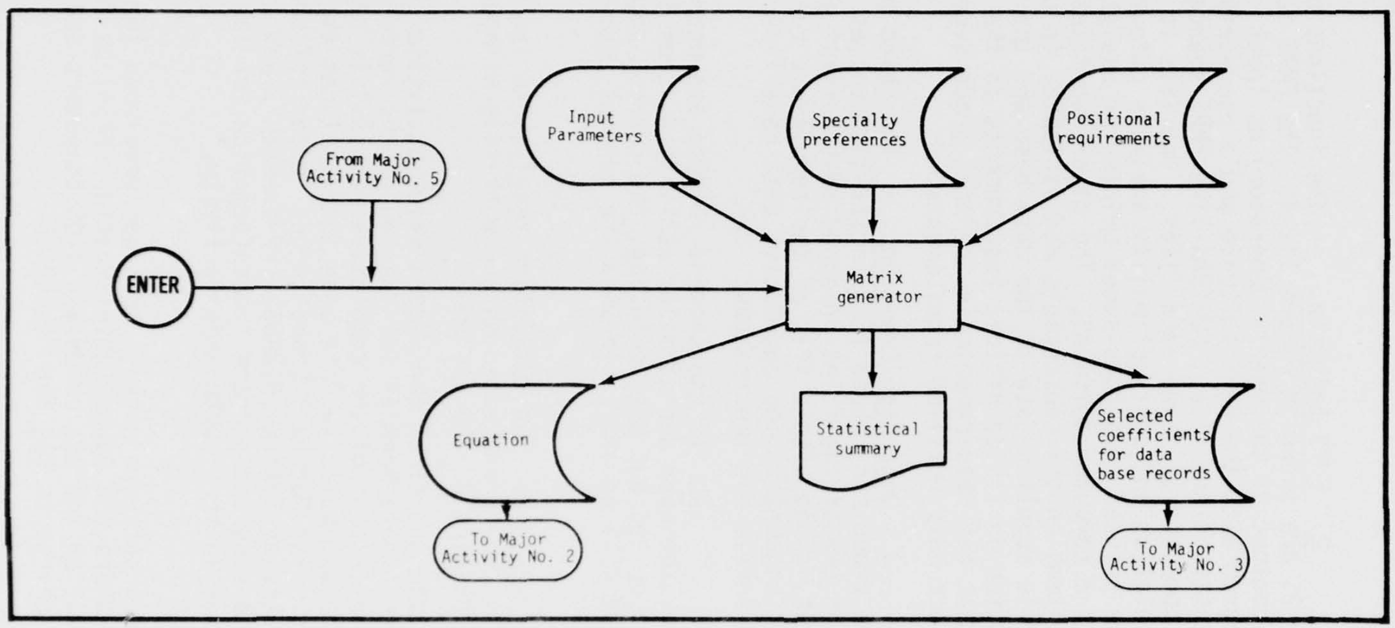


FIGURE III-3, Matrix Generator, Processing Phase Major Activity Number 1 structure and capacities and the characteristics of the linear program to be solved (e.g., number of constraints, number of variables).

2. FMPS Solution. - The functions of FMPS, major activity 2, are shown in Figure III-4. The FMPS accepts the equation file (output of the matrix generator) as input, and solves the linear program with the FMPS software and a user-defined set of implementing instructions (i.e., FORTRAN-like FMPS source statements). The output is composed of three data files. One file is the standard FMPS printed solution and post-optimality analysis output that can, selectively, be printed on a high-speed printer or analyzed with a text editor via a computer terminal. The other two files contain selected data items on the constraints and variables in the LP problem; one file supplies data to the data base and the other file passes information on filled officer requirements to the linkage activity, so that the requirements in the next grade segment initially reflect only unfilled requirements.

3. Data Base Creation. - The third major activity of the processing phase (Figure III-5) involves accessing information from two of the files produced in the first and second major activities, along with a file of the cumulative results of any previous system segments. The cumulative data base file is first copied to a work-file for two reasons:

a. If the segment results are unacceptable as determined by the user during major activity 4, then the actual cumulative file up to, but not including, the current segment is not updated, and will be available when the current segment is processed again.

b. The cumulative results, to include the current segment, can be evaluated on the work-file without inhibiting further processing of the system.

The two files from the first and second major activities are combined to produce a data base of information on the current segment. A temporary file (a copy of the cumulative results) is also updated to produce a cumulative data base that includes the current segment results. The Marshall Space Flight Center Information Retrieval and Display System (MIRADS) (references 3 and 4) is used to load the data base and prepare the information for the on-line inquiry conducted in the fourth major activity.*

---

*MIRADS is a software package that was developed for the National Aeronautics and Space Administration (NASA) by Computer Sciences Corporation for use on UNIVAC 1108 computers and was furnished free of charge to CAA and MILPERCEN.

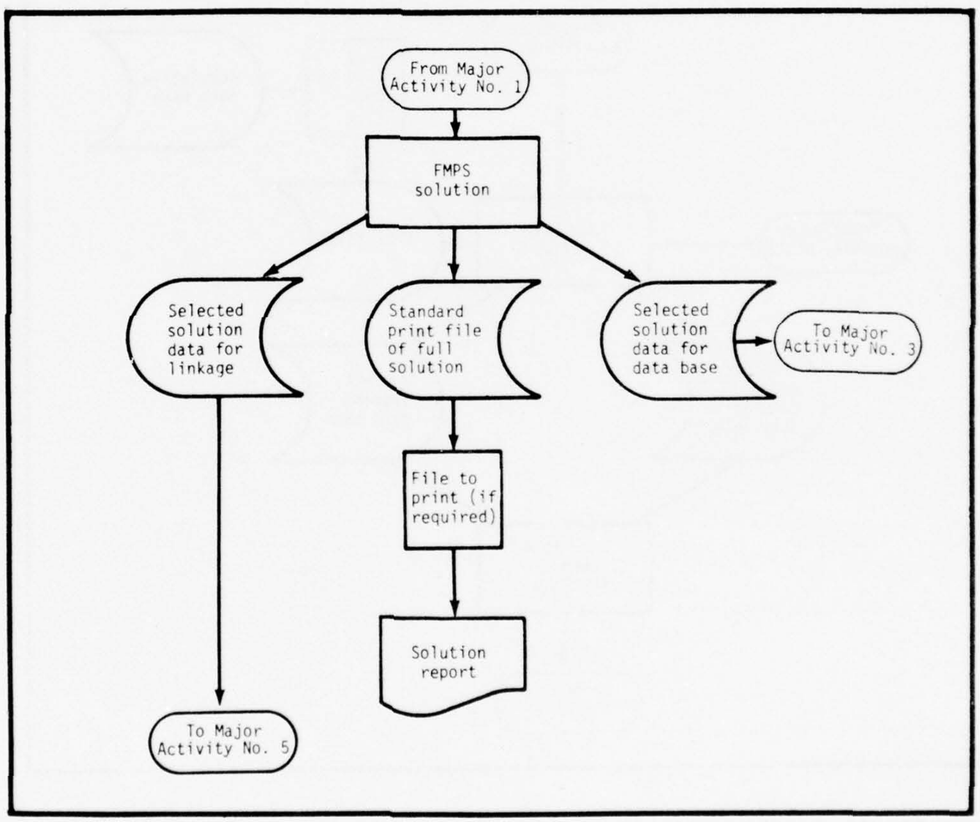


FIGURE III-4, FMPS, Processing Phase Major Activity Number 2

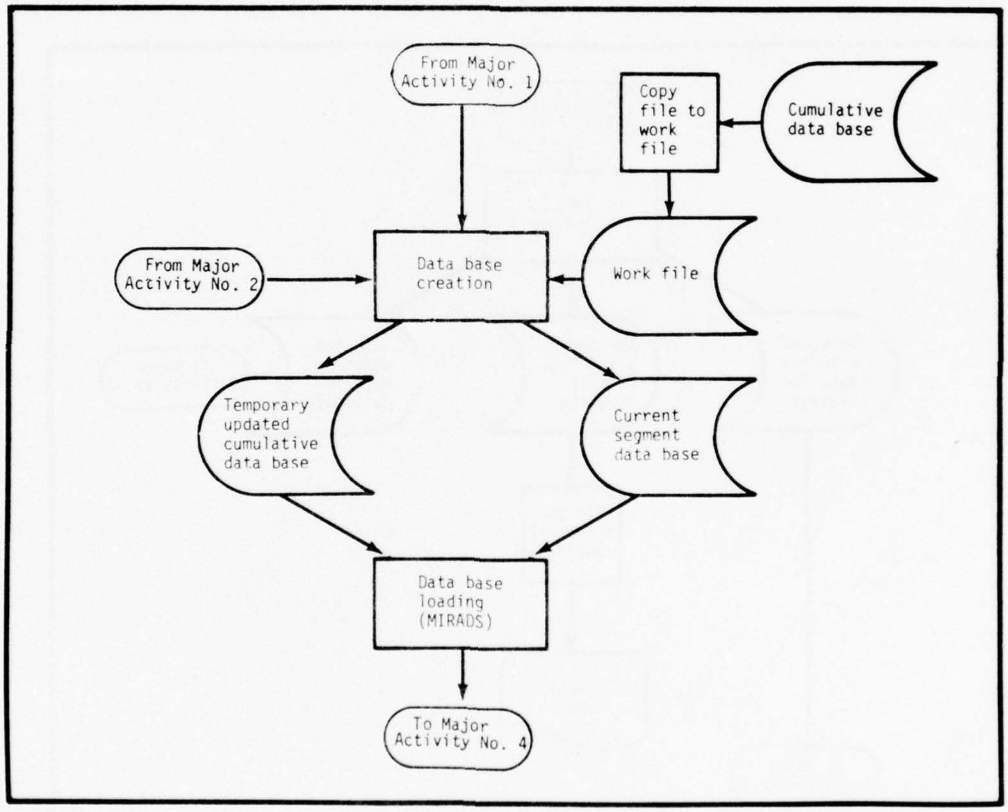


FIGURE III-5, Data Base Creation, Processing Phase Major Activity Number 3

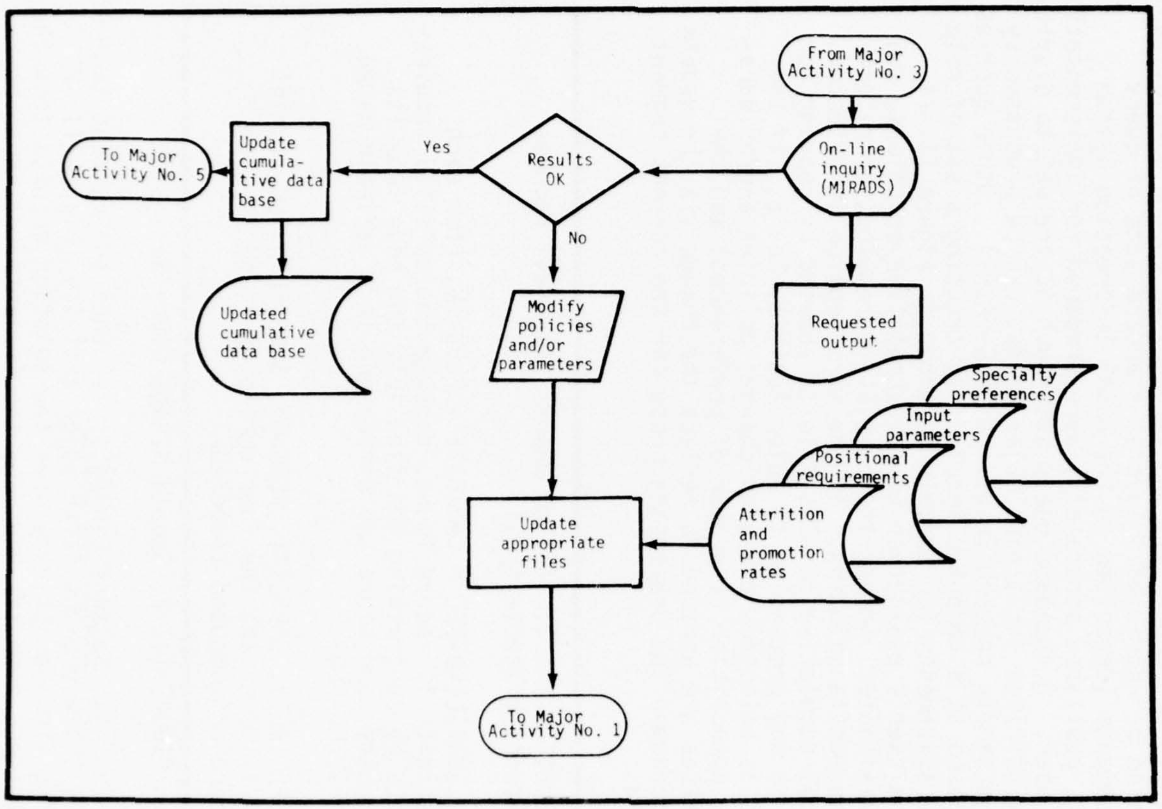


FIGURE III-6, On-Line Inquiry, Processing Phase Major Activity Number 4

4. On-Line Inquiry. - The fourth major activity (Figure III-6) involves using MIRADS query language to interrogate the several data bases developed in the system. Each officer segment can be evaluated separately and information on the cumulative results can also be retrieved. Several standard sets of query language statements (described in the ODSAS Information System documentation, published separately) were prepared for implementation by the ODSAS user. A standard query set, such as the set to display the specialty pairings for a particular grade, can be processed by specifying one simple command (e.g., DO SPEC-PAIRS). Other queries can be formulated at a computer terminal by creating a set of relatively simple statements (an example is shown in Figure III-7). Based upon the user's evaluation of the cumulative solutions, two options are available: accept the cumulative results, or reject the current segment's solution. If the first option is selected, then the actual cumulative results file is updated by copying the work-file to it and proceeding to Major Activity No. 5. If the second option is selected, the user changes policies and/or parameters (e.g., composition or number of preferences) and the appropriate files are updated to reflect the change via the update procedure, whereupon the processing phase for the current segment is begun again.

QUERY, SPECIALTY = 11, (which means: Find all records concerning specialty 11)

COMPUTE, $UNFILLED-REQ = CAPACITY - FLOW-IN, (for each specialty 11 record found, compute the unfilled requirements by subtracting the flow into the node from its capacity, and store the difference in a variable named $UNFILLED-REQ)

PRINT, SPECIALTY, CAPACITY, FLOW-IN, $UNFILLED-REQ, (print the value of the the four variables found in each record or computed therefrom)

FIGURE III-7, Sample MIRADS Query Set

5. Segment Linkages. - Once the current segment is accepted by the user, the fifth major activity (Figure III-8) can begin. The linkage activity uses the solution results from the current segment and computes how many requirements remain to be filled by subsequent segments. A new input file is created for the next segment in sequence and the requirements file is updated to reflect the unfilled requirements through the current segment. The next step is to begin the processing phase again by performing Major Activity No. 1 with the next segment or subsegment, in sequence. The

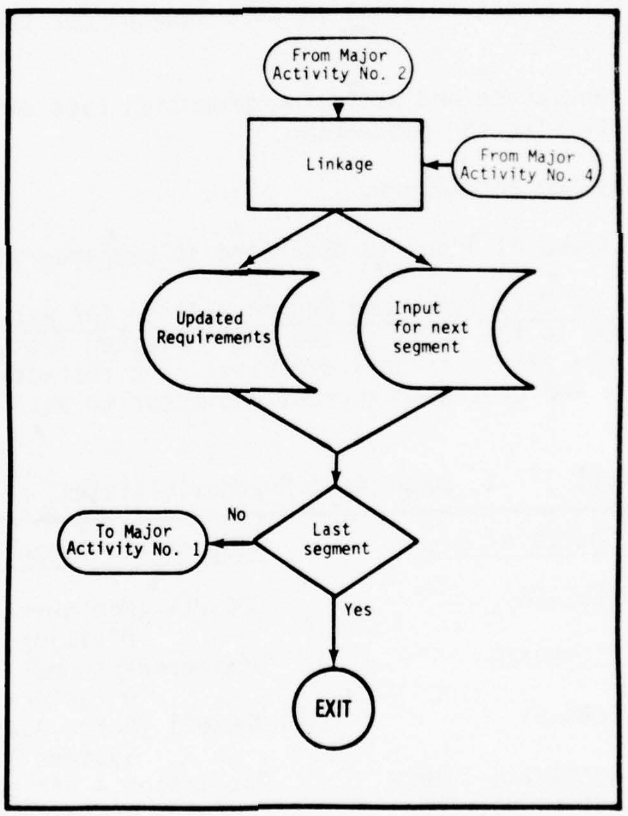


FIGURE III-8, Linkage, Processing Phase Major Activity Number 5 processing phase is repeated until the final (LT) segment is satisfactorily completed.

2. Input Requirements

a. Types of Input. - There are five general types of input required in the system:

(1) Force requirements.

(2) Management policies on utilization ratios for preferred specialty pairings.

(3) Management policies on tour lengths for preferred specialty pairings.

(4) Population and attrition/promotion rate data applicable to the reference starting population.

(5) System parameters.

Each of these types of input is described in subparagraph c, below.

b. Source of Data Types and Responsibility for Accuracy. - Data to be input to the ODSAS system are collected from numerous Department of the Army personnel agencies. The respective agencies are responsible for providing current and accurate data as indicated in Table III-1.

TABLE III-1, Data Input Responsibilities

Type	Source of Data	Responsible Organization
1	PERSACS	ODCSPER (Manpower Programs Division)
2	MILPERCEN	Officer Personnel Management Directorate (MILPERCEN)
3	PERSACS	ODCSOPS (Force Accounting Systems Division)
4	Automatic Interaction Detector - Officers (AID-O) and Central Integrating Model - Officers (CIM-O)	Population - Officer Personnel Management Directorate (MILPERCEN) Rates - Personnel Information Systems Directorate (MILPERCEN)
	RCS DCSPER 407	ODCSPER
5	MILPERCEN	Personnel Information Systems Directorate (MILPERCEN)

c. Description of Input by Type

(1) Force requirement data for each type position (e.g., infantry battalion commander) are extracted from the PERSACS tape file. Data elements for each type position include:

(a) Authorized grade.

(b) Primary specialty.

(c) Alternate specialty.

(d) Effective date (date the position was/will be authorized).

(e) Termination date (date the position will be terminated, if any).

(f) Number of officer positions authorized.

The aggregate requirements by grade, primary specialty, and year are computed in the initialization phase by first checking each PERSACS record for grade and primary specialty. Then, after determining if the PERSACS termination date is later than the year of interest (for example, if T_2 is 1979, and the termination date is 1979 or after), the number authorized is included for the appropriate grade and specialty. The alternate specialty is present in approximately 15 percent of the records. If present, it indicates that the positions are dual-coded and thus require an officer with both specialties. The number and description of the dual-coded positions are accumulated and reported in the Positional Requirements Report (Output 6 of the initialization phase). This information can then be used to determine if the solutions satisfy requirements for officers with dual specialties.

(2) Data records on management policies are entered as input, on cards, by preferred specialty pairs. For each of the approximately 600 preferred specialty pairs, the utilization ratio of the specialty pair and the tour length of the primary specialty are required for the grades of COL through MAJ. Utilization and tour length for CPTs with more than 8 YOS are the same as for MAJs. CPTs with 8 or less YOS and LTs have repetitive assignments in the primary specialty. Each card contains the following information:

(a) Primary specialty number.

(b) Preferred alternate specialty number for the primary specialty of (a), above.

(c) Utilization ratio for COLs in the primary and preferred alternate specialty.

(d) Tour length for COLs in the primary specialty.

(e) Utilization ratio for LTCs in the primary and preferred alternate specialty.

(f) Tour length for LTCs in the primary specialty.

(g) Utilization ratio for MAJs in the primary and preferred alternate specialty.

(h) Tour length for MAJs in the primary specialty.

A preferred specialty pair is required in each of the field grades. This assures a source of officers with specialties "m" and "n" to meet future requirements in those specialties.

(3) The starting population for all grades, 2LT through COL, must be described by a beginning year of service (BGNYOS) indicating length of service of the most junior officer in that grade, and an ending year of service (ENDYOS) indicating the length of service of the most senior officer in that grade. A population, an attrition rate that includes promotion to the next higher grade, and an attrition rate that does not include promotion to the next higher grade are required for each year of service in the interval (BGNYOS through ENDYOS).

(4) Input parameters define the number of authorized OPMS specialties and the number of years in the projection period. Additionally, if any or all of the field grades are to be segmented, then the segments must be specified along with the additional input associated with segmentation (i.e., designation of primary specialties to be included in the first subsegment, and limits on degree of fill in alternate specialties).

3. Reports Generated. - The system produces both standard and optional output reports. In addition, reporting of as-required information to the user is provided in the form of an on-line inquiry capability.

a. Initialization Phase Reports. - In the initialization phase, there are two types of standard output reports.

(1) The first type contains the calculated requirements by specialty and by grade. Figure III-9 is a sample of the report

TOTAL REQUIREMENTS FOR SPECIALTY 49					
YEAR OF SERVICE	GRADE 0-2	GRADE 0-3	GRADE 0-4	GRADE 0-5	GRADE 0-6
T0	10	60	175	220	43
T1	11	82	190	225	47
T2	9	83	189	225	47
T3	9	83	193	225	47
T4	9	83	188	225	47
T5	9	83	189	225	47
T6	9	83	189	225	47
T7	9	83	189	225	47
T8	9	83	189	225	47
T9	9	83	189	225	47
TOTALS	93	806	1875	2245	466

FIGURE III-9, Sample PERSACS Requirements Report - by Specialty (for Specialty 49) on requirements by specialty and Figure III-10 is a sample of the report on requirements by grade.

(2) The second report type contains the derivation and computations used to produce all the input rates to the system. An excerpt from that report for LTCs is at Figure III-11. The numbers highlighted in heavy lines are examples of the rates input to the matrix generator. Both of the initialization phase reports are for user verification of the derived input data.

b. Processing Phase Reports

(1) There is one standard report and one optional report in the matrix generator activity. The standard report is a statistical summary, and the optional report contains the internal programing codes used in the matrix generator.

(a) The statistical summary contains the key data and characteristics of the problem to be solved. The first part of the statistical summary (Figure III-12) shows both the unfilled higher grade requirements (passed down from the preceding segment) and the requirements for the grade of the current segment. (The requirements data values may be greater than the actual computed requirements if the user opts to provide input directing that requirements may be overfilled by a percentage of the authorized value.) Requirements values in this summary report are used as the capacities of the nodes. Column 2 of the report (entitled PCT AUTH) contains the maximum percentage fill allowed for a specialty in that segment. The second part of the statistical summary (Figure III-13) shows the problem size, in terms of the total number of rows for each constraint type, and a summation of all constraints (rows). This total number of rows should match the matrix statistics produced by FMPS described in subparagraph (2) below. Additionally, the report displays key parameter values (number of specialties, number of years in the projection period, and number of preferences) applicable to the current segment.

(b) The optional report (not shown here) contains the codes generated and used within the matrix generator program. This report is provided for use in changing or debugging the program. Explanation of this report is in the ODSAS Information System documentation, published separately.

(2) Most of the printed output from the FMPS activity consists of diagnostic messages concerning FMPS internal logic at periodic intervals during processing, and is explained in the FMPS documentation (reference 2). The two outputs of primary concern are the matrix statistics and the detailed listing of the solution.

TOTAL REQUIREMENTS FOR GRADE 6

SPECIALTY	YEAR T-0	YEAR T-1	YEAR T-2	YEAR T-3	YEAR T-4	YEAR T-5	YEAR T-6	YEAR T-7	[illegible]R [illegible]3
11	250	264	263	262	262	262	262	262	
12	118	115	115	115	115	115	115	115	
13	186	184	183	183	183	183	183	183	
14	68	74	75	75	75	73	73	73	
15	4	4	4	4	4	4	4	4	[illegible]
21	137	136	139	137	137	137	137	137	[illegible]7
25	44	41	41	41	41	41	41	41	
26	33	33	33	33	33	33			
27	34	32	32	32	[illegible]				
28	4	3	[illegible]						
31								6	
						[illegible]	11	11	
				[illegible]	20	20	20	20	
			10	10	10	10	10	10	[illegible]
	9	8	8	3	3	[illegible]	8	8	8
91	78	80	80	73	73	73	78	73	79
92	117	112	113	111	111	111	111	111	111
93	38	36	36	35	35	35	35	35	75
95	37	46	46	44	44	44	44	44	
97	82	77	78	77	77	77	77	77	
98	310	323	325	321	321	321	321	321	321
TOTALS	3315	3333	3316	3279	3279	3277	3277	3277	3[illegible]

FIGURE III-10, Sample PERSACS Requirements Report - by Grade (for Grade 6)

••••OFFICERS GRADE-5 AT T-0••••						
YOS	STARTING POPULATION	RATE W/O PROM	RATE W/PROM	PROMOTIONS (POPULATION•RATE DIFFERENCE)	POPULATION LESS PRMT	ATTRITION IN GRADE
13-14	42.0	.0490	.0490	.00	42.00	2.06
14-15	142.0	.0300	.0300	.00	142.00	4.26
15-16	282.0	.0230	.0280	1.41	280.59	6.45
16-17	945.0	.0330	.0410	7.56	937.44	30.94
17-18	1564.0	.0350	.0500	23.46	1540.54	53.92
18-19	1380.0	.0730	.0990	35.88	1344.12	98.12
19-20	1483.0	.2640	.2990	51.91	1431.10	[illegible].81
20-21	1048.0	.2340	.5920	375.18	672.82	157.44
21-22	792.0	.2300	.3000	55.44	736.56	169.41
22-23	311.0	.2270	.2840	17.73	293.27	66.57
23-24	211.0	.2650	.2960	6.54	204.46	54.18
24-25	136.0	.1960	.2470	6.94	129.06	[illegible]
25-26	80.0	.3000	.3000	.00	80.00	24.00
26-27	60.0	.7060	.7060	.00	60.00	42.36
27-28	38.0	.3570	.3570	.00	38.00	13.57
TOTAL POPULATION	8514.0		TOTAL PROMOTIONS	582.04 TOTALS	7931.96	1126.38

ATTRITION RATE IN GRADE 1126.38/ 7931.96 = .1420

PROMOTION RATE 582.04/ 8514.00 = .0684

FIGURE III-11, Excerpt of Attrition and Promotion Rates Computation Report

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UNFILLED REQUIREMENTS FOR GRADE O-6

	PCT AUTH	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
SPECIALTY 11	100.00	0	74	103	156	199	228				
SPECIALTY 12	100.00	0	30	40	60	78	90				
SPECIALTY 13	100.00	0	45	65	92	115	131				
SPECIALTY 14	100.00	0	19	26	41	49	55				
SPECIALTY 15	100.00	0	1	1	2	3	3				
SPECIALTY 21	100.00	0	59	88	132	165	189				
SPECIALTY 25	100.00	0	11	18	26	31	34				
SPECIALTY 26	100.00	0	11	14	22	30	35				
SPECIALTY 27	100.00	0	11	15	23						
SPECIALTY 28	100.00	0									
SPECIALTY 31											
						30	35				
				1	2	2	2				

LTC UNSEGMENTED ODSAS DATE 031676 PAGE 8

REQUIREMENTS FOR GRADE O-5

	PCT AUTH	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
SPECIALTY 11	100.00	689	676	678	676	665	643				
SPECIALTY 12	100.00	331	332	331	331	327	321				
SPECIALTY 13	100.00	559	553	554	543	530	514				
SPECIALTY 14	100.00	289	271	255	252	250	246				
SPECIALTY 15	100.00	36	36	36	36	36	36				
SPECIALTY 21	100.00	499	503	502	500	498	496				
SPECIALTY 25	100.00	194	190	189	189	188	186				

FIGURE III-12, ODSAS Statistical Summary Report--Part 1

```
COLONEL UNSEGMENTED

 SEGMENT NUMBER **0** FOR GRADE EQUAL TO **6**



            CONSTRAINTS BY TYPE
        OBJECTIVE FUNCTION                  1
        FLOW CONSERVATION                 315
        REQUIREMENTS - TOTAL              225  (HIGHER GRADE =         0)
        CONTROL OF X-ARCS                3158
        CONTROL OF Y-ARCS(PROMOTEES)        0
        CONTROL OF INPUT                    8
        KEY ARC RELATIONSHIPS             316
            TOTAL CONSTRAINTS            4023


        NUMBER OF SPECIALTIES EQUAL        45
        NUMBER OF YEARS EQUAL               5
        NUMBER OF PREFERENCES EQUAL       632
```

FIGURE III-13, ODSAS Statistical Summary Report--Part 2

(a) A sample matrix statistics output is at Figure III-14. The number of rows should be the same as shown in the statistical summary report from the matrix generator activity.

(b) The detailed listing of the solution is normally written out to a computer disc file for retention, possible future printing, and user inquiry via a text editor. The solution is written in three sections: identifier, rows, and columns.

1. A sample identifier section is shown at Figure III-15. The figure reflects that the LP problem had an optimal status, the objective function (OBJECTIV) had a maximum value of 1814.444443, and 3043 iterations were required to solve the problem.

2. An excerpt of the rows section is at Figure III-16. All the rows have unique names which relate to constraint types. There are four formats for the row names.

a. Format 1. - This format consists of one alphabetic character for an identifier (N or W), one number for year, two numbers identifying specialty, and a four character alphabetic name. For example, N011TREQ is a constraint for year T_0, specialty 11, for the total requirements capacity. There are six possible four character names: GOZO, indicating flow conservation; CINC, indicating flow control for Y arcs where "from" and "to" specialty numbers are identical; LINC, indicating for X arcs the same as CINC indicates for Y arcs; UBSG, indicating control of input for specialties; and, CREQ and TREQ, which are both capacity constraints.

b. Format 2. - This format is one alphabetic character "R" and a five character numeric identifier of an X arc. For example, R01121 is a flow control constraint upon arc X_{01121}. The R-named rows restrict the flow in X arcs.

c. Format 3. - This format consists of three alphabetic characters "RES" and a five character numeric identifier of a Y arc. For example, RES01121 is a flow control constraint upon arc Y_{01121}. The RES-named rows restrict the flow in Y arcs.

d. Format 4. - Two alphabetic characters "UR", and a four character numeric identifier of a predefined specialty pair, e.g., UR1121 is a key arc relationship constraint constructed using the utilization ratio for specialties 11 and 21.

```
COLONEL UNSEGMENTED

   1 ••  1      TITLE  ODSAS FMPS COL - MAJ
   2 ••  2      CALL ENTER(LP,DUBLFMPS)
   3 ••         CALL INPUT

NAME            TESTFLOW

BUFFER SIZES (WORDS) ARE.. MATRIX =  4256 INVERSE =  3584

MATRIX STATISTICS
ROWS.........    4023
COLUMNS......    4105
RHS..........       1
DENSITY......     .17
MAX-COL-NZ'S      549
ELEMENTS....    27537
LARGEST.....   .333500+004
SMALLEST....   .228255-001
MAJOR ERRORS        0
MINOR ERRORS        0
```

FIGURE III-14, Sample Matrix Statistics Output from FMPS

```
COLONEL UNSEGMENTED

            ODSAS FMPS COL - MAJ

IDENTIFIER SECTION

         PROBLEM...  NAME..
                     MODE.. LP
                     CLASS. LP
                     STATUS OPTIMAL*
         FUNCTIONAL  NAME.. OBJECTIV
                     OBJECT MAXIMIZE
                     VALUE.      1814.444443
         RESTRAINT   NAME.. B-VECTOR
         ITERATION   COUNT.      3043
```

FIGURE III-15, FMPS Solution Output--Identifier Section

COLONEL UNSEGMENTED

ODSAS FMPS COL - MAJ

SECTION 1 - ROWS PRIMAL-DUAL OUTPUT

NUMBER	..NAME..	AT	...ACTIVITY...	SLACK ACTIVITY	.LOWER LIMIT	.UPPER LIMIT	.DUAL ACTIVITY	..INPUT COST..	.REDUCED COST.
1	OBJECTIV	FR	1814.444443	-1814.444443	NONE	NONE	-1.000000	.000000	-1.000000
2	W011G070	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
3	W012G070	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
4	W013G070	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
5	W014G070	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
6	W015G070	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
7	W021G070	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
110	N125TREQ	UL	45.000000	.000000	NONE	45.00000	.000000	.000000	.000000
111	N025G070	EQ	.000000	.000000	.00000	.00000	-.236415	.000000	-.236415
112	N025LINC	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
113	N126TREQ	UL	47.000000	.000000	NONE	47.00000	.000000	.000000	.000000
114	N026G070	EQ	.000000	.000000	.00000	.00000	-.236415	.000000	-.236415
115	N026LINC	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
116	N127TREQ	UL	46.000000	.000000	NONE	46.00000	.000000	.000000	.000000
117	N027G070	EQ	.000000	.000000	.00030	.00000	-.236415	.000000	-.236415
118	N027LINC	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
119	N128TREQ	UL	3.000000	.000000	NONE	3.00000	-.000000	.000000	.000000
120	N028G070	EQ	.000000	.000000	.00000	.00000	-.236415	.000000	-.236415
121	N028LINC	EQ	.000000	.000000	.00000	.00000	-.000000	.000000	.000000
122	N131TREQ	UL	49.000000	.000000	NONE	49.00000	.000000	.000000	.000000
123	N031G070	EQ	.000000	.000000	.00000	.00000	-.236415	.000000	-.236415
124	N031LINC	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
125	N135TREQ	UL	100.000000	.000000	NONE	100.00000	.000000	.000000	.000000
1085	UR9195	UL	4.100000	.000000	-4.10000	4.10000	.000000	.000000	.000000
1086	UR9197	BS	.000000	4.850000	-4.85000	4.85000	.000000	.000000	.000000
1087	UR9293	UL	4.925000	.000000	-4.92500	4.92500	.000000	.000000	.000000
1088	UR9295	BS	.000000	5.425000	-5.42500	5.42500	.000000	.000000	.000000
1089	UR9297	LL	-6.175000	12.350000	-6.17500	6.17500	.000000	.000000	.000000
1090	UR9597	BS	.000000	5.100000	-5.10000	5.10000	.000000	.000000	.000000
1091	RO1115	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
1092	RO1121	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000
1093	RO112A	EQ	.000000	.000000	.00000	.00000	-.000000	.000000	.000000
1094	RO1131	EQ	.000000	.000000	.00000	.00000	.000000	.000000	.000000

FIGURE III-16, FMPS Solution Output--Rows Section

The control of input constraint for total authorized strength (per grade segment) is called "TOTAUTH". Other control of input constraints are named according to Format 1, with year equaling 0, the appropriate specialty number, and a four character name "UBSG" (meaning an upper limit in segment 1). The rows of primary interest are those for node capacity (i.e., CREQ and TREQ), since all others except control of input constraints are specified as equalities to zero (for instance, flow conservation constraints require that the node input, less the node output, be equal to zero). If the row name ends in TREQ, then the capacity is for the current grade plus the unfilled higher grade. If the name ends in CREQ, then the capacity is for only the unfilled higher grade requirements. For each row dealing with node capacities the activity is the number of officers assigned to a specialty for a given year. The slack activity is the difference between the activity and the upper limit (node capacity) shown in column 5. The lower limit (column 6) would appear as a zero or "None" unless minimum level of flow into a node has been specified. Such a minimum is used in the CPT segment to require filling of at least the unfilled higher grade requirements. The data values in the three rightmost columns are used for post-optimality analysis.

3. The columns section (*Figure III-17*) is similar to the rows section in that there are corresponding columns for name, activity, lower and upper limits. For columns however, activity value represents the amount of flow (dual qualified officers) in a path segment described by the arc name. The input cost is the coefficient of a variable in the objective function. A value other than zero would appear only for the variables representing the arcs exiting the network. The variables have unique names, XN_{nn}, where N indicates the last year and nn is the specialty or node number. The lower and upper limit columns contain the minimum and maximum values, respectively, that the flow in the arcs may attain. The reduced cost values are used in post-optimality analysis.

(3) All printed outputs are optional in the on-line inquiry activity of the processing phase. By use of an appropriate set of MIRADS instructions, selected information on the status of a solution or solutions may be displayed on a computer terminal. If the terminal display is to be saved, then that image on the terminal display device can be printed. There are two general types of MIRADS statement sets: predefined and user-generated.

(a) The user may select a predefined set of MIRADS instructions, modify the predefined set, or compose a new set of instructions depending upon information needs. The predefined sets of instructions provide answers to the following types of questions:

COLONEL UNSEGMENTED

ODSAS FMPS COL - MAJ

SECTION 2 - COLUMNS PRIMAL-DUAL OUTPUT

NUMBER	..NAME..	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
4024	X00011	BS	558.177971	.000000	.000000	689.000000	.000000
4025	X00012	BS	178.000000	.000000	.000000	178.000000	.000000
4026	X00013	BS	225.756887	.000000	.000000	308.000000	.000000
4027	X00014	BS	91.281246	.000000	.000000	118.000000	.000000
4028	X00015	BS	8.300000	.000000	.000000	NONE	.000000
4029	X00021	BS	96.000000	.000000	.000000	96.000000	.000000
4030	X00025	BS	56.224984	.000000	.000000	NONE	.000000
4031	X00026	BS	48.452777	.000000	.000000	NONE	.000000
4032	X00027	BS	14.147396	.000000	.000000	NONE	.000000
4033	X00028	BS	1.612500	.000000	.000000	NONE	.000000
4597	W01591	BS	.000000	.000000	.000000	NONE	.000000
4598	W02191	BS	.000000	.000000	.000000	NONE	.000000
4599	W04191	BS	.000000	.000000	.000000	NONE	.000000
4600	W04291	BS	.000000	.000000	.000000	NONE	.000000
4601	W04391	**	-.000003	.000000	.000000	NONE	.000000
4602	W04591	BS	4.343748	.000000	.000000	NONE	.000000
4603	W04791	BS	2.312500	.000000	.000000	NONE	.000000
4790	X19797	BS	62.208576	.000000	.000000	NONE	.000000
4791	X21111	BS	154.832436	.000000	.000000	NONE	.000000
4792	X21212	BS	54.599618	.000000	.000000	NONE	.000000
4793	X21313	BS	85.941478	.000000	.000000	NONE	.000000
4794	X21414	BS	35.699173	.000000	.000000	NONE	.000000
4795	X21515	BS	1.895991	.000000	.000000	NONE	.000000
4796	X22121	BS	134.786160	.000000	.000000	NONE	.000000
4797	X22525	BS	15.647215	.000000	.000000	NONE	.000000
4798	X22626	BS	21.896703	.000000	.000000	NONE	.000000
4799	X22727	BS	27.301240	.000000	.000000	NONE	.000000
4800	X22828	BS	1.562078	.000000	.000000	NONE	.000000
8084	XN11	BS	70.631643	1.000000	.000000	305.000000	.000000
8085	XN12	BS	28.605311	1.000000	.000000	122.000000	.000000
8086	XN13	BS	43.106357	1.000000	.000000	178.000000	.000000
8087	XN14	BS	16.476624	1.000000	.000000	73.000000	.000000

FIGURE III-17, FMPS Solution Output--Columns Section

1. How many officers, by grade, should be in each preferred specialty pair? (EEA 1)

2. How many CPTs with 8 YOS should be designated specific alternate specialties?

3. How many officers, by grade and specialty pairs, are assigned against a specialty requirement at a specified time?

4. How much grade substitution is required for a given personnel policy?

Excerpts of reports answering these types of questions are at Figures III-18 through III-21, respectively.

(b) The user-generated type of MIRADS statement sets is limited only by MIRADS capabilities (explained in the MIRADS-2 Users Manual, published by Marshall Space Flight Center, NASA (reference 4)).

(4) One report is produced in the linkage activity of the processing phase. That report contains the requirements for the current grade and the unfilled higher grade requirements before and after the current segment's solution values have been determined (Figure III-22). Derivation of the unfilled requirements is not a simple subtraction of a node's activity from its capacity; attrition of those officers assigned at T_i also has to be considered when computing the unfilled requirements at T_{i+1}.

FROM SPECIALTY	TO SPECIALTY	GRD	ACTIVITY
11	21	6	14
11	37	6	9
11	41	6	126
11	43	6	8
11	51	6	13
11	53	6	9
11	54	6	283
12	31	6	45
12	48	6	9
12	49	6	39
12	51	6	9
12	53	6	5
12	54	6	11
12	91	6	14
12	92	6	6
13	15	6	1
13	21	6	124
11	48	5	222
11	54	5	128
12	45	5	2
12	46	5	108
12	47	5	35
12	54	5	159
13	51	5	88
13	54	5	364
13	71	5	41
12	41	4	90
12	54	4	36
13	21	4	38
13	31	4	270

FIGURE III-18, Excerpt of MIRADS Report for Number of Officers by Grade in Each Specialty Pair

YEAR	FROM SPECIALTY	TO SPECIALTY	ACTIVITY
0	11	21	233
0	11	43	15
0	11	48	111
0	11	71	54
0	11	97	21
0	12	15	19
0	12	35	87
0	12	46	39
0	13	21	99
0	13	31	16
0	13	54	159
0	13	91	37
0	13	92	85
0	14	49	50
0	14	73	62
0	14	97	19

0	92	25	170
0	92	72	29
0	93	82	4
0	95	97	24
0	97	95	17
1	11	15	33
1	11	28	13
1	11	31	193
1	11	35	62
1	11	47	80
1	12	47	90
1	12	53	37
1	13	15	59
1	13	92	287
1	14	49	66
1	14	52	30
1	14	73	19

1	91	53	65
1	92	51	143
1	92	83	31
1	93	83	3
1	95	51	21
1	97	91	15
2	11	28	55
2	11	54	376
2	12	35	144
2	13	31	11
2	13	37	129
2	13	49	130
2	13	97	122

FIGURE III-19, Excerpt of MIRADS Report on Specialty Designations for Captains

PAY-GRADE	FROM SPECIALTY	TO SPECIALTY	ACTIVITY
4	11	11	1879
4	15	11	67
4	21	11	164
4	28	11	2
4	37	11	4
4	42	11	170
4	43	11	7
4	46	11	18
4	48	11	80
4	49	11	13
4	51	11	24
4	53	11	79
4	54	11	180
4	71	11	4
4	92	11	17
4	93	11	9
4	97	11	22
5	11	11	520
5	28	11	4
5	41	11	44
5	42	11	9
5	46	11	18
5	48	11	23
5	48	11	52
5	49	11	22
5	53	11	16
5	54	11	13
5	54	11	28
6	11	11	256
6	21	11	2
6	37	11	1
6	41	11	43
6	43	11	1
6	48	11	15
6	51	11	1
6	53	11	1
6	54	11	40

FIGURE III-20, Sample MIRADS Display for Number of Officers by Grade and Specialty Pairs Assigned to Specialty 11

YEAR	GRD	FROM SPECIALTY	GRD-SUB
0	6	15	1
0	6	26	2
0	6	27	46
0	6	35	4
0	6	36	3
0	6	42	2
0	6	45	9
0	6	46	2
0	6	48	2
0	6	49	5
0	6	52	35
0	6	95	5
0	6	97	9
0	5	13	61
0	5	14	73
0	5	15	21
0	5	27	13
0	5	28	9
0	5	35	232
0	5	36	102
0	5	42	72
0	4	28	24
0	4	35	8
0	4	36	34
0	4	37	33
0	4	97	106
1	6	11	21
1	6	12	9
1	6	13	11
1	6	14	5
1	6	15	1
1	6	21	38
1	6	25	2
1	6	26	4
1	6	27	76
1	4	95	91
1	4	97	99
2	6	11	60
2	6	12	22
2	6	13	38
2	6	14	17
2	6	21	102
2	6	25	12
2	6	26	6
2	6	27	63
2	6	31	9

FIGURE III-21, Excerpt of MIRADS Report on Grade Substitution

REQUIREMENTS FOR GRADE 6 ••• BEFORE ••• DERIVING UNFILLED REQUIREMENTS

	T0	T1	T2	T3
SPECIALTY 11 REQUIREMENTS	283	281	281	281
SPECIALTY 12 REQUIREMENTS	111	113	113	113
SPECIALTY 13 REQUIREMENTS	175	172	172	167
SPECIALTY 14 REQUIREMENTS	75	70	68	67
SPECIALTY 15 REQUIREMENTS	4	4	4	4
SPECIALTY 21 REQUIREMENTS	231	225	226	226
SPECIALTY 25 REQUIREMENTS	45	41	41	41
SPECIALTY 26 REQUIREMENTS	42	43	43	43
SPECIALTY 27 REQUIREMENTS	42	42	43	43
SPECIALTY 28 REQUIREMENTS	3	3	3	3
SPECIALTY 31 REQUIREMENTS	45	45	45	45
SPECIALTY 35 REQUIREMENTS	92	91	90	90
SPECIALTY 36 REQUIREMENTS	33	29	29	29
SPECIALTY 37 REQUIREMENTS	42	41	41	41

REQUIREMENTS FOR GRADE 6 ••• AFTER ••• DERIVING UNFILLED REQUIREMENTS

	T0	T1	T2	T3
SPECIALTY 11 REQUIREMENTS	0	67	94	136
SPECIALTY 12 REQUIREMENTS	0	27	36	52
SPECIALTY 13 REQUIREMENTS	0	41	59	80
SPECIALTY 14 REQUIREMENTS	0	17	24	35
SPECIALTY 15 REQUIREMENTS	0	1	2	2
SPECIALTY 21 REQUIREMENTS	0	54	80	115
SPECIALTY 25 REQUIREMENTS	1	10	13	18
SPECIALTY 26 REQUIREMENTS	0	10	14	20
SPECIALTY 27 REQUIREMENTS	0	10	15	21
SPECIALTY 28 REQUIREMENTS	0	1	1	1
SPECIALTY 31 REQUIREMENTS	0	11	15	22
SPECIALTY 35 REQUIREMENTS	35	38	42	48
SPECIALTY 36 REQUIREMENTS	1	7	10	14
SPECIALTY 37 REQUIREMENTS	0	10	14	21
SPECIALTY 88 REQUIREMENTS	0	1	2	2
SPECIALTY 91 REQUIREMENTS	0	17	23	34
SPECIALTY 92 REQUIREMENTS	0	27	30	46
SPECIALTY 93 REQUIREMENTS	40	47	53	56
SPECIALTY 95 REQUIREMENTS	0	19	27	39
SPECIALTY 97 REQUIREMENTS	0	24	32	47

FIGURE III-22, Excerpt of Unfilled Requirements Derivation Report

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

CHAPTER IV
INTERPRETATION OF SOLUTIONS

1. General. - A series of separate though interrelated evaluations should be performed by the user in order to determine the acceptability of an ODSAS solution. The first type of evaluation involves each grade segment or subsegment. At this level, the solutions of interest pertain to the officers in each grade at T_0, and how the officers would be utilized in their dual specialties during the projection period. The second type of evaluation involves the complete officer segment across the entire projection period. This involves analyzing from two to four segment solutions. For instance, in order to evaluate the grade of COL, both the COL segment and the LTC segment have to be completed, since the source of COLs in the projection period includes the COLs at T_0, and those LTCs who are promoted to COL. A third type of evaluation considers all grades for all the years in the projection period. This latter is the overview where results of the interaction of management policies on attrition, promotion, and utilization with the force structure in the projection period are evaluated for appropriateness and/or acceptability.

2. Interpretation of Optimality

a. Ideally, a segment terminates with an optimal solution that represents the maximum flow through the network.* The optimal solution value is strongly influenced, if not determined, by the smallest capacity of any node through which the specialty pairs must pass. The authorized strength input by the user (total and by specialty) also influences the optimal solution value when the strengths are more constraining than the node capacities mentioned above.

---

*There are three types of LP solutions: 1) unbounded, 2) infeasible, and 3) optimal. Unbounded solutions (i.e., no limit to the value of the objective function) do not obtain in ODSAS because the network flow is sufficiently constrained. Infeasible solutions in ODSAS can only occur in segments where lower bounds are used to replace constraints (i.e., in the CPT and LT segments). An infeasible solution can result when too high an input to the network is specified by the lower bounds. After the user analyzes the reasons that the lower bounds are too high, an appropriate reduction in the lower bound value will produce an optimal solution.

AD-A037 456 ARMY CONCEPTS ANALYSIS AGENCY BETHESDA MD F/G 5/9

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM (ODSAS).(U)

APR 76 J D THOMAS, G E ARMSTRONG

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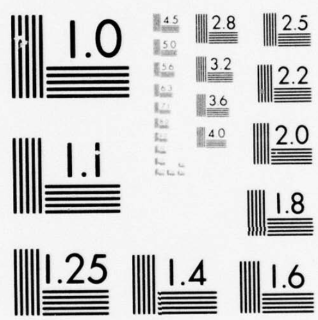

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(1) The optimal solution should satisfy all requirements at T_0 with the flow values representing the number of officers assigned to all the specialties. Such a solution indicates that the authorized strength levels can satisfy T_0 requirements and also that the flows into the nodes at T_0 can traverse the network from T_0 to T_N. Requirements beyond T_0 may not be satisfied in a segment's solution, since the officers at T_0 are subject to attrition and promotion. Additionally, if the requirements at T_1 and beyond exceed those at T_0 (i.e., if the smallest capacity is at T_0), then those additional requirements can only be filled by promotions from a lower grade, or by grade substitution.

(2) However, an optimal solution (i.e., maximum flow in the network) could also be obtained in which T_0 requirements are unfilled. The smallest node capacity in the paths and/or the authorized strength levels (mentioned above) could cause T_0 requirements to be unfilled in an optimal solution. The ODSAS employs a requirements-driven methodology; therefore, it does not manipulate requirements to improve the mathematical solution. Changing authorized strength levels in order to satisfy all T_0 requirements is a possible solution available to the personnel manager. The ODSAS does not depend upon level or increasing specialty requirements. If that were the case, then the smallest node capacity would be at T_0, and then only authorized strength levels less than requirements would be a problem.

(3) The changes in requirements over the projection period imply that the utilization ratios, tour lengths, and attrition and promotion rates should be synchronized to be compatible with the changing requirements. If they are not synchronized, then the smallest node capacity in a path creates what might be called a "bottleneck" in the network. A "bottleneck" is defined as a point in a path where the flow into a node either equals the total requirements, or exactly satisfies unfilled higher grade requirements without satisfying total requirements. If a bottleneck is encountered, then the flow into previous nodes in the path is less than or equal to that required. An illustration of a bottleneck is shown at Figure IV-1. Bottlenecks exist at nodes 41, 49, and 53 at T_1. The dashed line arcs depict the paths that are affected by the bottlenecks (dotted line arcs are explained later). Note that the requirements (capacity) of specialty 49 at T_0 (120 in this example) cannot be met by the flow in the possible input arcs coming from specialties 41 and 53 (i.e., the flow in arcs W_{04149} and W_{05349} only equals 100). Since the requirements of all the possible specialties that officers with specialty pairs 41/49 or 53/49 can go to are satisfied at T_1 (the sum of all flows into nodes 41, 49 and 53 at T_1 equals the node capacities), the result is insufficient flow into a node preceding the bottleneck in the path of the specialty pairs 41/49 or 53/49 (i.e., node 49 at T_0). One interpretation of an LP solution

involving a bottleneck is that more than the "optimal" number of officers are needed at T_0 in order to meet requirements from T_0 up to whenever the bottleneck occurs. In other words, there would eventually be an excess of officers if T_0 requirements were exactly satisfied and those flows continued in the network. Since an attrition factor is used to age the officers (flows) through the projection period, the excess would result in spite of expected attrition. The existence of a bottleneck condition is revealed in the "Slack Activity" column of the printed solution for the node capacity constraints at T_0 (Figure III-16). However, a bottleneck condition can be best observed through interrogating the MIRADS data base via the predefined query sets.

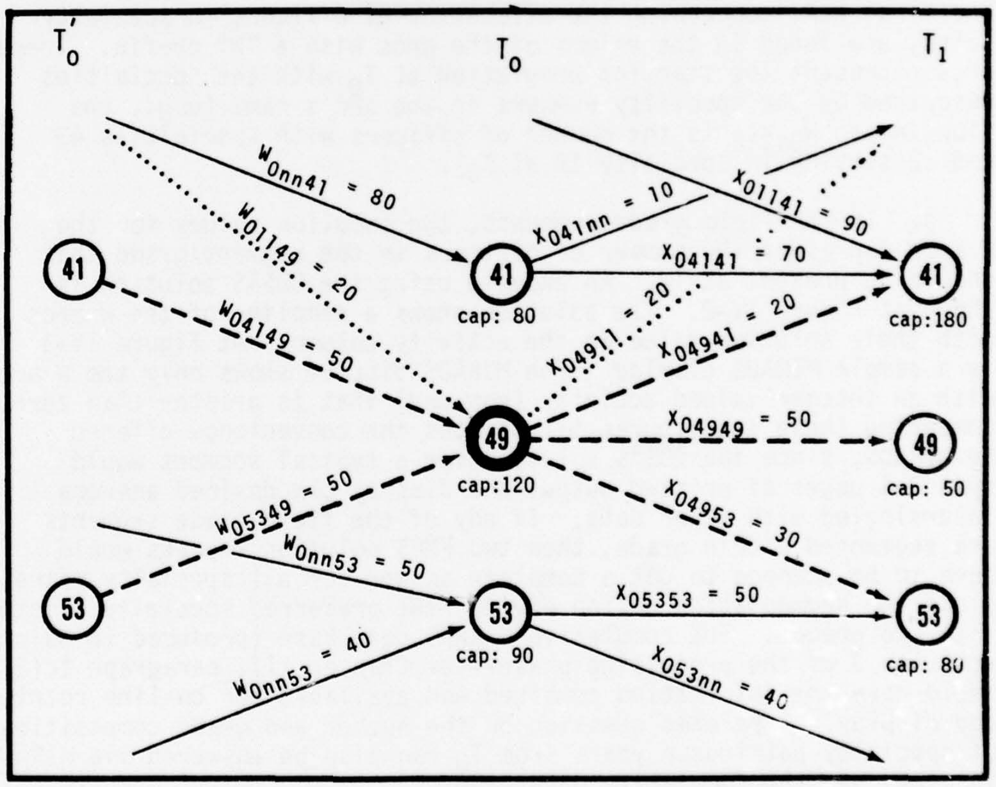

FIGURE IV-1, Illustration of a "Bottleneck" in the Network

b. Upon identifying a bottleneck, the user could investigate the possibility of whether a change to one or more of the management policies (input to the system) could resolve the situation. For instance, preferences could be changed or the utilization ratio for certain pairs could be altered to avoid or by-pass the bottleneck. As an example, referring to Figure IV-1, a preference of specialty 11 with specialty 49 could be added (dotted line arcs) with a utilization ratio such that 20 officers with specialty pair 11/49 would be in specialty 49 at T_0 (and thus meet the node 49 requirement at T_0); all 20 could then be reassigned to specialty 11 (assuming that there is excess capacity in specialty 11 and that no other constraints are violated). When an acceptable solution(s) is obtained, the answers to the EEA can be derived via the on-line inquiry capability and/or analysis of the FMPS solution reports. The following paragraphs detail how the three EEA and related questions are answered via the sequential processing of up to eight large linear programing problems (one for each possible ODSAS segment).

3. Allocation of Officers to Specialty Pairs. - The answers to the first EEA, concerning the allocation of officers to specialty pairs, are found in the values of the arcs with a "W" prefix. These arcs represent the starting population at T_0 with the specialties described by the specialty numbers in the arc's name (e.g., the flow in arc W_{04912} is the number of officers with specialties 49 and 12 serving in specialty 12 at T_0).

a. In the field grade segments, the solution values for the W arcs represent the number of officers in the segment/grade that should be present at T_0. An example using the ODSAS solution is shown at Figure IV-2. The solution shows a sampling of the W arcs with their solution value in the activity column. At Figure IV-3 is a sample MIRADS display. The MIRADS display shows only the W arcs with an integer valued activity (rounded) that is greater than zero. Comparing these two figures illustrates the convenience offered by MIRADS, since the ODSAS solution for a typical segment would span 3-4 pages of printed output and display the desired answers intermingled with other data. If any of the field grade segments are segmented within grade, then two FMPS solution reports would have to be scanned to get a complete answer for all specialty pairs, since the segmentation option divides the preferred specialty pairings into two groups. The cumulative MIRADS data base (produced in major activity 3 of the processing phase--see Chapter III, paragraph 1c(2)(b)3) would have the information combined and available for on-line retrieval and display. A related question on the number and grade composition of specialty pairings n years from T_0 can also be answered via MIRADS inquiry into the cumulative data base.

b. In the CPT segment, the solution values for the W arcs provide part of the answer to the first EEA. For CPTs some of the W arcs (i.e., those whose subscripts for "from" and "to" specialties are different) represent officers with 8 or more YOS at T_0. The remaining W arcs (i.e., those whose subscripts for "from" and "to" specialties are identical) represent CPTs with less than 8 YOS at T_0. The solution values of the former group are answers

COLONEL UNSEGMENTED

SECTION 2 - COLUMNS PRIMAL-DUAL OUTPUT

NUMBER	..NAME..	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
2723	W09715	AO	.000000	.000000	.000000	NONE	.000000
2724	W01121	BS	14.125000	1.000000	.000000	NONE	.000000
2725	W01321	BS	130.406256	1.000000	.000000	NONE	.000000
2726	W03521	BS	8.875000	1.000000	.000000	NONE	.000000
2727	W04121	BS	64.502058	1.000000	.000000	NONE	.000000
2728	W04221	BS	8.000000	1.000000	.000000	NONE	.000000
2729	W04521	BS	7.925018	1.000000	.000000	NONE	.000000
2730	W04721	BS	3.016667	1.000000	.000000	NONE	.000000
2731	W04821	BS	.000000	1.000000	.000000	NONE	.000000
2732	W04921	BS	7.550000	1.000000	.000000	NONE	.000000
2733	W05121	BS	.000000	1.000000	.000000	NONE	.000000
2734	W05221	BS	.000000	1.000000	.000000	NONE	.000000
2735	W05321	BS	.000000	1.000000	.000000	NONE	.000000
2736	W05421	BS	.000000	1.000000	.000000	NONE	.000000
2737	W09121	BS	.000000	1.000000	.000000	NONE	.000000
2738	W09221	BS	9.600000	1.000000	.000000	NONE	.000000
2739	W09721	AO	.000000	1.000000	.000000	NONE	.000000
2740	W02625	BS	.000000	.000000	.000000	NONE	.000000
2741	W02725	BS	8.633000	.000000	.000000	NONE	.000000
2742	W02825	BS	.000000	.000000	.000000	NONE	.000000
2743	W03725	BS	.000000	.000000	.000000	NONE	.000000
2744	W04125	BS	.000000	.000000	.000000	NONE	.000000
2745	W04225	BS	.000000	.000000	.000000	NONE	.000000
2746	W04525	BS	.000000	.000000	.000000	NONE	.000000
2747	W04625	BS	.000000	.000000	.000000	NONE	.000000
2748	W04725	BS	.785000	.000000	.000000	NONE	.000000
2749	W04825	BS	3.362500	.000000	.000000	NONE	.000000
2750	W04925	BS	.000000	.000000	.000000	NONE	.000000
2751	W05125	BS	.000000	.000000	.000000	NONE	.000000
2752	W05325	BS	.966667	.000000	.000000	NONE	.000000
2753	W05425	BS	.000000	.000000	.000000	NONE	.000000
2754	W07225	BS	.315000	.000000	.000000	NONE	.000000
2755	W09225	BS	29.604500	.000000	.000000	NONE	.000000
2756	W09725	AO	.000000	.000000	.000000	NONE	.000000
2757	W02526	BS	.000000	.000000	.000000	NONE	.000000
2758	W02726	BS	.000000	.000000	.000000	NONE	.000000
2759	W02826	BS	.000000	.000000	.000000	NONE	.000000
2760	W03726	BS	.000000	.000000	.000000	NONE	.000000
2761	W04126	BS	.000000	.000000	.000000	NONE	.000000
2762	W04226	BS	2.800000	.000000	.000000	NONE	.000000
2763	W04526	BS	.000000	.000000	.000000	NONE	.000000
2764	W04726	BS	.000000	.000000	.000000	NONE	.000000
2765	W04826	BS	.000000	.000000	.000000	NONE	.000000

FIGURE IV-2, Excerpt of ODSAS Solution for Allocation to Specialty Pairs as Displayed in FMPS Output

FROM SPECIALTY	TO SPECIALTY	GRD	ACTIVITY	RATIO
11	21	6	14	.667
11	37	6	9	.667
11	41	6	126	.600
11	43	6	8	.667
11	51	6	13	.750
11	53	6	9	.750
11	54	6	283	.600
12	31	6	45	.600
12	48	6	9	.833
12	49	6	39	.400
12	51	6	9	.667
12	53	6	5	.750
12	54	6	11	.500
12	91	6	14	.500
12	92	6	6	.667
13	15	6	1	.333
13	21	6	124	.600
95	86	6	26	.333
95	88	6	1	.167
95	91	6	15	.333
95	92	6	3	.600
97	11	6	4	.250
97	13	6	8	.500
97	14	6	30	.400
97	25	6	6	.333
97	26	6	40	.500
11	41	5	429	.600
11	42	5	3	.600
11	48	5	222	.600
11	54	5	128	.600
12	45	5	2	.600
12	46	5	108	.600
12	47	5	35	.833
12	54	5	159	.400
13	51	5	88	.600
13	54	5	364	.600
13	71	5	41	.500

FIGURE IV-3, Excerpt of ODSAS Solution for Allocation to Specialty Pairs as Displayed in MIRADS Output to the EEA. The latter group is the number of junior CPTs needed, at T_0, to fill CPT and unfilled higher grade requirements in the projection period.

(1) Beginning at T_0, some CPTs attain 8 YOS and thus are due to have alternate specialties designated. Although the determination of how many officers to designate into which specialties is not an EEA, it is an important ODSAS solution--ODSAS provides for designating alternate specialties according to requirements. However, the number of officers designated specific alternate specialties is not identified separately in any W, X, or Y arc, because CPTs with newly designated alternate specialties (those in their eighth YOS) are included in the flow of Y arcs (which represent CPTs with 8 or more YOS). The number to be designated each alternate specialty is presented in the rows section of the ODSAS printed solution (as illustrated in Figure IV-4). The values in the activity column of the printed solution (Figure IV-4) for the flow control constraints on the Y arcs (row names begin with "RES" followed by five numbers identifying the arc whose flow is to be controlled) are the alternate specialty designations.

(2) The activity values can also be found through interrogation of the CPT segment data base via MIRADS (Figure IV-5). The concept used in the ODSAS methodology (as explained in Appendix G) is to specify that the flow in a Y arc is at least equal to a fraction of an arc representing CPTs with more than 8 YOS. If there is any excess, then that amount represents the CPTs who were designated alternate specialties that year. The excess appears as the activity value of the appropriate flow control constraint. The identification of specialties is found in the name of the Y arc. For instance, assume that the following inequality was one of the constraints in the LP problem:

$$0.5 \times W_{04911} \leq Y_{01149}$$

This inequality implies: one-half of the CPTs with more than 8 YOS at T_0, who have specialties 49 and 11 (i.e., the left side of the inequality), is equal to or less than the number of CPTs with 8 or more YOS who are reassigned at T_0 from specialty 11 to specialty 49. Another equation in the ODSAS solution would specify that the other half of W_{04911} continued in specialty 11 from T_0 to T_1. If the solution values for W_{04911} and Y_{01149} were 100 and 67 respectively, then by substituting these values into the above inequality, the number of CPTs with specialty 11 to be designated alternate specialty 49, would be the excess of Y_{01149} over $(0.5 \times W_{04911})$. Therefore, 67 minus 50, or 17, equals the number of specialty 11 CPTs designated alternate specialty of 49 at T_0. This answer would be found in the rows section of the printed solution for the row name "RES01149."

CAPTAIN SEGMENT ODSAS

SECTION 1 - ROWS

PRIMAL-DUAL OUTPUT

NUMBER	..NAME..	AT	...ACTIVITY...	SLACK ACTIVITY	.LOWER LIMIT	.UPPER LIMIT	.DUAL ACTIVITY	..INPUT COST..	.REDUCED COST.
994	RES01115	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
995	RES01121	BS	-233.450378	233.450378	NONE	.00000	.000000	.000000	.000000
996	RES01128	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
997	RES01131	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
998	RES01135	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
999	RES01137	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1000	RES01141	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1001	RES01142	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1002	RES01143	BS	-15.174239	15.174239	NONE	.00000	.000000	.000000	.000000
1003	RES01145	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1004	RES01146	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1005	RES01147	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1006	RES01148	BS	-111.171082	111.171082	NONE	.00000	.000000	.000000	.000000
1007	RES01149	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1008	RES01151	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1009	RES01153	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1010	RES01154	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1011	RES01171	BS	-54.382123	54.382123	NONE	.00000	.000000	.000000	.000000
1012	RES01191	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1013	RES01192	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1014	RES01193	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1015	RES01197	BS	-21.354396	21.354396	NONE	.00000	.000000	.000000	.000000
1016	RES01215	BS	-19.349082	19.349082	NONE	.00000	.000000	.000000	.000000
1017	RES01228	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1018	RES01231	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1019	RES01235	BS	-87.007889	87.007889	NONE	.00000	.000000	.000000	.000000
1020	RES01241	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1021	RES01245	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1022	RES01246	BS	-39.025415	39.025415	NONE	.00000	.000000	.000000	.000000
1023	RES01247	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1024	RES01248	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1025	RES01249	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1026	RES01251	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1027	RES01253	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1028	RES01254	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1029	RES01271	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1030	RES01277	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1031	RES01291	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1032	RES01292	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1033	RES01297	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000
1034	RES01315	UL	.000000	.000000	NONE	.00000	.000000	.000000	.000000

FIGURE IV-4, Excerpt of ODSAS Solution for Alternate Specialty Designations for Captains as Displayed in FMPS Output

YEAR	FROM SPECIALTY	TO SPECIALTY	ACTIVITY
0	11	21	233
0	11	43	15
0	11	48	111
0	11	71	54
0	11	97	21
0	12	15	19
0	12	35	87
0	12	46	39

FIGURE IV-5, Excerpt of ODSAS Solution for Alternate Specialty Designations for Captains as Displayed in MIRADS Output

(3) The above example illustrates alternate specialty designation at T_0; designations in other years are found in the rows named RES_n_ _ _ _, where n is the year of interest, and the dashes represent the specialty numbers. A predefined MIRADS query set (set name is CPTDESIGN8) can be used to select the appropriate rows, and display the solution. The MIRADS CPTDESIGN8 query set is shown at Figure IV-6.

```
Q,ID = R and PREFIX = V AND YEAR GE 0 AND ACTIVITY GT 0
    (which means:  Find all row records for flow control constraints
                   for years T0 to TN whose activity value is greater
                   than zero)

S, YEAR, FROM, TO
    (which means:  Sort the row records found into specialty order
                   within year)

P,YEAR,FROM,TO, ACTIVITY
    (which means:  Print the year, primary specialty number alter-
                   nate, specialty number to be designated, and
                   number to be designated the alternate specialty)
```

FIGURE IV-6, MIRADS' CPTDESIGN8 Query Set

4. Procurement of Officers

a. The determination of the total procurement of officers (EEA 2), is computed by ODSAS at the completion of the LT segment. At the completion of each grade segment or subsegment, the number of unfilled requirements, by specialty, is computed and passed down to the next grade segment. The unfilled requirements computed at the satisfactory completion of the LT segment reflect the effects of the management policies on utilization, attrition, and promotion, and show the number of additional officers needed in each specialty.

The ODSAS solution for the W arcs (the input at T_0) represents how the current officer inventory should be aligned in the specialty pairs. Any disparity between the actual (current or projected) inventory and the ODSAS "optimal" allocation is a training question, not a procurement question (see paragraph 5 below).

b. The number of additional officers needed in the $T_0 - T_1$ interval is the unfilled requirements computed for T_1. Figure IV-7 is an example of the unfilled requirements report produced at the end of the LT segment. The numbers listed under the column headed "T-1" are the requirements that will be unfilled 1 year from T_0 if there is no input of 2LTs in the $T_0 - T_1$ interval. Conversely, that number represents the quantity of additional 2LTs needed in $T_0 - T_1$ to meet future requirements. The number to be procured in future years (e.g., in the $T_1 - T_2$ interval) can be derived using data in the same report; however, any procurement in prior years would have to be considered in arriving at the number to be procured in the year of interest. For instance, the unfilled requirements in the column headed "T-2" are computed on the basis that the only available sources of satisfying the T_2 requirements are those existing at T_0 and surviving to T_2. Procurement in the $T_0 - T_1$ interval which would provide an additional number of officers is not considered in the ODSAS computation of unfilled requirements. While the system does not consider the officer accessions in computing unfilled LT requirements, the system could be modified to accept anticipated accessions and "age" them in arriving at unfilled requirements n years from T_0.

5. <u>Insights into Determination of Training Requirements</u>. - Determination of training requirements (EEA 3) is not explicitly computed by ODSAS. Nevertheless, ODSAS provides insights into the training requirements question from three aspects.

a. The first insight concerns the training required for officers with more than 8 YOS. The ODSAS solution is not constrained to a known asset position (the reference population data input by the user is used only in the attrition and promotion rate computations); rather, the solution represents a recommended asset position. If the solution is acceptable to the personnel managers in ODCSPER and MILPERCEN, then any adjustments to the actual inventory of dual-qualified officers resulting from a comparison with the ODSAS solution could necessitate retraining of some officers--and thus affect training requirements. The identification of specific officers, and determination of the number to retrain are personnel management actions outside the scope of ODSAS.

REQUIREMENTS FOR GRADE 2 *** AFTER *** DERIVING UNFILLED REQUIREMENTS	T0	T1	T2	T3	T4	T5	T6
SPECIALTY 11 REQUIREMENTS	50	512	1020	1502			
SPECIALTY 12 REQUIREMENTS	86	275	613	863			
SPECIALTY 13 REQUIREMENTS	37	75	109	227			
SPECIALTY 14 REQUIREMENTS	13	166	293	426			
SPECIALTY 15 REQUIREMENTS	2	19	44	67			
SPECIALTY 21 REQUIREMENTS	28	315	631	956			
SPECIALTY 25 REQUIREMENTS	15	21	331	440			
SPECIALTY 26 REQUIREMENTS	2	9	18	28			
SPECIALTY 27 REQUIREMENTS	1	3					
SPECIALTY 28 REQUIREMENTS	1						
SPECIALTY 31 RE…				40			
SPECI…		15	31	49			
	1	7	15	21			
… REQUIREMENTS	9	93	178	278			
SPECIALTY 81 REQUIREMENTS	2	18	34	51			
SPECIALTY 82 REQUIREMENTS	0	5	11	14			
SPECIALTY 83 REQUIREMENTS	0	5	8	12			
SPECIALTY 86 REQUIREMENTS	0	4	7	10			
SPECIALTY 87 REQUIREMENTS	2	21	38	62			
SPECIALTY 88 REQUIREMENTS	26	61	124	180			
SPECIALTY 91 REQUIREMENTS	0	7	13	20			
SPECIALTY 92 REQUIREMENTS	38	89	164	209			
SPECIALTY 93 REQUIREMENTS	1	13	26	39			
SPECIALTY 95 REQUIREMENTS	0	1	2	3			
SPECIALTY 97 REQUIREMENTS	0	2	4	7			
SPECIALTY 98 REQUIREMENTS	0	2	12	26			

FIGURE IV-7, Example of Unfilled Requirements Report for Lieutenants (Grade 2)

b. The second insight into training requirements is derived from the solution values for specialty designations associated with CPTs. The solution specifies the number of CPTs, by BES, that should be designated specific alternate specialties in a particular year. With that information, the personnel managers will have advance knowledge of the specialties in which CPTs (with less than 8 YOS) should be trained and the time span to accomplish that training. For instance, the number of CPTs to be designated each alternate specialty in the T_1 - T_2 interval is contained in the ODSAS solution; this number indicates that, within 1 to 2 years, the appropriate number of CPTs who have 6-7 YOS at T_0 should be trained in the alternate specialties indicated in the solution.

c. The third insight on training requirements concerns the number of 2LTs to be procured. The ODSAS solution for LTs (1LTs and 2LTs are combined in ODSAS) provides procurement needs by specialty. Note that since procurement is, at present, legally restricted to be accomplished only by authorized "branches" (e.g., Infantry, Armor, Quartermaster), the procurement needs by specialty have to be translated by the personnel managers to the branch procurement needs. This information can be used to influence the selection of the new 2LTs brought on active duty (i.e., unfilled requirements indicate the skills needed by 2LTs). Advance information on needed skills could also impact on both the training of 2LTs on active duty and the training conducted before commissioning.

6. Operational Testing of ODSAS. - As a quality assurance measure, a test case with current actual data and a realistic problem description was constructed and input to the ODSAS system to allow the user to evaluate the system's performance. The input specified that all 46 OPMS specialties be considered for a 3-year projection period. The total number of preferred specialty pairings was 632 and T_0 was specified by the user as 1 January 1976. The processing of the field grade segments did not employ the segmentation-within-grade option. The size of the five LP problems and the computer time required were as shown in Table IV-1. The operational test with real data was actually processed and analyzed over a 10-day period. The observation was made that the amount of computer core memory required by FMPS (i.e., 128,000 words of core memory are required if the number of rows exceeds 3,500, otherwise 68,000 words), and the computer time necessary to solve the LP problems, make it desirable to schedule processing of the individual segments in non-prime time at MILPERCEN (i.e., other than 0800-1630 hours). The series of interrelated evaluations (paragraph 1 above) was conducted to assess the strengths and weaknesses of the solutions. The solutions to the segments were further analyzed via LP post-optimality procedures to assess the sensitivity of the solutions to changes in system input. The results of the testing are reported in Chapter V, Sensitivity Analysis.

TABLE IV-1, Summary Statistics of LP Problems Run During Operational Testing

Grade segment	Number of rows	Computer time (Hr:min:sec)
COL	2581	00:40:06
LTC	4702	04:10:33
MAJ	4702	04:10:33
CPT	2889	02:00:00
LT	465	00:10:22

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

CHAPTER V
SENSITIVITY ANALYSIS

1. General. - Each ODSAS grade segment will usually terminate in an optimal solution. (The exceptions and qualifications to an optimal solution were explained in Chapter IV, paragraph 2.) However, even the optimal solution(s) produced may vary depending on the segmentation options selected. For example, segmentation-within-grade is an optional procedure that can save computer time and, in some cases, may be the only way to obtain a solution. But a solution obtained without exercising the segmentation option may be significantly different than a solution for the same grade derived utilizing segmentation. In addition to the possible variances due to segmentation options, an optimal solution may also be sensitive to the input data. In this connection, variations in the force structure and in the computed annual attrition and promotion rates were explored to determine their impact on the optimal solution. Utilizing data supplied by MILPERCEN, a base case ODSAS solution was first obtained. Then sensitivity analyses were conducted to determine the impact upon the ODSAS solutions of segmentation, force structure changes, and the computed attrition and promotion rates. The results of those analyses are described in this chapter.

2. Impact of Segmentation-Within-Grade on ODSAS Solutions

a. In concept, when segmenting within grade, one subset of specialty preferences is processed in segment 1, and the remaining specialty preferences are processed in segment 2. This implies that the primary specialties in segment 1 are treated as if they compete among themselves for pairings with alternate specialties, and similarly, that the primary specialties in segment 2 are treated as competing among themselves for pairings with the alternate specialties of that segment. Furthermore, the specialty pairings which result from the ODSAS solution in segment 1 directly affect the availability of specialties for designation as alternates in segment 2--but segment 2 does not create a similar effect on segment 1. In contrast, the unsegmented processing mode provides for the simultaneous determination of all specialty pairs during one processing run. When utilizing the segmentation option, either segment may be considered to consist of two specialty subsets: primary specialties and specialties available for designation as alternates. If the primary specialties in either segment do not have preferred pairings with any specialties of the other segment (i.e., if specialties do not overlap), then the ODSAS solution using the segmentation option will be identical to the unsegmented solution. Identification and division of the specialties into two nonoverlapping subsets require specific knowledge of the preferred specialty pairings of each specialty, and a complex analysis to ascertain the composition of the subsets. As the number of preferred specialty pairings expands, there are increasing possibilities for any one specialty to be a preferred alternate for more than one other specialty. In the user-supplied base case data, it was observed that each primary specialty was associated with an average of 14 preferred alternate specialties--with some specialties having as few as four, and others having as many as 22 alternates. Two subsets with the special nonoverlapping characteristics described above could not be identified in the base case data since the number of preferred alternate pairs (632), and the analysis of the actual pairings specified, combined to preclude identification of nonoverlapping subsets.

b. The ODSAS system is designed to compensate partially for the variances in solution between the segmented and unsegmented processing modes.

(1) Arbitrary upper bounds on the requirements for the alternate specialties in segment 1 can be employed to reduce the variation in the sequentially derived solution of the segmented processing mode--compared to the unsegmented solution. Through this procedure a limit, lower than the specialty's actual requirements, can be specified as the maximum to be satisfied during processing of segment 1. This procedure guarantees that a minimum number of requirements are withheld for use in segment 2. If the upper bound was not reached in segment 1, then there would be more than the minimum available for segment 2. In actuality, these upper bounds, expressed as a percentage of the total requirements for a specialty, are a user influence on the requirements that drive the solution. If not selected carefully, the upper bounds can adversely affect the solutions. Consequently, the user must carefully consider the specification of these arbitrary upper bounds, and be prepared to justify the values selected.

(2) As expected, testing problems with the base case data resulted in different solution values for the W arcs (which answer EEA 1) between the unsegmented and segmented processing modes. For instance, a COL segment was run in both a segmented and an unsegmented mode (arbitrary upper bounds were not employed) and the solution values for the W arcs in each mode were different, examples are shown in Table V-1. In processing segment 1 (using the segmentation option), only 196 of the total 632 preferred specialty pairs

were considered for that segment's seven primary specialties (infantry, armor, field artillery, air defense artillery, engineer, law enforcement, and finance). The flows in the arcs considered in segment 2 were not a factor in arriving at an optimal solution for segment 1. For several specialties, requirements were completely met by the solution for segment 1. For example, at T_0 all the requirements for COL with specialty 49 (which was not a primary specialty in segment 1) were met by flows in the paths that included specialty 49. Consequently, only the primary specialties of segment 1 which preferred specialty 49 were paired with 49 in the ODSAS solution for COLs. The primary specialties in segment 2 could therefore not be paired with specialty 49 in the ODSAS solution, since that specialty's requirements were considered to be zero for segment 2.

TABLE V-1, Comparison of Selected Solution Values for W Arcs Derived in an Unsegmented and a Segmented ODSAS Processing Mode

Identification of W Arc (specialty pair)	Solution values	
	Unsegmented mode	Segmented mode
11/21	14.13	0.00
11/35	5.15	5.15
11/97	87.24	3.56
12/45	125.99	93.62
14/47	70.48	4.75
41/53	72.33	0.00
52.73	62.01	66.72
77/51	73.83	0.00
95/48	153.39	0.00
95/86	1.46	56.34

(3) Thus, the segmented mode provided different answers in the sample problems because the same constraints and interactions did not apply in both the segmented and unsegmented processing modes. Some of the differences are shown in Table V-1. Note that some solution values for the specialty pairs vary little between the two processing modes; whereas, for other specialty pairs, there

are larger differences in the number of officers allocated. As a result of testing and comparing the two segmentation options, it was determined that if segment 1 were increased in size (as measured by the number of preferred alternate specialties), then more interactions between specialty pairs would be introduced. This increased interaction would increase the similarity in solution values between the segmented and unsegmented processing modes.

3. Impact of Requirements and Computed Rates Upon the ODSAS Solutions. - Force structure requirements data and the promotion and attrition rates, the two primary user inputs, were evaluated as sensitive parameters. Sensitivity of the ODSAS solutions to these two types of input was evaluated in order to: 1) determine if selected changes in the force structure affect the base case allocation of officers to dual specialties; 2) observe the effects of changes in the attrition and promotion rates; and 3) establish procedures to answer "what if" type questions on possible changes in personnel policies or force structures, such as changes in promotion eligibility or expansion of specialty requirements in the force structure. The techniques used to evaluate variations in requirements and rates, and the results obtained, are explained in the subparagraphs below.

a. Sensitivity of ODSAS Solutions to Changes in Force Structure Requirements. - By design, ODSAS is a requirements-driven methodology; sensitivity of the solutions to changes in the force structure was evaluated to determine the effects induced by such changes. Since an LP solution technique is employed in ODSAS, standard LP post-optimality analysis procedures were considered for interpreting ODSAS solution sensitivity to changes in force structure requirements. However, post-optimality analysis is performed on the optimal solution value and the optimal value of the objective function does not address any of the EEA. Therefore, an analysis of the sensitivity of the objective function does not reveal changes in the answers to the EEA. An optimal ODSAS solution represents the maximum amount of flow that could traverse the network, measured at T_N, subject to all the stated constraints. In ODSAS, given the many possible inputs to each node (specialty), there may be many ways to accomplish the allocation problem. Possibly, more than one of these ways could yield solutions with the identical optimal values (called alternate optimal solutions). Due to the possibility of alternate optimal solutions, and the low utility of post-optimality analysis on the ODSAS objective function, the ODSAS sensitivity to changes in force requirements had to be evaluated using auxillary LP procedures. These procedures involved making modifications to the constraints upon the base case solution. The modified problem could then be solved by taking maximum advantage of the computations performed for the base case solution.

(1) The ODSAS solutions for the field grades (unsegmented) that were derived using the base case data were analyzed for selected changes in the force structure. This testing was performed to verify if, in fact, the solution was requirements-driven. If ODSAS were requirements-driven, then the solution values should: 1) be determined by the number of officers required in each specialty in each year of the projection period; and 2) change if the force structure changes. The results of the testing revealed that the ODSAS solutions do change whenever changes in force structure requirements occur, provided that the changes in requirements are not mitigated by the system constraints (e.g., control of input). For example, the base case COL segment was processed with the result that the control of input constraint for total authorized strength was a binding constraint. A constraint is "binding" if a change in the value of the "righthand side" of the constraint (Chapter II, paragraph 1a(2)) affects the optimal objective function value. Excerpts of the solution values for selected W arcs of that COL base case remain as shown in Table V-1. In the first sensitivity test, the requirements for specialty 49 at T_1 (arbitrarily selected) were increased by 20. The solution values for the flows in the W arcs did not change. The values did not change because the control of input constraint precluded any increase in flow representing COLs from entering the network to satisfy the increased requirement. The solution values for the W arcs in the LTC segment did change, however, since the increased requirements for COLs in specialty 49 at T_1 produced 20 additional unfilled requirements. These requirements, in turn, were passed to the LTC segment where they were satisfied by promotees or grade substitution. (The control of input constraint was not binding in the LTC segment for this test.)

(2) The original requirements for COLs with specialty 49 at T_1 were then decreased by 20. The base case solution and the solution of the modified problem for the affected W arcs are shown at Table V-2. A consequence of this decreased requirement was that the total of flows representing specialties paired with specialty 49 was decreased by 20. In the base case, the requirements for specialty 49 at T_1 were satisfied and all but six of the other specialty requirements at T_1 were also satisfied. The effect of reducing requirements for specialty 49 at T_1 was to reduce the flow in the preferred specialty pairs, including specialty 49, by 20.

TABLE V-2, Comparison of Solution Values for W arcs Derived with Base Case Data and with Modified Base Case Data

Identification of W Arc (specialty pair)	Solution values Base Case	Modified (reduced requirement)
11/49	0.00	0.57
12/49	17.65	0.00
13/49	0.00	0.00
14/49	0.00	0.00
15/49	0.65	0.65
21/49	0.00	0.00
25/49	0.00	0.00
26/49	0.47	0.47
35/49	1.24	1.24
37/49	0.00	0.00
71/49	0.68	0.68
73/49	0.45	0.45
74/49	0.00	0.00
75/49	6.00	5.93
77/49	0.00	0.00
91/49	0.02	0.00
92/49	17.65	14.82
95/49	0.68	0.68
	45.49	25.49

(3) If, as in the base case, any of the specialty requirements at T_1 were not satisfied, then a decrease in specialty 49 requirements at T_1 would appear in those preferred specialty pairs which include 49. But, because the LP algorithm maximizes flow through the network, there could be increases in the flows associated with nodes that were not satisfied. In other words, the reduction in one specialty's requirements could cause a reallocation of network flow in order to meet other specialty requirements. As shown in Table V-2, significant differences in solutions values caused by reducing the specialty 49 requirements by 20 occurred in W arc flows to specialty 49 from specialties 12 and 92. The flow from specialty 12 was reduced by 17.65, and from specialty 92 by 2.83. The resulting reallocation of flows from specialties 12 and 92 are as shown in Table V-3 (no other specialty pairings were affected). Note that the reduction in the flow to specialty 49 from either specialty 12 or 92 is not necessarily equal to increases in flows to other specialties (e.g., the flow from specialty 12 to 49 was reduced by 17.65, whereas the combined flow into 41 and 71 increased by 26.73). This illustrates one of the characteristics of the LP solution technique, i.e., that a single change to the constraints can cause a series of related changes affecting many flows.

TABLE V-3, Example of the Reallocation of Network Flows Resulting from Changes in Requirements

Primary specialty	Alternate specialty	Base case	Modified (reduced requirements)
12	41	38.02	64.02
12	49	17.65	0.00
12	71	24.12	24.85
92	49	17.65	14.82
92	82	6.21	1.75
92	83	4.90	11.93
92	93	0.00	18.74

(4) The sensitivity testing for changes in force level requirements included simultaneous changes in many specialty requirements. The above examples illustrate the results obtained. When many changes are introduced at one time, the interpretation and illustration of the result become more complex, since the effects of one change can be masked by the effects of the other changes.

It is conceivable that even minor changes in requirements could yield drastic changes in solution values. The effects of changes can be channelized by establishing upper and lower bounds based upon analysis of the original solution flows. However, by analyzing the results from introducing a limited number of changes, it was observed that the ODSAS solution does change as the requirements change. Further, more than one grade segment solution may be affected by those changes.

b. Sensitivity of ODSAS Solutions to Changes in Attrition and Promotion Rates. - The objective of this analysis was to test the sensitivity of the ODSAS solution to changes in the attrition and promotion rates. The effects of changes in these two types of rates, as employed in ODSAS, cannot be isolated from the interaction of the set of constraints in the linear program for each grade segment. Further, any changes to the ODSAS solution of one grade segment resulting from a change in attrition or promotion rates, can produce a ripple effect in the sequential processing of the following grade segments. The interaction of the five types of constraints (flow conservation, node capacities, flow control, control of input, and key arc relationships) strongly influence the effects of changes in the promotion and attrition rates, as noted below.

(1) Effects of changes in the annual promotion rates are subject to influences of the constraint set. The promotion rates, in effect, control the transition of flows from the X arcs to the Y arcs. However, two values associated with specialty requirements limit the effects of the promotion rate: 1) the unfilled requirements derived from processing a grade segment impose an upper limit on the number of officers that can be promoted in the next segment to be processed, and 2) the requirements for a specialty in a grade (e.g., the number of LTC spaces for specialty 11) equal the maximum number of officers that can be promoted from that specialty. To illustrate the first point, if the unfilled COL requirements for a specialty were 40, then no more than 40 LTCs could be promoted and assigned to that specialty. No matter how much the promotion rate were increased, the 40 unfilled requirements for the COL grade is the limit, in that specialty, on the number of LTCs promoted; thus beyond a point, the promotion rate has no influence on the ODSAS solution for a specialty pair. Where the unfilled COL requirements limit the promotions in one specialty, an increase in the promotion rate could be effective for other specialties, up to the point where all COL requirements are met; then, no additional promotions are permitted. Under these latter circumstances, further increases in the promotion rate would have no effect on the ODSAS solution. To illustrate the second point, for the same unfilled COL requirements mentioned above, if the requirements for LTC were 100, and if the

requirements were satisfied, then the promotion rate, multiplied by the requirement, is the maximum number of LTC that could be promoted. Assuming the annual promotion rate were 8 percent and flows in Y arcs (promotees) from four specialties (each with requirements for 100 LTC) could possibly satisfy the unfilled COL requirements, then no more than 32 (8 percent x 400) could be promoted. At least eight COL positions (40 unfilled COL requirements minus the maximum of 32 promotees) would therefore be filled with LTCs by grade substitution. In this instance, the available sources of promotees to COL were the limiting factors to the number promoted, and not the unfilled COL requirements.

(2) Effects of changes in the attrition rates are also subject to influences of the constraint set. In a manner analogous to the way changes in promotion rates are reflected in the ODSAS solution, the synergistic effects of requirements and flow control constraints can produce instances where changes in attrition rates have no effect on the ODSAS solution for a grade segment. Additionally, some specialty pairs may be affected by a change in the annual attrition rate, and others may not be affected at all due to the influences of other constraints and/or requirements.

(3) Analysis of the effects of changes in attrition and promotion rates must consider the possible mitigating conditions described above. Selected base case attrition and promotion rates were changed to observe the effects of the changes when compared with the base case solution. Analysis of the effects is more complex and time consuming than analyzing changes in force structure requirements.* The complexity results from attempting to isolate where the new solutions differ from expectations because of the mitigating effects of the constraints. For example, in one test, the attrition rates for each year in the projection period for the COL segment were increased by 10 percent of their original computed values. The maximum flow through the network did not change--however it could have. For example, if a bottleneck condition had existed in the network then the increased attrition would diminish the flow into the bottleneck node, and conceivably

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*The process is more time consuming because each annual attrition/promotion rate is used as a component in the computation of many coefficients for the linear equations. Thus, evaluation of changes in rates, in most cases, requires starting the solution process from the beginning, as opposed to the advanced position used in analysis of changes in force structure requirements (subparagraph 3a above).

increase the flow through the network. In this test, increased attrition rates for COLs resulted in more unfilled requirements being passed to the LTC segment. These, in turn, relaxed one of the limits on promotions (paragraph (1) above). Thus, for those LTC specialties with unfilled higher grade requirements completely satisfied in the base case increased attrition of COLs resulted in increased promotion opportunities for LTCs. For those LTC specialties in which promotees were limited by LTC requirements, the increased attrition of COLs had no effect. Also, in the absence of any logical bounds on the base case solution values, the test case LP solution was observed to have redistributed and reallocated some of the flows in the W arcs in order to arrive at the maximum flow through the network.

(4) An LP solution of the size considered by ODSAS is neither transparent nor subject to simple analysis; it is not within the scope of this study to interpret all the nuances of the changes. Suffice it to say that all the changes in solutions result from changes in input parameters; logical bounds can influence the degree of change in solution values and the new solutions derive from the interaction of 4000-6000 constraints acting upon the problem input.

4. Summary

a. Segmentation Sensitivity. - Sensitivity testing has revealed that the unsegmented processing mode is preferable to the segmented-within-grade mode. Differences in solution values resulting from sequentially solving two smaller LP problems versus one large LP problem led to the preference for the unsegmented mode. If the problem's size is too large to be processed in the unsegmented mode, then by judicious selection of specialties and arbitrary upper bounds for segment 1 (paragraph 2b), the segmented processing mode can yield results that approach those of unsegmented processing.

b. Input Sensitivity. - The analysis of sensitivity to changes in input (force structure requirements and attrition/promotion rates) revealed that ODSAS solutions change as the requirements change (it is requirements-driven) and also the solution is affected by changes in attrition and promotion rates. Additionally, the sensitivity of ODSAS to changes in input is subject to the influences of the total constraint set and the optimization function of the LP algorithm. In some instances, changes in input have a significant effect on the solution, whereas in other instances the solution does not change. The full impact of changes in input data is controlled in a nontransparent manner by one or more of the 4000-6000 constraints which act upon the LP problem for each grade segment.

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

CHAPTER VI
OBSERVATIONS

1. General

a. The first of two objectives for this study was to determine the feasibility of developing a methodology to analyze any given force structure and project officer requirements, by grade level, with a proper composition of primary and alternate OPMS specialties. Following a period of research, it was determined that the question of officer allocation was solvable by analogy to a network flow problem and that linear programing was an appropriate solution technique. The second objective was to develop a computer-based model that would assist OPMS managers in satisfying Army officer personnel requirements. Consequently, the ODSAS automated information system was designed to be utilized at MILPERCEN utilizing the UNIVAC computer hardware and linear programing software.

b. The ODSAS solution is driven by the requirements of any force structure specified by the user. The methodology is employed to compute the optimum number of officers for allocation to specific OPMS specialty pairings, consistent with the force structure requirements. The system addresses officer grades, from LT through COL, over a period of up to 9 years. The solution to each officer grade is computed in sequence, starting with the grade of COL. Attrition and promotion rates are applied to model, as realistically as possible, the changes in the composition of the officer corps expected to occur with the passage of time.

c. The ODSAS addresses the allocation of dual specialties at a macro level. That is, only the requirements for the total numbers of officers with specific dual specialties are computed. The assignment of individual officers to dual specialties is beyond the scope of ODSAS; that action remains the responsibility of the officer personnel managers at MILPERCEN.

2. Essential Elements of Analysis (EEA). - The EEA defined by the study directive and the responses to the EEA follow:

a. EEA 1

(1) EEA Statement. - In any given year, based upon the requirements generated by a given force structure, can the number

of officers to be allocated specific specialty pairings at each grade level, not to exceed the utilization ratio limits, be determined?

(2) EEA Response. - The number of officers allocated to specialty pairings is the solution value of specific flows in the networks representing the grades of CPT through COL. Designation of alternate specialties to CPTs attaining 8 YOS is accomplished in the CPT and LT segments.

b. EEA 2

(1) EEA Statement. - In any given year based upon the requirements generated by a given force structure, can the total procurement of officers by basic entry specialty (BES) be determined?

(2) EEA Response. - The total procurement of officers by BES is determined by computing the unfilled LT requirements at the end of the processing for that segment.

c. EEA 3

(1) EEA Statement. - In any given year based upon the requirements generated by a given force structure, can the training requirements for basic entry and alternate specialties to support the force be determined?

(2) EEA Response. - The user can derive the training requirements for BES and alternate specialties by comparing the actual officer asset position to the optimum position determined in ODSAS.

3. Observations. - During the conduct of this study several important observations were made; these observations are presented below.

a. The ODSAS can be used as a viable planning tool by officer personnel managers at MILPERCEN/ODCSPER to evaluate the following:

(1) The optimum composition of the officer corps based upon perceived force structure requirements.

(2) Alternative officer personnel management policies prior to implementation.

(3) The impact of projected force structure changes.

b. The use of ODSAS provides information to assist officer personnel managers in determining the following:

(1) The number of officers, by grade, to be allocated specific specialty pairings.

(2) The total procurement of officers by basic entry specialty.

(3) The training requirements to support the optimum composition of the officer corps.

c. The solutions for allocation of dual specialties to officers is driven by whatever force structure requirements the user specifies.

d. The large size of the linear programing problem was recognized early in the formulation of the ODSAS methodology. Any attempt to solve the LP problem without segmenting the processing would exceed the UNIVAC hardware and software capabilities at MILPERCEN.

(1) For a 5-year projection period, the LTC or MAJ segments approach the capacity of the UNIVAC computer and LP software.

(2) The ODSAS contains options to employ additional segmentation-within-grade. These procedures provide for processing the grades in two parts and mitigate the hardware and software limitations but impose burdens on the interpretation of the solution. Therefore, the additional segmentation-within-grade option is generally not preferred.

(3) Experience gained through operational testing with user supplied input data indicates that solution times are very long. The time required to obtain solutions of a grade segment ranges from 1 to 8 hours. Consequently, processing of all grade segments is likely to occur during non-prime time over a 1-week period.

e. The ODSAS solutions are sensitive to changes in the input data. The impact of input changes on the solutions is affected by the 4000 to 6000 constraints which act upon the LP problem for each grade segment. Therefore, it is difficult to predict the changes to the ODSAS solution resulting from changes in the input.

APPENDIX A

STUDY CONTRIBUTORS

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
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APPENDIX A
STUDY CONTRIBUTORS

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APPENDIX B

REFERENCES

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(ODSAS)

APPENDIX B
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APPENDIX C

GLOSSARY

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
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APPENDIX C
GLOSSARY

1. Abbreviations, Acronyms, and Short Terms

ADP	automatic data processing
AFCS	active federal commissioned service
CAA	Concepts Analysis Agency
COL	colonel
CONUS	Continental United States
CPT	captain
DA	Department of the Army
DCSPER	Deputy Chief of Staff for Personnel
DOPMS	Defense Officer Personnel Management System
EEA	essential elements of analysis
HUMINT	the intelligence collection function which uses human beings as both sources and collectors
LP	Linear Programing
LT	lieutenant
LTC	lieutenant colonel
MAJ	major
MILPERCEN	United States Army Military Personnel Center
MTOE	Modification Table of Organization and Equipment

NASA	National Aeronautics and Space Administration
ODCSOPS	Office, Deputy Chief of Staff for Operations and Plans
ODCSPER	Office, Deputy Chief of Staff for Personnel
OPD	Officer Personnel Directorate
OPMS	Officer Personnel Management System
ORSA	Operations Research/Systems Analysis
pct auth	percentage authorized
SACS	structure and composition system
SAG	Study Advisory Group
TDA	tables of distribution and allowances
TOE	table(s) of organization and equipment
1LT	first lieutenant
2LT	second lieutenant

2. Terms Unique to this Study

AES	advanced entry specialty
BES	basic entry specialty
BGNYOS	beginning year of service
CINC	unique suffix qualifier for name of one type of flow control for Y arcs
CREQ	unique suffix qualifier for name of capacity constraint on Y arc input to a node
SPEC-PAIRS	a standard MIRADS query set used to display specialty pairings

ENDYOS	ending year of service
LINC	unique suffix qualifier for name of one type of flow control for X arcs
NPREF	total number of preferred, or logical, specialty pairings considered in arriving at a solution
NSPEC	total number of authorized OPMS specialties
NYRS	number of years in projection period
OBJECTIV	objective function name
PROM	promotion
TREQ	unique suffix qualifier for name of capacity constraint (X+Y input)
UBSG	unique suffix qualifier for name of control of input constraint for specialties
YOS	year(s) of service

3. Computer Models, Routines, Simulations, Related Terms, and Definitions.

AID-O	Automatic Interaction Detector-Officers. A model which provides data on attrition rates and populations by grade and years of service.
CIM-O	Central Integrating Model-Officers. A model which provides data on attrition rates and populations by grade and years of service.
FMPS	Functional Mathematical Programing System
FORTRAN	Formula Translation (a computer language used in scientific applications)

MIRADS	Marshall Information Retrieval and Display System
MPS-X	Mathematical Programing System-Extended
ODSAS	Officer Dual Specialty Allocation System
PERSACS	Personnel Structure and Composition System
SPRINT	Specialized routine within FMPS which accelerates solution time

APPENDIX D

ATTRITION AND PROMOTION RATES COMPUTATION

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

APPENDIX D
ATTRITION AND PROMOTION RATES COMPUTATION

1. Introduction. - The ODSAS methodology is designed to assist in determining what the composition of the officer corps should be, by grade and specialty pairings, to satisfy a given force structure. The composition of the officer corps over time is subject to changes reflecting retirements, promotions, resignations, and similar occurrences. These changes are portrayed in the LP model via attrition, promotion, and continuation rates derived from user-supplied input data describing an officer corps population by grade and YOS.

2. Purpose. - This appendix contains descriptions of how attrition, promotion, and continuation rates are derived for the ODSAS system. The descriptions include requirements for user-supplied input data, an explanation of how the automated system computes the rates from the input data, and examples of the output produced by the system.

3. Underlying Assumptions

a. The four assumptions on which the ODSAS system was based are set forth in Chapter I, paragraph 5. The first two of those assumptions, reiterated below, are applicable to the computation of attrition and promotion rates.

(1) Attrition/Promotion. - All officers within a grade and year of service (YOS) population have an equal opportunity for promotion and are equally susceptible to attrition, without regard to their specialties, i.e., for a given grade, attrition and promotion are functions of the YOS distribution only. This implies that all YOS are represented proportionately in each specialty.

(2) Applicability of Attrition/Promotion Rates. - Annual attrition and promotion rates (percentages) are used to "age" the population of a given grade across the time span being analyzed. In calculating the annual attrition and promotion rates, the rates (input by the user) for a YOS within a given grade are assumed to be valid for any population which attains that grade and YOS. For example, if an attrition rate of 20 percent per year applies for COLs with 22 YOS in the first year (T_1), that rate also applies 3 years later (T_4) for COLs who attain 22 YOS.

b. The first assumption above reflects one of the fundamental precepts of the OPMS system--that all officers of a given grade have equal opportunity for promotion and professional development, regardless of specialties. As stated in the assumption, promotion opportunity equity and equal susceptibility to attrition necessarily require that each grade and YOS group be represented proportionately in each specialty.

c. The second assumption above specifies that, in the absence of any foreknowledge of changes in attrition/promotion patterns, experience gained with the reference officer population (as reflected in the user input) regarding attrition, promotion, and continuation will be applicable in future years.

4. General Concept Used in Deriving Attrition and Promotion Rates

a. The network algorithm requires that attrition and promotion rates be applied as percentages of the total population leaving a node within a particular grade segment. Since the total population leaving a node is made up of officers with various YOS, the attrition and promotion rates must reflect the relative proportion of each YOS group. The ODCSPER's CIM-O and AID-O models provide data on attrition rates and populations by grade and YOS. The ODSAS uses these data to compute annual weighted average (by population density by year) attrition and promotion rates. The concept of a weighted average attrition/promotion rate, as opposed to a simple arithmetic average, was employed to reflect 1) the varying sizes of the YOS populations within the total officer grade population, and 2) varying proportions of the population represented by each YOS group within that grade, with the aging of each YOS group during the projection period. For instance, at T_0, COLs with 20 YOS may represent 15 percent of the total COL population, whereas at T_1 that same group would have 21 YOS and might comprise a different proportion of the COL population. These time dependent differences are reflected in the annual attrition and promotion rates computed from the user input in the initialization phase of ODSAS and are displayed in the Attrition and Promotion Rates report (Chapter III, paragraph 3a(2)). The derivation of the rates is explained in paragraphs 5 through 8 below. The examples used to illustrate the rate derivations for each grade reflect only the computation of the rates needed in the T_0 - T_1 interval; however, the rates needed for each interval in the projection period are computed by the same process and displayed in the Attrition and Promotion Rates report produced by ODSAS.

b. The general concept described above is applicable in computing the rates for all grade segments, COL through LT; however, in three grades (i.e., COL, CPT and LT) there are unique characteristics which require modification of the general concept. The application of the concept for each of the officer grades is described in the following paragraphs. Since the basic procedures to implement the concept apply in the case of the LTC and MAJ grades, procedures for those two grades are described first; computations in the other grades employ modifications to the basic procedures.

5. Derivation of Attrition and Promotion Rates for Lieutenant Colonels and Majors

a. Inputs. - The user input required to compute the annual attrition and promotion rates consists of the following data on a reference population; Table D-1 is used as an illustration.

(1) Number of officers by grade and YOS ("YOS" and "Starting Population" columns in Table D-1).

(2) Attrition rate, by YOS within grade, excluding promotion as a form of attrition. ("Rate w/o Prom" column in Table D-1).

(3) Attrition rate, by YOS within grade, with promotion included as a form of attrition ("Rate w/Prom" in Table D-1).

TABLE D-1, Example of User Input for Grade 4

Officers Grade 4 at T_0			
YOS [a]	STARTING POPULATION	RATE W/O PROM	RATE W/PROM
8- 9	.0	.0470	.0470
9-10	40.0	.0340	.0510
10-11	343.0	.0290	.0330
11-12	2300.0	.0230	.0300
12-13	2156.0	.0240	.0700
13-14	2161.0	.0260	.0910
14-15	2275.0	.0900	.1770
15-16	1821.0	.0410	.6830
16-17	929.0	.0900	.4060
17-18	.0	.0780	.3210
18-19	.0	.1880	.2210
19-20	.0	.6700	.6790
20-21	.0	.6880	.6880
TOTAL POPULATION	12025.0		

[a] Values for the YOS indicate the interval starting with the lower year number and ending immediately prior to the higher year number (i.e., 8-9 indicates officers who are in their eighth YOS).

b. <u>Calculation for Year T_0</u>. - Given these initial input data, the annual attrition and promotion rates are produced by a three-step process:*

(1) In the first step, a weighted average promotion rate and a weighted average attrition rate for each grade are computed. Computations are described in subparagraphs (a) and (b) below, and are illustrated in Table D-2, using the same input data as in Table D-1.

(a) Since the user-supplied attrition "rate with promotion" represents the rate of loss due to all causes, while the "rate without promotion" represents losses due to all causes except promotion, the difference between the two rates is the promotion rate. The weighted average promotion rate therefore is computed by first multiplying the number of officers in each YOS group within that grade by the difference between the two attrition rates, to find the number promoted in each YOS. The promotions, by YOS, are then summed across all YOS represented, and divided by the total starting population.

(b) The weighted average attrition rate, for those remaining in grade, is computed by first subtracting the promotions in each YOS group from the starting population for that YOS group, and multiplying the difference by the attrition rate without promotion. The attrition for those remaining in grade is then summed across all YOS represented and divided by the total starting population less the total promotions.

(2) In the second step, an attrition rate is computed for officers who have been promoted to the next higher grade in the interval T_0 - T_1. The computations are described below, and are illustrated in Table D-3 (which is a continuation of the computations in Table D-2 for the annual rates used for the year beginning at T_0 and ending at T_1).

(a) The new promotees in each YOS (computed in the first step (subparagraph (1) above), and shown in the "Promotions

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*The input data for the number of officers, by grade and YOS, is required as a basis for defining the relative proportions of the YOS groups in the total officer population by grade, and is used only in the initial year (T_0 - T_1) computations. For subsequent years the populations remaining in the YOS groups are computed by ODSAS. The input data for attrition rates, however, are used in all computations to "age" all officers attaining the grade and YOS for which the rate applies.

TABLE D-2, Sample Attrition and Promotion Rates Report for Grade 4 at T_0

....OFFICERS GRADE-4 AT T-0....

YOS	STARTING POPULATION	RATE W/O PROM	RATE W/PROM	PROMOTIONS (POPULATION*RATE DIFFERENCE)	POPULATION LESS PRMT	ATTRITION IN GRADE
8- 9	.0	.0470	.0470	.00	.00	.00
9-10	40.0	.0340	.0510	.68	39.32	1.34
10-11	343.0	.0290	.0330	1.37	341.63	9.91
11-12	2300.0	.0230	.0300	16.10	2283.90	52.53
12-13	2156.0	.0240	.0700	99.18	2056.82	49.36
13-14	2161.0	.0260	.0910	140.47	2020.54	52.53
14-15	2275.0	.0900	.1770	197.92	2077.08	186.94
15-16	1821.0	.0410	.6830	1169.08	651.92	26.73
16-17	929.0	.0900	.4060	293.56	635.44	57.19
17-18	.0	.0780	.3210	.00	.00	.00
18-19	.0	.1880	.2210	.00	.00	.00
19-20	.0	.6700	.6790	.00	.00	.00
20-21	.0	.6880	.6880	.00	.00	.00
TOTAL POPULATION	12025.0		TOTAL PROMOTIONS	1918.36	TOTALS 10106.64	436.53

ATTRITION RATE IN GRADE 436.53/ 10106.64 = .0432

PROMOTION RATE 1918.36/ 12025.00 = .1595

TABLE D-3, Sample Report of Attrition Rates for Officers Promoted Between T_0 and T_1

****ATTRITION RATES FOR GRADE O-4 UPON PROMOTION TO O-5

YOS	O-5 PROMOTED BEFORE T-0	NEW-PROMOTEES	TOTAL PROM	ATTR. RATE FOR GRADE-5	ATTRITION
8- 9	.0	.00	.00	.0000	.00
9-10	.0	.68	.68	.0000	.00
10-11	.0	1.37	1.37	.0000	.00
11-12	.0	16.10	16.10	.0000	.00
12-13	.0	99.18	99.18	.0000	.00
13-14	.0	140.47	140.47	.0490	6.88
14-15	.0	197.92	197.92	.0300	5.94
15-16	.0	1169.08	1169.08	.0230	26.89
16-17	.0	293.56	293.56	.0330	9.69
17-18	.0	.00	.00	.0350	.00
18-19	.0	.00	.00	.0730	.00
19-20	.0	.00	.00	.2640	.00
20-21	.0	.00	.00	.2340	.00
TOTALS	.0	1918.36	1918.36		49.40

ATTRITION RATE IN GRADE 5 = 49.40 / 1918.36 = .0257 column in Table D-2) must be added to those officers who had already been promoted to the next higher grade from T_0 up to the year being considered. Since the promotions commence at T_0 in this example, the values in the column "0-5 Promoted Before T-0" in Table D-3 are necessarily zero because the system considers that T_0 is the beginning of all activity. However, the population values which will appear in this column for subsequent years will reflect promotees from earlier years. The total promotees at T_0 ("Total Prom" column) are therefore comprised of only the "New-Promotees" in each YOS represented. The total number promoted, by YOS, is then multiplied by the user-supplied input attrition rate ("Attr. Rate for Grade-5" Column) for officers of that grade and YOS, to compute the number attrited in that grade and YOS ("Attrition" column).

(b) The values in the "Total Prom" and "Attrition" columns are each summed across all YOS represented. The "Attrition" total (49.40 in Table D-3) is divided by the "Total Prom" sum (1918.36 in Table D-3) to compute an attrition rate for those officers promoted.

(3) In the third step of calculating attrition and promotion rates, the starting population at T_0 must be "aged" to reflect the attrition and promotion that occurred in the T_0 - T_1 interval, to arrive at the starting population at T_1.

(a) This procedure consists of subtracting the promotions and the attrition in grade from the T_0 starting population, by YOS, to arrive at the amount of that YOS group remaining at T_1. Table D-4 illustrates the "aging" of the populations presented in Tables D-1 through D-3. In Table D-4, the "Starting Population" of 331.7 MAJs in their 11th YOS at T_1, represent the 343.0 "Starting Population" in their 10th YOS at T_0 (in Table D-2), less "Promotions" of 1.37 at T_0 (in Table D-2) and "Attrition in Grade" of 9.91 (in Table D-2). Similarly the "Starting Population" with 13 YOS at T_1 (Table D-4), 2007.5, represents the "Starting Population" with 12 YOS at T_0 (Table D-2), 2156.0, less "Promotions" of 99.18 and "Attrition in Grade" of 49.36.

(b) An exception to the "aging" procedure is employed for the last YOS represented in a grade (i.e., the 20-21 YOS line in Table D-4). The values on this line include that YOS and later YOS, for computation purposes (which, in Table D-4, are both zero and are therefore not readily apparent). When the values on this line are non-zero, in computing the starting population with 20 YOS and over, at T_1, that population is the sum of the starting populations at T_0 with 19-20 YOS plus those with 20-21 YOS and over, less promotions and attrition in grade for both groups. For example, if the "starting population" of the 19-20 and 20-21 (and over) YOS groups at T_0, in Table D-2, were 13.0 and 3.0, respectively; "Promotions", 0.12 and 0.00; and "Attrition in Grade" 8.63 and 2.06, then the "Starting Population" for the 20-21 YOS group line in Figure D-4 (representing the population with 20 YOS and over) would be 5.31. This value would have been computed by adding together the "Starting Population" of the 19-20 and the 20-21 (and over) YOS groups at T_0 from Table D-2 (i.e., 13.0 + 3.0 = 16), subtracting the combined "Promotions" (0.12 + 0.00 = 0.12), and the combined "Attrition in Grade" (8.63 + 2.06 = 0.69); or (16.0 - 0.12 - 0.69 = 5.31). The value 5.31, the "Starting Population" for the 20-21 YOS line, when rounded to the nearest one tenth, would be 5.3.

c. Calculation for Subsequent Years. - Upon completion of the three-step procedure in b above, the attrition and promotion rates for each subsequent year in the projection period are computed, applying the same three-step procedure to the attrition rates supplied by the user and the starting populations derived in b.

6. Derivation of Attrition and Promotion Rates for Colonels. - The three-step procedure described in paragraph 5 for producing annual attrition and promotion rates for LTCs and MAJs is modified to a two-step procedure for COLs. Weighted average promotion rates and attrition rates for COLs promoted to general officer are not needed for the COL segment, because general officer grades are not included in ODSAS. Consequently, the annual attrition rates for COL are computed in a manner similar to the attrition rate for LTCs or MAJs remaining in grade, except that the COL attrition rate for each YOS represented includes promotion as a form of attrition. Attrition rates for LTCs/MAJs remaining in grade do not include promotion as a form of attrition (paragraph 5b(1) (b) above).

a. The first step is to multiply each YOS population by the corresponding rate with promotion. Computations are illustrated at Table D-5. The values in the "Population" and "Rate w/Prom" columns, which are extended as input by the user, are multiplied to produce the attrition by YOS shown in the "Population * Rate w/Prom" column. The population values and the attrition values are summed across all YOS represented, to produce the column totals shown. Then the total "Attrition" is divided by the "Population Sum" to produce the "Attrition Rate" in grade 6 for that year.

b. The second step is the same as the third step in the process described in paragraph 5. That is, the COL population with n years of service, less the attrition of those with n years of service, becomes the COL population 1 year later, with n+1 YOS. Table D-6 illustrates the "aging" of the COL population at T_0 to a point 1 year later (T_1). (Note: The last YOS group (i.e., 29-30)

TABLE D-4, Sample Report on Effect of Attrition and Promotion on the "Aging" of the Officer Population

****OFFICERS GRADE-4 AT T-1****

YOS	STARTING POPULATION	RATE W/O PROM	RATE W/PROM	PROMOTIONS (POPULATION*RATE DIFFERENCE)	POPULATION LESS PRMT	ATTRITION IN GRADE
9-10	.0	.0340	.0510	.00	.00	.00
10-11	38.0	.0290	.0330	.15	37.83	1.10
11-12	331.7	.0230	.0300	2.32	329.40	7.58
12-13	2231.4	.0240	.0700	102.64	2128.73	51.09
13-14	2007.5	.0260	.0910	130.48	1876.98	48.80
14-15	1968.0	.0900	.1770	171.22	1796.79	161.71
15-16	1890.1	.0410	.6830	1213.47	676.67	27.74
16-17	625.2	.0900	.4060	197.56	427.63	38.49
17-18	578.2	.0780	.3210	140.51	437.73	34.14
18-19	.0	.1880	.2210	.00	.00	.00
19-20	.0	.6700	.6790	.00	.00	.00
20-21	.0	.6880	.6880	.00	.00	.00
TOTAL POPULATION	9670.1		TOTAL PROMOTIONS	1918.36 TOTALS	7711.75	370.65

ATTRITION RATE IN GRADE 370.65/ 7711.75 = .0481

PROMOTION RATE 1918.36/ 9670.11 = .1984

TABLE D-5, Sample Report of Results of ODSAS Computation of the Weighted Average Attrition Rate for Colonels

••••OFFICERS GRADE-6 AT T-0••••

YOS	POPULATION	RATE W/PROM	ATTRITION (POPULATION•RATE W/PROM)
17-18	6•0	•1390	•83
18-19	21•0	•0790	1•66
19-20	70•0	•1150	8•05
20-21	132•0	•0620	8•18
21-22	241•0	•0600	14•46
22-23	510•0	•1000	51•00
23-24	464•0	•1540	71•46
24-25	577•0	•1950	112•51
25-26	465•0	•2280	106•02
26-27	343•0	•2110	72•37
27-28	283•0	•3480	98•48
28-29	164•0	•3220	52•81
29-30	59•0	•5170	30•50
POPULATION SUM	3335•0	ATTRITION	628•35

ATTRITION RATE IN GRADE 6 = 628.35 / 3335.0 = .1884

TABLE D-6, Sample Report on Effect of the "Aging" Process on the Colonel Population

••••OFFICERS GRADE-6 AT T-1••••

YOS	POPULATION	RATE W/PROM	ATTRITION (POPULATION•RATE W/PROM)
18-19	5•2	•0790	•41
19-20	19•3	•1150	2•22
20-21	62•0	•0620	3•84
21-22	123•8	•0600	7•43
22-23	226•5	•1000	22•65
23-24	459•0	•1540	70•69
24-25	392•5	•1950	76•55
25-26	464•5	•2280	105•90
26-27	359•0	•2110	75•74
27-28	270•6	•3480	94•18
28-29	184•5	•3220	59•41
29-30	139•7	•5170	72•22
POPULATION SUM	2706•7	ATTRITION	591•25

ATTRITION RATE IN GRADE 6 = 591.25 / 2706.7 = .2184 is computed in a manner similar to that described for LTCs and MAJs in paragraph 5b(3)(b) to include all COLs with 30 or more YOS.

7. Derivation of Attrition and Promotion Rates for Captains

a. The same general concept as applied for LTCs and MAJs also applies for CPTs; however, there are three significant methodological refinements employed in the CPT segment, which in turn cause changes in the procedures for rate computations. The three refinements are:

(1) The X arcs represent only CPTs with less than 8 YOS.

(2) Alternate specialty designation for CPTs attaining 8 YOS imposes an additional requirement which must be represented in the network.

(3) Promotion to MAJ is implicitly represented in the network (Y arcs represent both CPTs with 8 or more YOS and CPTs promoted to MAJ; however the attrition rates employed for the Y arcs are computed by explicitly considering promotion rates from CPT to MAJ and attrition rates applicable to both groups).

b. Since the X arcs in the CPT segment represent only officers with less than 8 YOS (and therefore with only one specialty), an attrition rate that applies to the flows in the X arcs is needed to "age" this portion of the CPT population. Therefore, in each year of the projection period, starting at T_0, a weighted average attrition rate is computed for that portion of the CPT population. The computations to derive this attrition rate for T_0 are illustrated at Table D-7. The values in the "Population" and "Rate w/Prom" columns are supplied by the user for the T_0 computations (the "Population" values for future years are derived in ODSAS, as previously described in paragraphs 4 and 5). The "Population" value for each YOS is multiplied by the corresponding "Rate w/Prom" value to compute attrition by YOS as shown in the "Attrition" column. The subtotal of "Attrition", divided by the subtotal of "Population" produces the weighted average attrition rate for CPTs with only one specialty.

c. To implement the alternate specialty designation methodology, additional computations are needed to derive for each year the proportion of the total CPT population which will have less than 8 YOS.

(1) The computations for T_0' and T_0 are shown at Table D-8 (which includes the data in Table D-7). The number of CPTs in each YOS group shown in the "Population" column are considered to have attained the YOS interval indicated. Consequently, the CPTs

TABLE D-7, Sample Report on Input Data Required for Computing Weighted Average Attrition Rate for Captains With Less Than 8 Years of Service

****OFFICERS GRADE-3 AT T-0****

YOS	POPULATION	RATE W/PROM	ATTRITION (POPULATION*RATE W/PROM)
3- 4	.0	.3330	.00
4- 5	2750.0	.0820	225.50
5- 6	3818.0	.0790	301.62
6- 7	4032.0	.0560	225.79
7- 8	3361.0	.0620	208.38
SUBTOTALS	13961.0		961.30
8- 9	3613.0	.0510	184.26
9-10	4274.0	.4480	1914.75
10-11	2704.0	.3330	900.43
11-12	.0	.2000	.00
12-13	.0	.1920	.00
13-14	.0	.2500	.00
TOTAL POP	24552.0	TOTAL ATTR	3960.74

ATTRITION RATE IN GRADE 3 FOR THOSE WITH ONE SPECIALTY = 961.3 / 13961.0 = .06886

TABLE D-8, Sample Report on Additional Rates Computed by ODSAS to Implement the Alternate Specialty Designation Methodology for Captains

****OFFICERS GRADE-3 AT T-0****

YOS	POPULATION	RATE W/PROM	ATTRITION (POPULATION*RATE W/PROM)
3- 4	.0	.3330	.00
4- 5	2750.0	.0820	225.50
5- 6	3818.0	.0790	301.62
6- 7	4032.0	.0560	225.79
7- 8	3361.0	.0620	208.38
SUBTOTALS	13961.0		961.30
8- 9	3613.0	.0510	184.26
9-10	4274.0	.4480	1914.75
10-11	2704.0	.3330	900.43
11-12	.0	.2000	.00
12-13	.0	.1920	.00
13-14	.0	.2500	.00
TOTAL POP	24552.0	TOTAL ATTR	3960.74

CAPTAINS REMAINING T-0 PRIME THRU T-0 =(13961.0 + 3613.0) / 24552.0 = .71579

CAPTAINS REMAINING T-0 THRU T-1 = 13961.0/ 24552.0 = .56863

ATTRITION RATE IN GRADE 3 FOR THOSE WITH ONE SPECIALTY = 961.3 / 13961.0 = .06886 who will have less than 8 YOS beginning at T_0 (which equals the "Subtotals" of the "Population" column--i.e., 13961.0 in Table D-8) plus the number of CPTs who will have 8-9 YOS beginning at T_0 (i.e., 3613.0 in Table D-8), must be summed to find the number of CPTs that have less than 8 YOS in the T_0' - T_0 interval. That sum, divided by the total population for all YOS represented, equals the "Captains Remaining T-0 Prime Thru T-0" (0.71579). The corresponding rate for T_0 through T_1 is computed in a similar manner except that those CPTs with 8-9 YOS beginning at T_0 (313.0) are not included in the numerator, since they will be designated alternate specialties in the T_0 - T_1 interval.

(2) The rates for subsequent yearly intervals are computed after the population is aged, as in the third step described for LTCs and MAJs in paragraph 5b(3) above.

d. The third refinement (implicit representation for promotion of CPTs to MAJ) requires computation of an attrition rate to the flows in the Y arcs. As defined in the CPT segment methodology, (Chapter II, paragraph 3d(3)), flows in the Y arcs represent CPTs with 8 or more YOS and CPTs promoted to MAJ. Therefore, the attrition rate must account for both subsets of the population and for the movement from one subset to the other (i.e., promotion). To compute this attrition rate requires the following: 1) computing the number promoted in year n, by YOS; 2) adding the number promoted to those promoted since T_0 and before the current year; and 3) determining the attrition, by YOS, for the total number of CPTs promoted to MAJ and the non-promoted CPTs with 8 or more YOS (CPTs with two specialties).

(1) The computations to find the number promoted, by YOS, are illustrated at Table D-9 (which is a further extension of the data shown in Tables D-7 and D-8). The promotions, by YOS, shown in the rightmost column ("Promotions"), are computed in the same manner as previously described for LTCs and MAJs in paragraph 5.

(2) The summing of all CPTs promoted to MAJ since T_0, and the computation of attrition within this group, are illustrated in the upper half of Table D-10. In that table, the CPTs promoted to MAJ at T_0 are reflected in the "Prom to MAJ" column. For T_0, the "MAJ Remng" values are all zero, since no promotions occur before T_0 in ODSAS. The values in the "Tot.MAJ" column are the sum of the promotions to MAJ and the MAJs remaining.

(3) The "Tot.MAJ" values, by YOS, are then multiplied by the user-supplied attrition rate for grade 4 in the "Rate w/Prom" column to compute the attrition values shown in the

TABLE D-9, Sample Report on Results of ODSAS Computations to Find the Number of Captains Promoted to Major, by Years of Service

••••OFFICERS GRADE-3 AT T-0••••					
			ATTRITION		
YOS	POPULATION	RATE W/PROM	(POPULATION•RATE W/PROM)	RATE W/O PROM	PROMOTIONS (POPULATION•RATE DIFFERENCE)
3- 4	•0	•3330	•00	•3330	•0
4- 5	2750•0	•0820	225•50	•0820	•0
5- 6	3818•0	•0790	301•62	•0780	3•8
6- 7	4032•0	•0560	225•79	•0460	40•3
7- 8	3361•0	•0620	208•38	•0380	80•7
SUBTOTALS	13961•0		961•30		
8- 9	3613•0	•0510	184•26	•0280	83•1
9-10	4274•0	•4480	1914•75	•0540	1684•0
10-11	2704•0	•3330	900•43	•0650	724•7
11-12	•0	•2000	•00	•0740	•0
12-13	•0	•1920	•00	•1540	•0
13-14	•0	•2500	•00	•0630	•0
TOTAL POP	24552•0	TOTAL ATTR	3960•74	TOTAL PROM	2616•5

CAPTAINS REMAINING T-0 PRIME THRU T-0 =(13961.0 + 3613•0) / 24552•0 = •71579

CAPTAINS REMAINING T-0 THRU T-1 = 13961•0/ 24552•0 = .56863

ATTRITION RATE IN GRADE 3 FOR THOSE WITH ONE SPECIALTY = 961.3 / 13961•0 = •06886

TABLE D-10, Sample Report on Results of ODSAS Computation of Attrition Rates for Captains With More Than 8 Years of Service and Captains Promoted to Major

****CAPTAINS PROMOTED TO MAJOR AT T-0****

TOS	PROM TO MAJ	MAJ REMNG	TOT. MAJ	RATE W/PROM (GRADE 4)	ATTRITION (POPULATION*RATE W/PROM)
3- 4	.00	.00	.00	.00	.00
4- 5	.00	.00	.00	.00	.00
5- 6	3.82	.00	3.82	.00	.00
6- 7	40.32	.00	40.32	.00	.00
7- 8	80.66	.00	80.66	.00	.00
8- 9	83.10	.00	83.10	.05	3.91
9-10	1683.96	.00	1683.96	.05	85.88
10-11	724.67	.00	724.67	.03	23.91
11-12	.00	.00	.00	.03	.00
12-13	.00	.00	.00	.07	.00
13-14	.00	.00	.00	.09	.00
TOTALS	2616.53	.00	2616.53		113.70

CAPTAINS WITH TWO SPECIALTIES AT T-0

TOS	POP/2 SPEC	RATE W/PROM (GRADE 3)	ATTRITION (POP/2 SPEC*RATE W/PROM)
8- 9	3613.0	.0510	184.26
9-10	4274.0	.4480	1914.75
10-11	2704.0	.3330	900.43
11-12	.0	.2000	.00
12-13	.0	.1920	.00
13-14	.0	.2500	.00
TOTAL POPULATION	10591.0	TOTAL ATTRITION	2999.45

ATTRITION RATE (113.70 + 2999.45)/(2616.53 + 10591.00) = 3113.15/ 13207.53 = .2357
FOR CPT AND MAJ WITH TWO SPECIALTIES

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"Attrition" column. The "Tot.MAJ" values and "Attrition" values are summed across all YOS and are components of the denomimator and numerator respectively in the attrition rate computations. The remaining components of the attrition rate computations are computed as shown in the lower half of Table D-10. The number of CPTs with two specialties, in each YOS, is multiplied by the attrition rate for grade 3, which includes promotion, to compute the attrition by YOS. The number of CPTs with two specialties at T_0 is summed across all the YOS represented, as is the attrition. The "Total Population" value (10591.0) and the "Total Attrition" value (2999.45) are the two remaining components needed to compute the attrition rate for CPTs and CPTs promoted to MAJ, with two specialties, shown at the bottom of Table D-10.

(4) The CPT populations in the two subsets in (3) above must be aged for each succeeding year of interest, and attrition rates again computed for each as described for LTCs and MAJs in paragraph 5 above.

8. Derivation of Attrition and Promotion Rates for Lieutenants

a. As with the CPT segment, modified procedures are necessary for rate computations. The methodological refinements for the LT segment are:

(1) The flows in the X arcs represent 2LTs and 1LTs combined, but each of the two LT grades is subject to different attrition rates by YOS.

(2) Promotion to CPT is explicitly represented; however the computed promotion rate must reflect the combined 2LT and 1LT population. The implication of this refinement is that the promotion rate will appear to be lower than expected because a large proportion of the combined LT population represents 2LTs whose promotion rate to CPT is zero.

(3) Alternate specialty designations for LTs attaining 8 YOS and LTs promoted to CPT and attaining 8 YOS impose an additional requirement which must be represented in the network. (This is similar to one of the requirements in the CPT segment.)

b. The user-supplied input data required to compute all the annual rates for the LT segment are shown at Table D-11. Derivation of the attrition rates required by refinement (1) and derivation of the promotion rates required by refinement (2) are illustrated at Table D-12 (which includes the data shown at Table D-11). For each YOS represented, the promotions to CPT, promotions to 1LT, the attrition for each grade, and the sum of the attrition for both grades are computed.

TABLE D-11, Sample of User Input Required to Compute Annual Rates for the Lieutenant Segment

••••LIEUTENANTS AT T-0••••						
YOS	POPULATIONS		RATE W/PROM		RATE W/O PROM	
	1LT	2LT	1LT	2LT	1LT	2LT
0- 1	.00	5366.00	.1000	.0820	.1000	.0820
1- 2	.00	4780.00	.5970	.9420	.5970	.0000
2- 3	4099.00	.00	.2830	.9840	.2830	.9840
3- 4	3400.00	.00	.9370	.7690	.0000	.7690
4- 5	521.00	.00	.7410	.8330	.7410	.8330
5- 6	80.00	.00	.5710	.9990	.5710	.9990
TOTALS	8100.00	10146.00				

(1) "Promotions to CPT" in each YOS represented are computed by multiplying the corresponding 1LT "Population" by the difference between the 1LT "Rate w/Prom" and the 1LT "Rate w/o Prom". For example, 1LTs with 3-4 YOS in Table D-12 (3400.00) multiplied by corresponding difference in the attrition rates (0.9370 minus 0.0000) equals the promotions to CPT (3185.80). The promotions to CPT are summed across all YOS represented and divided by the sum of the total 1LT and 2LT populations to produce the "Promotion rate for Lieutenants" shown in the last line of Table D-12.

(2) "Promotions to 1LT" are computed in a similar fashion, using the populations and rates for 2LTs. A weighted average promotion rate for 2LT to 1LT is not computed since this type promotion is not explicitly portrayed in the network; however these promotions are used to compute the 1LT population 1 year later at T_1.

(3) The "Attrition" for each grade (1LT and 2LT), by YOS, is computed by first subtracting the promotions out of the grade population (e.g., the 1LT population less promotions to CPT), and then multiplying that differnece by the appropriate grade's "Rate w/o Prom". For example, in Table D-12, the "Attrition" of 1LTs with 2-3 YOS (1160.02) is equal to the 1LT "Population" with 2-3 YOS (4099.00), less "Promotions to CPT" (0.00), multiplied by the 1LT "Rate w/o Prom" (0.2830). The total "Attrition" in both grades, by YOS, is the sum of the 1LT and 2LT "Attrition" values. The total "Attrition" is then summed across all YOS represented. That sum (2031.77) is then divided by the total LT population at T_0 (8100.00 + 10146.00), less the sum of "Promotions to CPT" for all YOS (3185.80) to derive the "Attrition Rate for Lieutenants"

TABLE D-12, Sample Report on Results of ODSAS Computation of Separate Attrition and Promotion Rates for First and Second Lieutenants

....LIEUTENANTS AT T-0....

YOS	POPULATIONS		RATE W/PROM		RATE W/O PROM		PROMOTIONS TO	PROMOTIONS TO	ATTRITION ((POP - PRMT)*RATE W/O PROM)		
	1LT	2LT	1LT	2LT	1LT	2LT	CPT	1LT	1LT	2LT	TOT
0- 1	.00	5366.00	.1000	.0820	.1000	.0820	.00	.00	.00	440.01	440.01
1- 2	.00	4780.00	.5970	.9420	.5970	.0000	.00	4502.76	.00	.00	.00
2- 3	4099.00	.00	.2830	.9840	.2830	.9840	.00	.00	1160.02	.00	1160.02
3- 4	3400.00	.00	.9370	.7690	.0000	.7690	3185.80	.00	.00	.00	.00
4- 5	521.00	.00	.7410	.8330	.7410	.8330	.00	.00	386.06	.00	386.06
5- 6	80.00	.00	.5710	.9990	.5710	.9990	.00	.00	45.68	.00	45.68
TOTALS	8100.00	10146.00					3185.80	4502.76	1591.76	440.01	2031.77

ATTRITION RATE FOR LIEUTENANTS 2031.77 / (8100.00 + 10146.00 - 3185.80) = .1114

PROMOTION RATE FOR LIEUTENANTS 3185.80 / (8100.00 + 10146.00) = .1746

TABLE D-13, Sample Report of ODSAS Computation of Attrition Rates for Lieutenants Promoted to Captain

....CAPTAINS POPULATION AT T-0....

YOS	PROM TO CPT	CPT REMAINING	TOT. CPT	RATE W/O PROM (GRADE 3)	ATTRITION (TOT. CPT *RATE W/O PROM)
0- 1	.00	.00	.00	.0000	.00
1- 2	.00	.00	.00	.0000	.00
2- 3	.00	.00	.00	.0000	.00
3- 4	3185.80	.00	3185.80	.3330	1060.87
4- 5	.00	.00	.00	.0820	.00
5- 6	.00	.00	.00	.0780	.00
TOTALS	3185.80	.00	3185.80	TOTAL ATTRITION	1060.87

CAPTAINS REMAINING =3185.80 /3185.80 = 1.0000

ATTRITION RATE IN GRADE 3 = 1060.87 /3185.80 = .3330

(0.114). Note that the "Promotions to CPT" are subtracted from the LT population to derive the attrition rate, whereas the "Promotions to 1LT" are not subtracted, reflecting that the latter promotions result in no change to the LT population.

c. The alternate specialty designation methodology used in the LT segment (refinement (3)) requires computation of two rates each year. One is an attrition rate for those LTs promoted to CPT, and the second is similar to the rates computed in the CPT segment to reflect the portion of the CPT population attaining 8 YOS.

(1) The computation of the attrition rates for LTs promoted to CPT is similar to that for LTCs and MAJs, i.e., those promoted to the next higher grade each year must be added to the number who were promoted since T_0 and are remaining in the current year. This is illustrated at Table D-13. Since the example is for the interval beginning at T_0, the "CPT Remaining" column is comprised of all zero values. (Note that the values in the "Prom to CPT" column are those shown in the "Promotions to CPT" column in Table D-12). Therefore, the "Tot.CPT" populations by YOS (in Table D-13) is multiplied by the corresponding "Rate w/o Prom" for grade 3 to find the "Attrition" value for that YOS. The "Total Attrition" for all YOS represented (2160.87) is then divided by the total "Prom to CPT" (3185.80) to derive the "Attrition Rate in Grade 3" (0.3330), shown on the last line of Table D-13.

(2) Computation of the portion of the CPT population attaining 8 YOS (the second rate required) is shown on the next to the last line of Table D-13. This rate will equal 1.0000 as long as the "Tot.CPT" population includes only CPTs with less than 8 YOS. Since the user input specified that only LTs with as much as 5 YOS were to be included in the LT population, the computations at T_0 consequently consider that any of the LTs promoted to CPT would necessarily have less than 8 YOS (and thus the required rate is 1.0000). However, in years beyond T_0, through the aging procedure, there could be LTs with more than 8 YOS promoted to CPT and, thus, the numerator (representing CPTs with less than 8 YOS) would be less than the denominator ("Tot.CPT" summed across all YOS) and the resulting "Captains Remaining" rate would be less than 1.0000. A rate less than 1.0000 implies that there are some CPTs due to be designated alternate specialties.

d. The final consideration for the rate computations at T_0 is that the attrition and promotion rates input by the user must be used to "age" the T_0 populations to derive the starting populations at T_1. This is similar to the procedure used in all the other segments. One minor refinement to this procedure is provided for in the LT segment and reflects the promotion to 1LT, by YOS, as a loss from the 2LT population and a gain to the 1LT population.

APPENDIX E

PROBLEM SIZE ESTIMATION

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

APPENDIX E
PROBLEM SIZE ESTIMATION

1. General. - The size of any linear programing (LP) problem is measured in terms of the number of rows, or constraints, to be considered. When the number of constraints exceeds the capacity of available computer hardware and/or software, LP solutions can often be obtained by segmenting the problem. In the case of ODSAS, the large size of the LP problem was recognized early in the formulation of the methodology and thus the model was designed to be segmented, as required.

2. Purpose. - This appendix provides the ODSAS user with a procedure for estimating the LP problem size based upon the values of input parameters. Knowing the approximate problem size, the user may then decide either to selectively apply segmentation-within-grade options or to modify parameter values in order to reduce the problem size.

3. Determinants of Problem Size

a. The key determinants of an ODSAS problem's size are the three parameters defined below:

(1) NSPEC = total number of authorized OPMS specialties

(2) NYRS = number of years in projection period

(3) NPREF = total number of preferred, or logical, specialty pairings considered in arriving at a solution. (Note: A preference for a specialty pairing of specialty "m" with "n" is counted twice when computing NPREF, since some officers allocated to the "m/n" pair enter the system with a specialty "m" assignment and some start with a specialty "n" assignment.)

b. The computations for the actual number of rows in a LP problem for ODSAS are also influenced by the specific preferences and the values of the utilization ratios and tour lengths input to the system. Since all of the above will, by definition, be variable, a precise calculation of problem size cannot be formulated until a complete set of input data is specified. However, a reasonable estimate can be derived by the procedures presented in the following paragraphs. The actual number of rows for a problem is computed within the ODSAS ADP system processing phase (matrix generator activity), and is displayed in the statistical summary report (Chapter III, paragraph 3b(1)).

4. Estimating Number of Rows by Constraint Type - Unsegmented System. - The types of constraints to be considered are flow conservation, node capacity, flow control, control of input, and key arc relationships; (these are defined in Chapter II, paragraph 1i, of this report). The notation used for the years in the projection period is described in Chapter II, paragraph 1a.

a. Flow conservation. - This type constraint is used in each grade segment. There is one constraint for each node (specialty) in each year, starting at T_1 and continuing through the projection period (i.e., T_1 through T_{NYRS}). Additionally, each node at T_0' and T_0 requires a flow conservation constraint. The following equation applies for computing the number of flow conservation constraints for each grade segment except LT:

(NSPEC) x (NYRS + 2) = number of rows for flow conservation in each grade segment except LT*

b. Requirements or Node Capacities

(1) Each system segment has one total-requirements constraint for each specialty in each year T_0 through T_{NYRS-1}; a logical upper bound is placed on the flows leaving the nodes at T_{NYRS} and is equal to the total number of requirements for a specialty at T_{NYRS}. The equation for calculating the number of these requirements constraints is as follows:

(NSPEC x NYRS) = minimum number of rows for total requirements for each grade

(2) The LTC and MAJ segments each have one additional constraint for each specialty in years T_1 through T_{NYRS}. These constraints represent that portion of a specialty's total requirements which was unfilled in a higher grade segment. The COL segment does not require these additional constraints since no unfilled higher grade requirements are passed to that segment. The equation for calculating the number of these constraints is:

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*The numeral "2" in the expression "NYRS + 2" accounts for the nodes at T_0' and T_0. Since T_0' is not used in the LT segment, a "1" replaces the "2" in the equation when computing the estimated number of flow conservation constraints for the LT segment.

(NSPEC x NYRS) = additional rows for LTC and MAJ segment only

(3) The methodology in the CPT segment employs only the total-requirements constraint; the unfilled higher grade requirements are employed as lower bounds.

(4) The LT segment has additional capacity constraints for each specialty, but only after LTs reach their eighth year of service in the projection period. The point where the additional capacity constraints begin therefore depends on the years of service represented in the LT population (input by user). The appropriate equation is:

(NSPEC x NYRS') = additional rows for LT segment only. (NYRS' is normally less than NYRS, e.g., if the lieutenant YOS distribution input by the user ranged from 0 to 6 YOS, then NYRS' would be 2 years (eighth YOS minus 6) before any LTs would be due for designation of alternate specialties.)

c. Control of X arcs. - Each year, the officers within a preferred specialty pair can either stay in their primary specialty or move to their alternate. Therefore, control of the flows representing dual qualified officers must start at T_0 and continue throughout the projection period. Note that there are no flow control constraints in the $T_0' - T_0$ interval. In this initial interval, the flow values are determined by the requirements in the paths (which start at T_0 and terminate at T_{NYRS}). Whereas the number of constraints for flow conservation and requirements can be calculated from input parameter values, the number of constraints for control of X arcs can only be estimated--unless the exact composition of the user-supplied input files (i.e., specialty preferences and rates/population files) is known. The exact number of X arc constraints depends upon the number of specialties included as preferences, along with the utilization ratios and tour lengths for each specialty pair. However, an estimate can be determined by substituting parameter values into the following relationship:

(NYRS x NPREF) + NSPEC $\sim$ number of rows for control of X arcs for the COL, LTC, and MAJ segments.

The CPT segment requires less control than the field grade segments, because most officers in this grade have only one specialty. Since the X arcs in the CPT segment represent only CPTs with less than 8 YOS in the 30 BES, that implies that there are fewer flows to control. This is not only because 30, instead of 46 specialties, have to be considered, but also because the flows entering a node can only exit via the one X arc leading to the same node number (specialty) 1 year later (i.e., CPTs with less than 8 YOS have repetitive assignments in the BES). If there would be CPTs with less than 8 YOS throughout the projection period (as determined from user input), the equation to determine number of flow control constraints for the X arcs would be:

(30 x NYRS) = number of flow control constraints for X arcs in the CPT segment*

The LT segment also requires less control than the field grades, because the X arcs represent the LTs with only one specialty. Thus, the situation is similar to that just described for CPTs, except that all 46 specialties are considered. The equation would be:

(NSPEC x NYRS) = number of flow control constraints for X arcs in the LT segment**

d. Control of Y arcs. - Except for COL, control of Y arcs is required in all grade segments (for the same reason as for the X arcs). The Y arcs are not constructed in the COL segment because promotees to brigadier general in the COL segment are not explicitly represented. As with the X arcs, control of the flows representing promoted dual qualified officers must start at T_0 and continue throughout the projection period. The number of flow control constraints (for Y arcs) required for the LTC and MAJ segments must be estimated--unless exact composition of input files is known. An estimate can be determined by substituting parameter values into the following relationship:

(NYRS x NPREF) + ((NYRS-1) x NSPEC) → number of flow control constraints for Y arcs in the LTC, MAJ, and CPT segments.

Note that this estimating relationship will reflect a larger number of constraints than the one used for X arcs (for LTCs and MAJs). This is because every X arc does not need a flow control constraint

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*If there were CPTs with less than 8 YOS in only some of the years (e.g., NYRS-2) in the projection period, then NYRS-2 should replace the parameter value of NYRS in the equation.

**This equation applies as long as any of the LT population continue as LTs throughout the projection period; otherwise NYRS is too large a multiplier, and should be replaced with the smaller value appropriate for the number of years.

(i.e., one output arc per node is logically redundant and therefore not created by the matrix generator program). There are fewer rows needed in the LT segment, since Y arcs do not appear in the network until LTs begin reaching their eighth YOS; this normally occurs after T_0. Thus, for the LT segment, the relationship is expressed as:

(NYRS") x (NPREF + NSPEC) = number of flow control constraints for Y arcs in the LT segment, where NYRS" is the number of years in which Y arcs represent LTs with 8 or more YOS.

e. Control of Input. - This type constraint appears in all grade segments. In each grade segment there is one constraint for each specialty in which the user wishes to restrict the amount of input. The specialties normally included are the largest ones in terms of authorized strength. In addition, there is one constraint in each segment limiting the total amount of input to an authorized strength level for the particular grade.

f. Key Arc Relationships. - This type constraint appears in all grade segments, except the LT segment. The number of this type of constraint is equal to one-half of the total number of preferred, or logical, specialty pairings considered in arriving at a solution (the NPREF parameter). The fraction "one-half" applies since this type constraint relates two of the preferred specialty pairings to each other.

g. Estimation Example, Unsegmented System. - Examples of computations to estimate the problem sizes for an unsegmented system are shown at Figure E-1.

5. Modifications to Estimating Procedures for the Segmentation-Within-Grade Option

a. When the problem size, as estimated from procedures in paragraph 4 above, exceeds computer hardware or software capabilities, the user must decide which of the two available alternatives to apply (i.e., segmentation-within-grade or modification of parameter values). Frequently, the segmentation alternative is more desirable because it allows for solving of the problem as originally defined by the parameter values.

Given: NYRS = 5

NSPEC = 46

NPREF = 600

Assume: Control of input is desired by the user for the combat arms specialties (i.e., specialties 11, 12, 13, 14)

a) Number of rows for the COL segment:

(1) Flow conservation

46 x (5 + 2) = 322

(2) Node capacities

(46 x 5) = 230

(3) Control of X arcs (approximate)

(5 x 600) + (46) ~3046

(4) Control of Y arcs

None = 0

(5) Control of Input

Total authorized 1

Authorized combat arms 4 = 5

(6) Key arc relationships

½ x 600 = 300

Approximate total number of constraints (COL) ~3903

b) Number of rows for LTC and MAJ segments

(1) Flow conservation

46 x (5 + 2) = 322

(2) Node capacities

(46 x 5) + (46 x 5) = 460

(3) Control of X arcs (approximate)

(5 x 600) + (46) ~3046

(4) Control of Y arcs (approximate)

(5 x 600 + ((5-1) x 46) ~3184

(5) Control of Input

Total authorized 1

Authorized combat arms 4 = 5

(6) Key arc relationships

½ x 600 = 300

Approximate total number of constraints for each grade (LTC or MAJ) ~7317

c) Number of rows for CPT segment

(1) Flow conservation

46 x (5 + 2) = 322

(2) Node Capacities[a/]

46 x 5 = 230

FIGURE E-1, Estimation Example, Unsegmented System
(continued on next page)

(3) Control of X arcs[b]

30 x 5 = 150

(4) Control of Y arcs (approximate)

(5 x 600) + ((5-1) x 46) ~3184

(5) Control of Input

Total authorized 1

Authorized combat arms 4 = 5

(6) Key arc relationships

½ x 600 = 300

Approximate total number of constraints (CPT) ~4191

d) Number of rows for LT segment

(1) Flow conservation

46 x (5 + 1) = 276

(2) Node capacities[c]

(46 x 5) + (46 x 3) = 368

(3) Control of X arcs

(46) x (5) = 230

(4) Control of Y arcs (approximate)[d]

(2) x (600 + 46) ~1292

(5) Control of Input

Total authorized 1

Authorized combat arms 4 = 5

Approximate total number of constraints (LT) ~2171

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a/ One capacity constraint per specialty per year. Unfilled higher grade requirements are treated as lower bounds on the node capacities.

b/ Assume the YOS distribution of the starting population ranged from 3-10 YOS, then that proportion with less than 8 YOS would have only one specialty. It would take 5 years for the most junior group to reach 8 YOS; therefore, X arcs, and control thereof, reflecting repetitive assignment in one specialty, are needed for 5 years for each of the 30 BES.

c/ Assume the YOS distribution of the starting population ranged from 0-6 years, then the first year that more than one Y arc enters a node is at T_3. Thus, for T_3, T_4, and T_5, unfilled higher grade requirements capacity constraints are needed. Prior to T_3, lower bounds replace the capacity constraints for unfilled higher grade requirements, thus keeping the LP problem size smaller.

d/ Assume the YOS distribution of the starting population ranged from 0-6 years, then some 1LTs could reach the eighth YOS within 2 years. Since the most senior LTs would therefore be designated alternate specialties at T_2, control of the Y arcs must begin at T_3 (in the interval T_2 - T_3 the specialty requirements draw the flows to where they are needed). This leaves 2 years of the projection period when LTs have 8 or more YOS.

FIGURE E-1, Estimation Example, Unsegmented System (concluded)

b. When segmenting within grade, the same five types of constraints apply (e.g., flow conservation, node capacity, flow control, control of input and key arc relationships). Additionally, the user must decide which specialties should be included in subsegment 1 and, consequently, which ones will be included in subsegment 2. There is an optional capability to specify the percentage of the requirements that may be filled in subsegment 1. If a percent value is not specified, then the ODSAS system default allows as much as 100 percent of a given specialty's requirements to be satisfied in subsegment 1. (Note, however, that control of input to the network prohibits totally filling all specialty requirements in subsegment 1--see Chapter II, paragraph 2c(4).) As described in Chapter II, paragraph 3a, the control of input constraints is employed differently when segmenting within grade. The authorized strengths for the primary specialties in subsegment 1 define the upper limits used for the only control of input constraints in that segment. In subsegment 2, the total authorized strength for a grade, minus the authorized strength of the primary specialties in subsegment 1, is the upper limit used for the only control of input constraint used in that subsegment.

c. *Segmenting within grade also requires the introduction* of three additional parameters, derived from NSPEC and NPREF. These additional parameters are defined as:

(1) NSPEC(-) = number of specialties in subsegment 2. (i.e., all NSPEC specialties, less those the user identifies to be included in subsegment 1)

(Note: When segmenting the field grades, subsegment 1 considers all specialties in all years even though some specialties may not be preferred alternates. This results in the matrix generator program constructing too many constraints; however, a logical analysis is performed within the FMPS programs, and the excess constraints are deleted. Subsegment 2 then excludes the nodes for the primary specialties defined in subsegment 1.)

(2) $NPREF_1$ = number of preferred specialty pairs in subsegment 1.

(3) $NPREF_2$ = number of preferred specialty pairs in subsegment 2.

The value for $NPREF_1$ is derived from the preferences file by separating those preferences which have primary specialty numbers the same as the specialties defined by the user to be in subsegment 1. The value for $NPREF_2$ is the remainder of the entries in the preferences file.

d. The above three additional parameters are substituted into the equations/relationships of paragraph 4, above, as follows:

(1) NSPEC(-) is substituted for NSPEC when computing row sizes for subsegment 2.

(2) $NPREF_1$ is substituted for NPREF when computing row sizes for subsegment 1.

(3) $NPREF_2$ is substituted for NPREF when computing row sizes for subsegment 2.

e. Estimation Example, Fully Segmented System. - The computations necessary to estimate the size of the LP problem where each field grade is segmented are illustrated in Figure E-2. (Since CPT and LT segments cannot be segmented within grade, the computations for these grades remain as shown in Figure E-1.)

Given: NYRS = 5

NSPEC = 46

NPREF = 600

NSPEC(-) = 42 (all specialties, except 11, 12, 13, 14 are in subsegment 1)

$NPREF_1$ = 240 } Sum equals NPREF, or 600
$NPREF_2$ = 360 }

a) Number of rows for the COL segment

Subsegment 1:

(1) Flow conservation		
46 x (5 + 2)	= 322	same as unsegmented
(2) Node capacities		
46 x 5	= 230	same as unsegmented
(3) Control of X arcs (approximate)		
(5 x 240) + 46	~1246	
(4) Control of Y arcs		
None	= 0	
(5) Control of input to network		
4 (one for each specialty 11, 12, 13, 14)	= 4	
(6) Key arc relationships		
½ x 240	= 120	
Approximate total number of constraints (COL subsegment 1)	~1922	

Subsegment 2:

(1) Flow conservation	
42 x (5 + 2)	= 294
(2) Node capacities	
42 x 5	= 210
(3) Control of X arcs (approximate)	
(5 x 360) + (42)	~1842
(4) Control of Y arcs	
None	= 0
(5) Control of input to network	
Total authorized strength for the grade, minus the authorized strength of the specialties in subsegment 1	= 1
(6) Key arc relationships	
½ x 360	= 180
Approximate total number of constraints (COL subsegment 2)	~2527

FIGURE E-2, Estimation Example, Segmentation-Within-Grade (continued on next page)

b) Number of rows for the LTC and MAJ segments		
Subsegment 1:		
(1) Flow conservation		
46 x (5 + 2)	= 322	same as unsegmented
(2) Node capacities		
(46 x 5) + (46 x 5)	= 460	same as unsegmented
(3) Control of X arcs (approximate)		
(5 x 240) + 46	~1246	
(4) Control of Y arcs (approximate)		
(5 x 240) + ((5-1) x 46)	~1384	
(5) Control of input to network		
Same as for COL, subsegment 1	= 4	
(6) Key arc relationships		
½ x 240	= 120	
Approximate total number of constraints for each grade (LTC or MAJ sub-segment 1	~3536	
Subsegment 2:		
(1) Flow conservation		
42 x (5 + 2)	= 294	
(2) Node capacities		
(42 x 5) + (42 x 5)	= 420	
(3) Control of X arcs (approximate)		
(5 x 360) + 42	~1842	
(4) Control of Y arcs (approximate)		
(5 x 360) + ((5-1) x 42)	~1968	
(5) Control of Input		
Same as COL, subsegment 2	= 1	
(6) Key arc relationships		
½ x 360	= 180	
Approximate total number of constraints for each grade (LTC or MAJ sub-segment 2)	~4705	

FIGURE E-2, Estimation Example, Segmentation-Within-Grade (concluded)

APPENDIX F

LIST OF OPMS SPECIALTIES

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

APPENDIX F
LIST OF OPMS SPECIALTIES

11	Infantry
12	Armor
13	Field Artillery
14	Air Defense Artillery
15	Aviation
21	Engineer
25	Combat Communications-Electronics
26	Fixed Telecommunications Systems
27	Communications-Electronics Engineering
28	Audio-Visual Instructional Technology
31	Law Enforcement
35	Tactical/Strategic Intelligence
36	Counterintelligence/HUMINT
37	Cryptology
41	Personnel Management
42	Personnel Administration
43	Club Management
44	Finance
45	Comptroller
46	Information
47	Education
48	Foreign Area Officer
49	Operations Research/Systems Analysis
51	Research and Development
52	Atomic Energy
53	Automatic Data Processing
54	Operations and Force Development
71	Aviation Materiel Management
72	Communications-Electronics Materiel Management
73	Missile Materiel Management
74	Chemical
75	Munitions Materiel Management
76	Armament Materiel Management
77	Tank/Ground Mobility Materiel Management
81	POL Management
82	Food Management

83	General Troop Support Materiel Management
86	Traffic Management
87	Marine and Terminal Operations
88	Highway and Rail Operations
91	Maintenance Management
92	Supply Management
93	Logistics Services Management
95	Transportation Management
97	Procurement
98	Logistics Management

APPENDIX G

METHODOLOGY FOR DESIGNATION OF ALTERNATE SPECIALTIES FOR COMPANY GRADE OFFICERS

OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

APPENDIX G
METHODOLOGY FOR DESIGNATION OF ALTERNATE SPECIALTIES
FOR COMPANY GRADE OFFICERS

1. General. - A modified methodology from that employed in the field grade segments is used in the CPT and LT segments to represent the designation of alternate specialties as officers attain 8 YOS in the projection period. The designation of alternate specialties is accomplished by first deriving statistics on the CPT or LT population (performed in the initialization phase and explained in Appendix D) from the user's input data on the populations and YOS represented at T_0. Then those statistics are employed in constructing the constraints. The LP algorithm considers the interaction of these constraints and produces a solution that includes the specialty designations for company grade officers. An example is presented in the following paragraphs, using specialty 21 to illustrate the process.

2. Rates Required for Alternate Specialty Designation. - The percentages of the CPT or LT population in three YOS categories are needed for the CPT and LT segments in addition to the required attrition and promotion rates. For the first YOS category, the portion of the population at the beginning of each year (i.e., T_0, T_1 through $T_{(N-1)}$) that represents CPTs attaining 8 YOS has to be computed so that that group can be designated alternate specialties. As mentioned above, the computation is done in the initialization phase, and entails identifying the portion of the CPT population that has just completed 7 YOS, and is about to begin the eighth YOS, as a fraction of the total number of CPTs with less than 8 YOS.

a. As an example, suppose the three following percentages were computed from user-supplied input data:

(1) The percent of CPTs with specialty 21 who will complete their seventh YOS at T_0 = 10

(2) The percent of CPTs with specialty 21 who will have completed less than 7 YOS at T_0 = 60

(3) The percent of CPTs with specialty 21 who will complete 8 or more YOS at T_0 = 30

The total percentage of CPTs with specialty 21 for all YOS, is the sum of the three rates above, or 100 percent.

b. As mentioned above, a similar set of rates is computed for T_1 through $T_{(N-1)}$. Rates are computed by first aging the T_0 populations and then determining the percentages that would be in the YOS groupings shown in the above example.

3. Interaction of Constraints. - The interaction of the constraints can best be explained by referring to Figure G-1. The portion of the network of interest is for specialty 21 in the CPT segment in the interval T_0' to T_1. Constraints in this interval interact to determine the alternate specialty designations for CPTs with BES 21. The labeled arcs are defined as follows (assume for this example that the only preferred specialty pairs are 21/53 and 21/49):

X_{00021} represents all CPTs with primary specialty 21 at T_0'.

W_{02121} represents CPTs with only specialty 21 and less than 8 YOS at T_0 (includes CPTs that will be in the eighth YOS in the T_0 - T_1 interval)

W_{04921} represents CPTs, with 9 or more YOS at T_0, allocated to specialty pair 21/49.

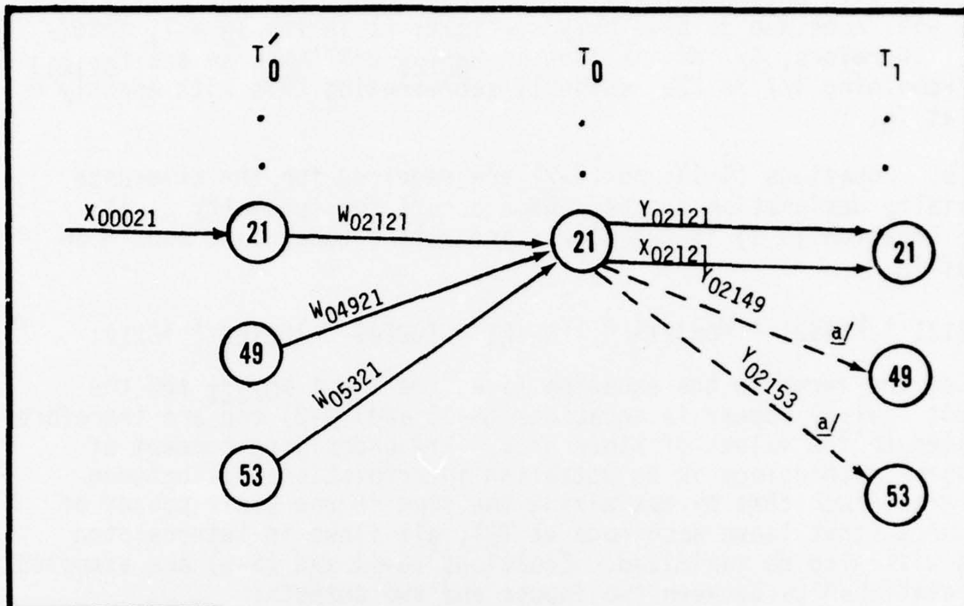
W_{05321} represents CPTs, with 9 or more YOS at T_0, allocated to specialty pair 21/53.

Y_{02121} represents CPTs, with 9 or more YOS at T_0, allocated to either specialty pair 21/49 or 21/53.

X_{02121} represents CPTs, with less than 8 YOS at T_0 allocated primary specialty 21 (does not include CPTs that will be in the eighth YOS in the T_0 - T_1 interval).

Y_{02149} represents CPTs, with 8 or more YOS at T_0, allocated to specialty pair 21/49.

Y_{02153} represents CPTs, with 8 or more YOS at T_0, allocated to specialty pair 21/53.



a/ - *dashed lines indicate that CPTs with 8 YOS, designated alternate specialties, are included in the flow in the arc*

FIGURE G-1, Illustration of Flow for Company Grade Officers Upon Designation of Alternate Specialties

a. Using the rates calculated from the user-supplied input data, the flow control constraints direct the flows in two of the arcs as shown in the following two equations:

$$0.70 \times (X_{00021}) = W_{02121} \qquad \text{(G-1)}$$

$$\frac{6}{7} \times (W_{02121}) = X_{02121} \qquad \text{(G-2)}$$

Equation (G-1) specifies that the CPTs with less than 8 YOS at T_0 having only specialty 21 (W_{02121}) be equal to 70 percent of all CPTs at T_0' with specialty 21 (X_{00021}). The 70 percent represents the sum of the first two percentages computed in paragraph 2a above, and is the fraction of CPTs with less than 8 YOS at T_0. The remaining 30 percent of X_{00021} represents dual qualified CPTs and does not directly affect this example. Whereas equation (G-1) set the flow in W_{02121} equal to a portion of the flow in another arc, equation (G-2) specifies that most of the flow (i.e., 6/7) in W_{02121} will go to arc X_{02121} at T_0. The second equation expresses that, according to the rates derived from the input data, for every seven captains with only specialty 21 and less than 8 YOS at T_0, six of them will continue to have only specialty 21 in the T_0 - T_1 interval. Therefore, 6/7 of the flow in W_{02121} will move to arc X_{02121}; the remaining 1/7 is the residual, representing CPTs with exactly 8 YOS at T_0.

b. Equations (G-1) and (G-2) are required for the alternate specialty designation process which occurs for specialty 21 at T_0. Equation (G-3) is the flow conservation constraint upon node 21 at T_0.

$$(W_{02121} + W_{04921} + W_{05321}) = (Y_{02121} + Y_{02149} + Y_{02153} + X_{02121}) \quad \text{(G-3)}$$

Two of the terms in the equation (i.e, the input W_{02121} and the output X_{02121}) appear in equations (G-1) and (G-2) and are therefore related to the values of other arcs. The underlying concept of ODSAS LP methodology is to establish interrelationships between the arcs, such that by maximizing the flow in one small subset of the arcs (that leave each node at T_N), all flows in interrelated arcs will also be maximized. Equations (G-4) and (G-5) are examples of relationships between two inputs and two outputs:

$$0.5 \times (W_{04921}) \leq Y_{02149} \quad \text{(G-4)}$$

$$0.5 \times (W_{05321}) \leq Y_{02153} \quad \text{(G-5)}$$

These two inequalities state that one-half of the CPTs with 9 or more YOS at T_0 will be reassigned to their alternate specialty (fraction value depends upon tour length of the specialty and utilization ratios of the specialty pairs). In this example, each specialty pair serves one 2-year tour in specialty 21; thus at T_0, one-half would be completing the second year, and one-half would be completing the first year in a specialty 21 assignment. Furthermore, the flow in the arcs where the reassignments will be reflected (Y_{02149} and Y_{02132}) can exceed one-half of the flow in W_{04921} and W_{05321}. The excess is the CPTs with 8 YOS at T_0, and specialty 21, for whom alternate specialties are being designated in the T_0 - T_1 interval. The remaining one-half of the CPTs with 9 or more YOS remain in specialty 21 from T_0 to T_1 to complete their second year in specialty 21. This is shown in equation (G-6).

$$0.5 \times (W_{04921}) + 0.50 \times (W_{05321}) = Y_{02121} \quad \text{(G-6)}$$

c. The six equations together account for all the input and output flows at node 21 at T_0. Note that the fraction (1/7, mentioned in subparagraph 3a above) representing CPTs attaining 8 YOS at T_0 is included as an input (in arc W_{02121}). As an output, the fraction is represented in arcs $Y_{02149}$and Y_{02153} as the amount that exceeds one-half of W_{04921} and W_{05321} respectively. The flows in the output arcs are limited by the requirements for specialties 49 and 53 (node capacities) at T_1 and beyond. In this example, the requirements for specialties 49 and 53 at T_1 and beyond determine the direction and division of the residual. Thus the specialty designations for CPTs or LTs with 8 YOS and primary specialty 21 are requirements-driven and will appear in an ODSAS solution as part of the flow in a Y arc in the CPT or LT segment.

APPENDIX H

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OFFICER DUAL SPECIALTY ALLOCATION SYSTEM
(ODSAS)

APPENDIX H
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APR 76 J D THOMAS, G E ARMSTRONG
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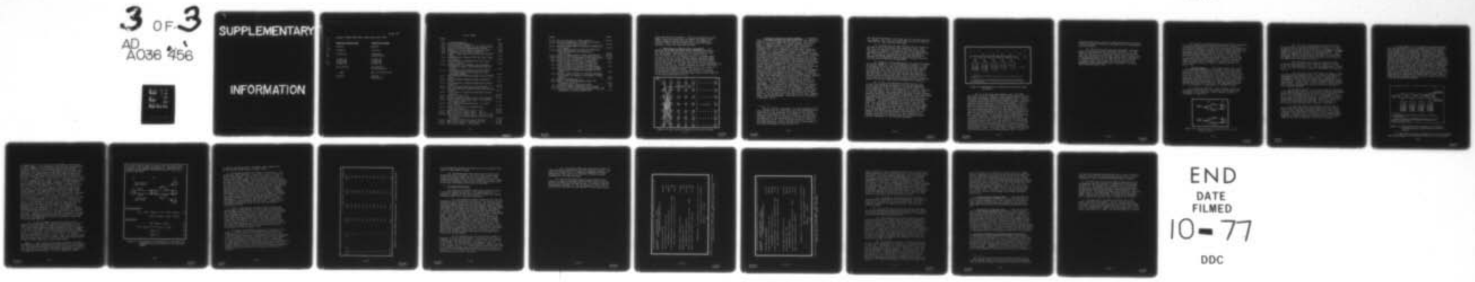

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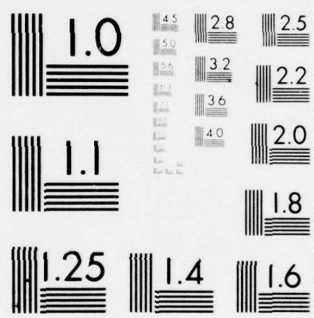

MICROCOPY RESOLUTION TEST CHART
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AD-A037 456

20 May 1977

Changes to ODSAS Study Report, CAA-SR-76-6, April 1976:

Remove and destroy pages	Substitute new pages
xxi/xxii	xxi/xxii
II-5/II-6	II-5/II-6
II-23/II-24	II-23/II-24 II-24.1/II-24.2
II-25/II-26 II-27/II-28 II-29/II-30	II-25/II-26 II-27/II-28 II-29/II-30
III-17/III-18	III-17/III-18 III-18.1/III-18.2
none	add: III-22.1/III-22.2
D-9/D-10	D-9/D-10 D-10.1/D-10.2

LIST OF FIGURES

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FIGURE		Page

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unspecified pairings from ODSAS). This policy decreased the total number of possible permutations, and reduced the number of constraints needed to control specialty pairs. The mathematical solution of the LP then more closely conformed to the planner's guidance on logical (or preferred) pairings.

e. <u>Modifications to General Form of the Network.</u> - To determine how to meet the Army's officer personnel requirements, the simple network described thus far and illustrated in Figure II-2 was modified. That modification is shown in Figure II-3. At the far left, an interval from T_0' to T_0 has been added. The flow in the arcs in this leftmost interval represents numbers of officers with two specialties (identified by the node numbers at both ends of the arc) who enter the solution at the true beginning of the system--T_0. The model solution for the flow associated with the arcs in the T_0' to T_0 interval represents the number of officers that should be allocated to the specialty pairs at T_0. Figure II -3 illustrates this important concept. For instance, the flow in the arc connecting node 11 at T_0' and node 15 at T_0 is the number of officers of a particular grade who should have a primary specialty 11 and alternate specialty 15 at T_0.

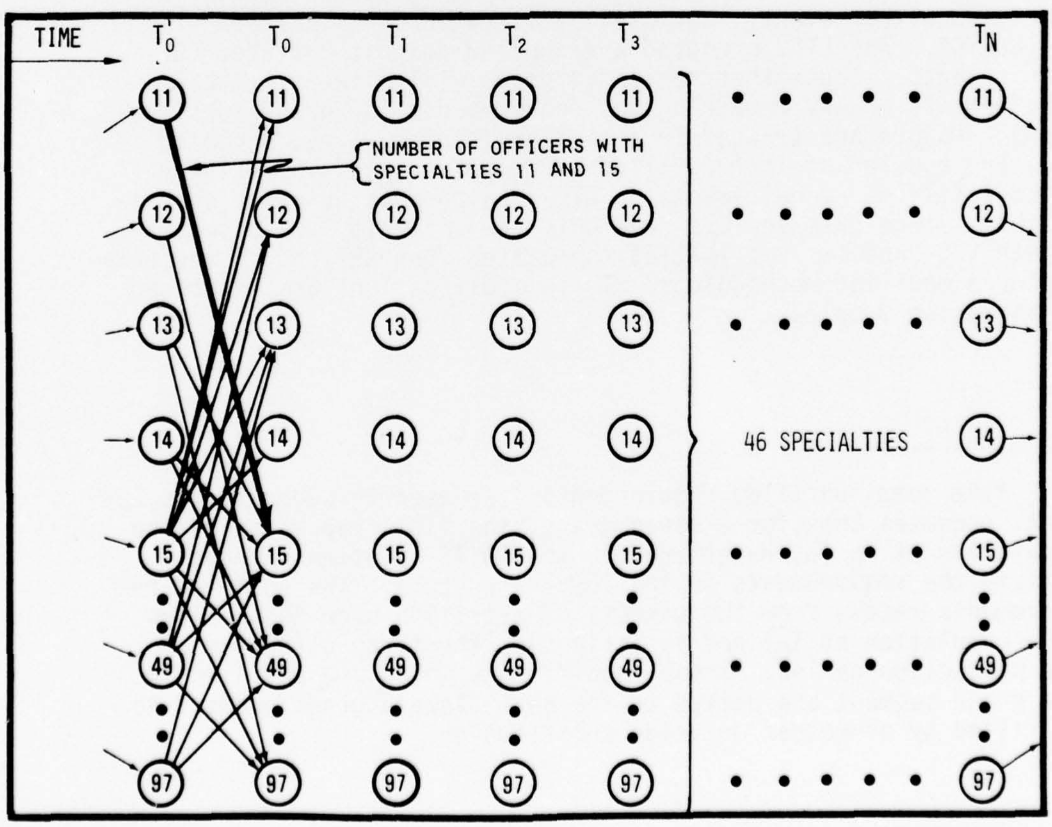

FIGURE II-3, Multi-time Period Network with T_0' Interval Added

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f. Sequential Processing of System Segments. - As shown at Figure II-4, ODSAS considers the allocation of officers, defined by grade and YOS, to the authorized OPMS specialties. Each officer grade is a segment of ODSAS. The system considers all officer grades in sequence starting with colonel (COL), followed by lieutenant colonel (LTC), major (MAJ), captain (CPT), and lieutenant (LT). First lieutenants (1LT) and second lieutenants (2LT) comprise a single segment for purposes of this system. No two segments are completely alike; however, all segments do assume officers as being distributed according to number of YOS. Attrition and promotion rate data (furnished by the user) for each YOS and grade are used to compute weighted average promotion and attrition rates needed as input to the system. These averages are computed for each year in the projection period and reflect the aging of the officer population (Appendix D). During processing of the COL segment, the number of COLs required to have particular specialties will be computed for that grade; the number of COLs that will leave the network via attrition or promotion will also be computed. Promotions to COL are computed in the LTC segment. If there are any unfilled COL requirements* after the COL segment is processed by ODSAS, these requirements are passed to the LTC segment. Annually, starting at T_0, LTCs can either be promoted to COL or remain in grade; in either event, they will be attrited as a function of the YOS. Any LTCs promoted are applied against unfilled COL requirements. Those that remain in grade will either fill LTC requirements or any remaining COL requirements (by grade substitution). Majors are treated in a similar fashion, i.e., promoted MAJs are applied against unfilled LTC requirements, while the remainder fill MAJ requirements or LTC requirements by grade substitution. Since CPTs and LTs have only one specialty up to their eighth YOS, and two specialties thereafter, the CPT and LT segments employ a modified methodology. These modifications are explained in paragraph 3 below.

---

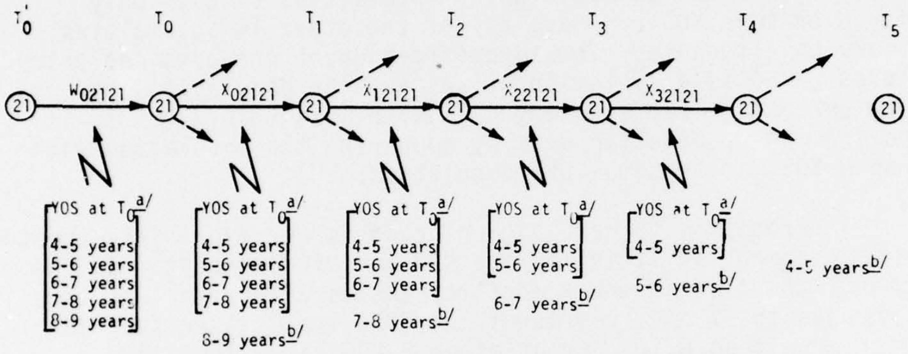
*The term "unfilled requirements," as used throughout this report, connotes that for a given grade, the flows representing the population at T_0 (as determined in the ODSAS solution) cannot satisfy the requirements in the force structure. The unfilled requirements result from the effects of attrition upon those flows (the population at T_0) and variations in the force structure in the projection period. Those requirements which are unfilled in one grade segment are passed to the next (lower) grade segment to be filled by promotees or grade substitution.

the same specialty number in the "from" and "to" specialty positions, e.g., W_{02121}. This is the only segment where W arcs with identical "from" and "to" node identifications appear.

(2) The CPTs with less than 8 YOS have only one specialty and that is one of the 30 basic entry specialties (BES). Only CPTs with 8 or more YOS can have any of the other 16 specialties for primary or alternate. The identification of the advanced entry specialties (AES) is a system input, as are the populations by YOS. The percentage representing CPTs with less than 8 YOS is computed from the population data by comparing the population with less than 8 YOS to the total CPT population.

(3) Promotion to next higher grade is not explicitly treated for the CPT segment as it is for the MAJ and LTC segments. In the CPT segment, the flow in the X arcs represents CPTs with less than 8 YOS, whereas the Y arcs represent the CPTs that either started at T_0 with more than 8 YOS, or attained 8 YOS since that time. The computation of the attrition rates for the two categories of CPTs (less than 8, and 8 or more YOS) considers that some CPTs are promoted within the projection period. Thus, the flow in the Y arcs is attrited at a rate that is derived by explicitly considering promotion to the next higher grade (see Appendix D for details).

(4) For CPTs, the transition of flows from the X arcs to the Y arcs (caused by designation of the alternate specialty for CPTs attaining 8 YOS) is treated as a residual, rather than being computed for either of two specialties as is done for promotions in the field grades. CPTs in the eighth YOS are required to have an alternate specialty designated during that year, and that alternate specialty should meet future specialty requirements. Such a designation is assured by explicitly controlling the flow of the entire CPT population except the percentage that is due for alternate specialty designation. The percentage of CPTs with 8 YOS must be uniquely identified. This value is computed from variable input data and used in the designation of alternate specialties as shown in Figure II-8. The figure shows that the fraction of CPTs that would remain with only a single specialty from 1 year to the next is specified, as is the reassignment of all CPTs who have two specialties. The number of CPTs due to be designated alternate specialties is the residual of all the flows into a node. The allocation of the residual--designation of alternate specialties--depends upon the computed requirements for the preferred alternates.



a/ Arcs contain the indicated YOS groups associated with the CPT population at T_0 (see paragraph d(6)).

b/ Indicates original YOS group designated alternate specialties in the interval shown. This group travels along Y-arcs (indicated by dashed lines) since the members of the group are now dual qualified.

FIGURE II-8, Representation of Captains with Less Than 8 Years of Service

(5) As in the field grade segments, each of the OPMS specialties in the CPT segment has a node capacity constraint based upon total requirements. However, when processing CPTs, a bias is introduced in the alternate specialty designation logic to favor the pairing of AES with BES rather than pairings of two BES. The bias specifies minimum levels for filling AES requirements. These minimum levels are percentages of the total requirements for each AES. The minimum fill requirement for each AES varies by year, with the minimum decreasing as time in the network increases (i.e., since the flows representing dual qualified officers are attriting, there is less flow available to satisfy the AES requirements in each succeeding year). The percentage used to compute the minimum fill level in each year is computed by selecting the minimum continuation rate for each year, and multiplying that rate by the minimum continuation rate in previous years (e.g., if the minimum continuation rate for T_0-T_1 was 0.80, and for T_1-T_2 was 0.70, then the minimum fill for AES requirements at T_1 would be 80 percent (continuation before T_0 is not considered), and for T_2 would be 56 percent (0.80 x 0.70)). This lower limit, or minimum fill, will be met from one or more of the following network flows: (1) CPT's

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promoted to MAJ since T_0; and/or (2) dual qualified CPTs with eight or more YOS; and/or (3) CPTs with less than eight YOS and possessing only one specialty.

(6) The X arcs for CPTs are only constructed to the year where all CPTs would reach the eighth year of service. As illustrated in Figure II-8, if the most junior CPTs at T_0 had 4-5 YOS (this would be specified in the user's input), then in 4 years that YOS group would have 8-9 YOS and thus would be due for designation of alternate specialties at T_4. There are no X arcs in the T_4 - T_5 interval (only Y arcs) because the last YOS group is to be designated alternate specialties and, as described in (4) above, those flows move along Y arcs.

(7) The final difference between processing CPTs and processing field grade officers concerns control of the Y arcs. Whereas in the field grade segments, the flow control constraints are equalities (as defined in paragraph 1m above), in the CPT segment some constraints are inequalities in order to provide for the alternate specialty designation methodology described in (4) above. As detailed in that paragraph and in Appendix G, the flow out of a node, along a Y arc, can include an unspecified number of CPTs with 8 YOS due for designation of alternate specialties. Therefore, because the number is unspecified, an inequality is used to allow the flow out of that node to equal, at least, a specified fraction of an earlier flow.

e. Lieutenant Segment. - This segment employs logic similar to that used in the CPT segment, since some of the LT population at T_0 could expect promotions to CPT during the projection period. Additionally, some LTs would reach their eighth YOS, and thus need to receive an alternate specialty. As mentioned in paragraph 1f above, the LT segment considers 2LTs and 1LTs together. The PERSACS requirements data refer to only one LT grade, and the ODSAS methodology was modified accordingly, to model flows representing the combined population of 2LTs and 1LTs. The methodology utilized for LTs is explained in subparagraphs (1) through (6) below.

(1) There are fewer arcs in the LT network since, until the eighth YOS, LTs have only one specialty and have repetitive assignments in that specialty. This is modeled in ODSAS as illustrated in Figure II-9.

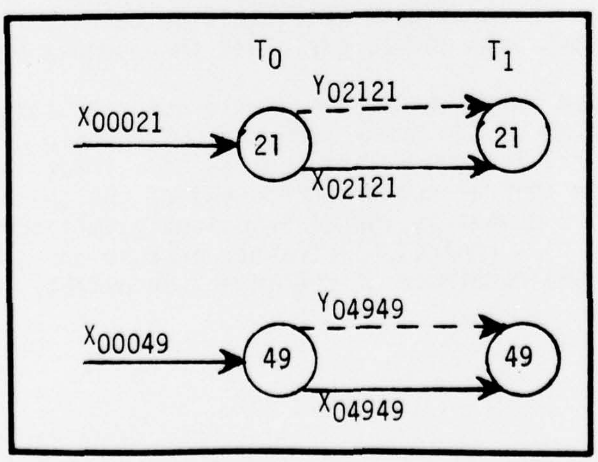

FIGURE II-9, Representation of Lieutenants with Less Than 8 Years of Service

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(a) The W arcs (representing dual qualified officers at T_0) and the $T_0 - T_0$ interval are omitted in Figure II-9. Thus, the arcs at the far left of the figure (e.g., arcs X_{00021} and X_{00049}) terminate at T_0, rather than T_0' as in the other segments. In this segment the X_{000nn} arcs represent LTs with specialty "nn". Thus, the W arcs, and the interval in which they appear, are superfluous. Consequently, the key arc relationship constraints do not apply in the segment due to the absence of W arcs.

(b) The only X arcs for LTs in the interval after T_0 are the ones in which the "from" specialty number is the same as the "to" specialty number (i.e., arcs X_{02121} and X_{04949} in Figure II-9). This fact reflects the repetitive assignments in a specialty for LTs.

(c) The Y arcs (e.g., arcs Y_{02121} and Y_{04949} in Figure II-9) represent LTs promoted to CPT. This reflects the repetitive assignments of CPTs before they attain 8 YOS. As explained in subparagraph (4) below, when any of these newly promoted CPTs reach the eighth YOS, Y arcs in the LT segment can connect different nodes (specialties). In other words, in the LT segment, promoted officers with at least 8 YOS become dual qualified and can be assigned to their alternate specialty.

(2) Promotion from 2LT to 1LT is not explicitly represented in the network; that promotion is considered in computing the weighted average attrition rates used for the X arcs (which represent all LTs). First lieutenants promoted to CPT are represented in the network by the Y arcs (previous paragraph). An additional calculation is performed to determine when, and what fraction of, the LTs promoted to CPT would reach the eighth YOS. This calculation is derived from user-input data and is explained in Appendix D.

(3) There are only two arcs leaving a node (as shown in Figure II-9) until some of the newly promoted CPTs attain 8 YOS. Since the flow conservation constraint equates node input to node output, only one flow control constraint on one of the two outputs is needed. The second output is therefore uniquely defined without constructing another flow control constraint, because the second output has to equal the remainder of the input (or output).

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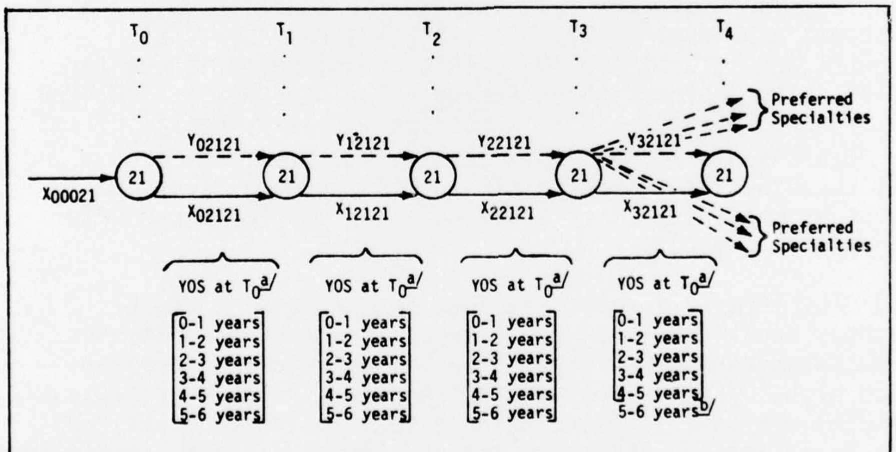
(4) Once members of the LT population reached the eighth YOS, then additional Y arcs are introduced to allow utilization in alternate specialties (as mentioned in paragraph (1)(c) above). As an example, if the LT population at T_0 consisted of officers having no more than 5 YOS, then after 2 years the most senior YOS group would complete the seventh YOS, and begin the eighth YOS. Figure II-10 illustrates the example. The first year of alternate specialty designations shown in the example is the T_3 - T_4 interval. The flow into node 21 at T_3 is associated with arcs representing LT and CPT with less than 8 YOS (arcs X_{22121} and Y_{22121}, respectively). The fraction of the former input flow, representing LTs promoted to CPT upon attaining 8 YOS and who are due for alternate specialty designation, is not specified in a constraint. The Y arcs leaving node 21 at T_3, portrayed by dashed lines in Figure II-10, provide paths for the officers to be designated alternate specialties. The requirements for promotable LTs (established in the CPT segment) determine what alternate specialties will be assigned the LTs with 8 YOS and the quantities required.



a/Arcs contain the indicated YOS groups associated with the LT population at T_0 (see subparagraph e(4)).

b/This is the YOS group to be designated alternate specialties. Dividing the number of LTs with 8 YOS by the total LT population gives the percentage due to be designated alternate specialties.

FIGURE II-10, Representation of Lieutenants, and Lieutenants Promoted to Captain, Upon Attaining 8 Years of Service

(5) When some of the newly promoted CPTs are due for alternate specialty designation, the flow control constraints are constructed

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as inequalities. This is similar to the treatment of flow control in the CPT segment. The inequalities allow LTs with newly designated alternate specialties to be reassigned from their BES to their alternate. Figure II-11 lists the constraints and illustrates their interaction, as a continuation of the example shown at Figure II-10. Constraint (1) specifies that the node input equal the node output (the flow in the two input arcs must equal the flow in the four output arcs). As shown, (1.0 - 0.25), or 0.75, of X_{22121} and (1.0 - 0.10), or 0.90, of Y_{22121} arrives at node 21 at T_3. That input departs node 21 at T_3 along the four arcs named. Equations (2) and (3) specify where a portion of the input flows will depart. In equation (2), a portion of X_{22121} will continue as LT in specialty 21 from T_3 to T_4 (arc X_{32121}). This portion is computed in the model from the tour length and attrition rate data input by the user--0.60 was chosen for this example. The remaining X arc input (0.75 - 0.60 = 0.15) representing LTs promoted to CPT at T_3. This portion will move along arc Y_{32121} in the T_3 - T_4 interval (shown in equation (3)). Similarly, a portion of Y_{22121} will continue as CPTs in specialty 21 from T_3 to T_4 (representing CPTs with less than 8 YOS). The portion of Y_{22121} is also computed in the model from tour length and attrition rate data--0.70 was chosen for this example (in equation (3)). A portion of the Y arc input (0.90 - 0.70 = 0.20) represents LTs promoted to CPT and attaining 8 YOS. This group, which is due for alternate specialty designation in the T_3 - T_4 interval, is included as an input to node 21 at T_3, but is not specifically identified as an output. Constraints (4) and (5) identify the available arcs along which flows representing CPTs attaining 8 YOS can move (i.e., designation of either specialty 21 or 53 as an alternate for those CPTs with primary specialty 21).

(6) The last refinement required for processing the LT segment imposes additional node capacity constraints once alternate specialty designation begins. These capacity constraints are for the unfilled higher grade requirements (computed in the CPTs segment). In the example at Figure II-11, alternate specialties were assigned in the T_3 - T_4 interval. Therefore the additional capacity constraints would be needed beginning at T_4. Prior to the T_3 - T_4 interval there was only one Y arc entering a node. From T_4 on, in this example, there can be more than one Y arc entering a node, and therefore a constraint is needed rather than a logical upper bound.

4. Summary. - After evaluating alternative approaches, the ODSAS study team selected a methodology which applied a LP solution technique to a multi-time period network flow problem. Because of the problem size, the resultant LP formulation required segmentation by grade, and then segmentation-within-grade. The latter segmentation scheme

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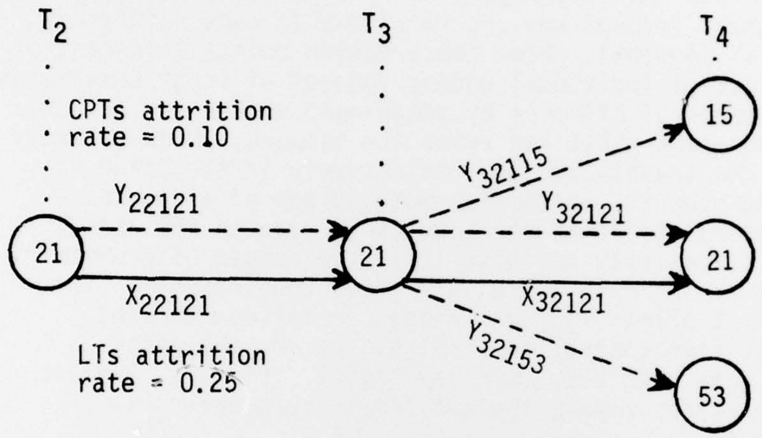
LT and CPT attrition rates are derived from user-supplied data. The rates in this example are hypothetical. Assume for this example that the preferred specialty pairings for specialty 21 are 21/15 and 21/53.



Flow Conservation:

$$(1.0 - 0.25) \times X_{22121} + (1.0 - 0.10) \times Y_{22121} = X_{32121} + Y_{32115} + Y_{32121} + Y_{32153} \quad (1)$$

Flow Control:

$$0.60 \times X_{22121} = X_{32121} \quad (2)$$

$$0.15 \times X_{22121} + 0.70 \times Y_{22121} = Y_{32121} \quad (3)$$

$$Y_{32115} \geq 0 \quad (4)$$

$$Y_{32153} \geq 0 \quad (5)$$

FIGURE II-11, Illustration of the Interaction of Constraints for Alternate Specialty Designation in the Lieutenant Segment

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is optional and can be used if the largest grade segments (LTC and MAJ) exceed hardware and/or software limits.

a. The methodology employs five types of constraints: flow conservation, node capacities, flow control, control of input, and key arc relationships. All five types of constraints are used in each grade segment (except key arc relationship constraints do not apply in the LT segment). Flow conservation constraints control the input and output of individual nodes; control of input constraints limit the total number of officers by grade--and number for selected specialties within grade--that can enter the network. Node capacity and flow control constraints are used selectively in the grade segments depending upon the particular methodology of a segment. Node capacity constraints limit the input to a node to the annual requirements for a specialty and also limit the number of promotees to a higher grade to the unfilled higher grade requirements. This important constraint allows for only enough promotions to meet requirements. The flow control constraints specify the paths in the network that each specialty pair may travel. Finally, key arc relationship constraints relate the two flows representing a specialty pair at T_0.

b. For each grade segment, the ODSAS system determines the maximum number of officers that can be utilized in a user-defined set of preferred specialty pairings considering attrition and promotion throughout the time span being analyzed. Unfilled requirements, computed after processing one grade segment, are passed to the next lower grade segment for use as limits on promotions and/or grade substitution. The three field grade segments use similar logic; the CPT and LT segments differ significantly from the field grades because, most CPTs and LTs have only one specialty and, during the projection period, an alternate specialty must be designated to those who attain 8 YOS.

c. In summary, the methodology addresses all three EEA. The number of officers to be allocated specific specialty pairings at each grade level (EEA 1) is the solution value of the W arcs in the CPT through COL segments. Designation of alternate specialties to CPTs attaining 8 YOS is accomplished in the CPT and LT segments. The total procurement of officers by BES (EEA 2) is determined by computing the unfilled LT requirements at the end of the processing for that segment. Finally, the training requirements for BES and alternate specialties (EEA 3) can be derived by comparing the actual officer asset position to what ODSAS computes the asset position should be.

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			TOTAL REQUIREMENTS FOR SPECIALTY 49		
YEAR OF SERVICE	GRADE O-2	GRADE O-3	GRADE O-4	GRADE O-5	GRADE O-6
T0	10	60	175	220	43
T1	11	82	190	225	47
T2	9	83	183	225	47
T3	9	83	183	225	47
T4	9	83	188	225	47
T5	9	83	189	225	47
T6	9	83	189	225	47
T7	9	83	189	225	47
T8	9	83	189	225	47
T9	9	83	189	225	47
TOTALS	93	806	1875	2245	456

FIGURE III-9, Sample PERSACS Requirements Report - by Specialty (for Specialty 49)

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on requirements by specialty and Figure III-10 is a sample of the report on requirements by grade.

(2) The second report type contains the derivation and computations used to produce all the input rates to the system. An excerpt from that report for LTCs is at Figure III-11. The numbers highlighted in heavy lines are examples of the rates input to the matrix generator. Both of the initialization phase reports are for user verification of the derived input data.

b. <u>Processing Phase Reports</u>

(1) There is one standard report and one optional report in the matrix generator activity. The standard report is a statistical summary, and the optional report contains the internal programing codes used in the matrix generator.

(a) The statistical summary contains the key data and characteristics of the problem to be solved. The first part of the statistical summary (Figure III-12) shows both the unfilled higher grade requirements (passed down from the preceding segment) and the requirements for the grade of the current segment. (The requirements data values may be greater than the actual computed requirements if the user opts to provide input directing that requirements may be overfilled by a percentage of the authorized value.) Requirements values in this summary report are used as the capacities of the nodes. Column 2 of the report (entitled PCT AUTH) contains the maximum percentage fill allowed for a specialty in that segment. The second part of the statistical summary (Figure III-13) shows the problem size, in terms of the total number of rows for each constraint type, and a summation of all constraints (rows). This total number of rows should match the matrix statistics produced by FMPS described in subparagraph (2) below. Additionally, the report displays key parameter values (number of specialties, number of years in the projection period, and number of preferences) applicable to the current segment.

(b) An additional part of the statistical summary is produced for the LTC and MAJ segments. The derivation of a revised promotion rate (one that attempts to promote to fill all vacancies) is displayed in the additional part. An example is shown at Figure III-13a. The "TOTAL UNFILLED REQUIREMENTS" value is computed in the linkage activity. The "STARTING GRADE n POPULATION LAST YEAR" is, initially, the budget authorized amount (input by the user) for grade 0-5 or 0-4, and thereafter reflects the effects of attrition and promotion on the initial population.

(c) The optional report (not shown here) contains the codes generated and used within the matrix generator program. This report is provided for use in changing or debugging the program. Explanation of this report is in the ODSAS Information System documentation, published separately.

(2) Most of the printed output from the FMPS activity consists of diagnostic messages concerning FMPS internal logic at periodic intervals during processing, and is explained in the FMPS documentation (reference 2). The two outputs of primary concern are the matrix statistics and the detailed listing of the solution.

```
*INITIALIZATION PROMOTION RATE FOR YEAR 1 RECOMPUTED BASED UPON PREVIOUS SEGMENT

OLD RATE WAS     .16720 VS NEW RATE     .24942
THEREFORE     .24942 WILL BE USED IN THIS SEGMENT
                    ***DERIVATION OF PROMOTION RATE***

TOTAL UNFILLED REQUIREMENTS                                           3000.799

MINUS: REQUIREMENTS SATISFIED LAST YEAR                                   .000

     RAW REQUIREMENTS TO BE FILLED THIS YEAR                          3000.799

PLUS: ATTRITION IN GRADE 5 LAST YEAR (ATTRITION RATE = .0000)             .000

     TOTAL REQUIREMENTS TO BE FILLED BY PROMOTION THIS YEAR           3000.799


STARTING GRADE 4 POPULATION LAST YEAR                                12031.000

MINUS: PROMOTIONS LAST YEAR                                               .000

    NON-PROMOTED GRADE 4 POPULATION                                  12031.000

MINUS: ATTRITION OF NON-PROMOTED (ATTRITION RATE =  .0000)                .000

GRADE 4 POPULATION AVAILABLE FOR PROMOTION                           12031.000


          PROMOTION RATE = TOTAL REQUIREMENTS TO BE FILLED ' BY PROMOTION /

                           GRADE 4 POPULATION AVAILABLE FOR PROMOTION

                         =   3000.799 /    12031.000

                         =       .249
```

FIGURE III-13a, ODSAS Statistical Summary Report - Additional Part; Derivation of Revised Promotion Rate for LTC and MAJ Segments (continued on next page)

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*INITIALIZATION PROMOTION RATE FOR YEAR 2 RECOMPUTED BASED UPON PREVIOUS SEGMENT

OLD RATE WAS     .21880 VS NEW RATE     .17771
THEREFORE     .17771 WILL BE USED IN THIS SEGMENT
                    ***DERIVATION OF PROMOTION RATE***

TOTAL UNFILLED REQUIREMENTS                                            4437.399

MINUS: REQUIREMENTS SATISFIED LAST YEAR                                3000.799

     RAW REQUIREMENTS TO BE FILLED THIS YEAR                           1436.600

PLUS: ATTRITION IN GRADE 5 LAST YEAR (ATTRITION RATE = .0195)            58.516

     TOTAL REQUIREMENTS TO BE FILLED BY PROMOTION THIS YEAR            1495.115


STARTING GRADE 4 POPULATION LAST YEAR                                 12031.000

MINUS: PROMOTIONS LAST YEAR                                            3000.799

    NON-PROMOTED GRADE 4 POPULATION                                    9030.201

MINUS: ATTRITION OF NON-PROMOTED (ATTRITION RATE =  .0683)              616.763

GRADE 4 POPULATION AVAILABLE FOR PROMOTION                             8413.438


          PROMOTION RATE = TOTAL REQUIREMENTS TO BE FILLED BY PROMOTION /

                                GRADE 4 POPULATION AVAILABLE FOR PROMOTION

                           =    1495.115 /     8413.538

                           =         .178
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FIGURE III-13a, ODSAS Statistical Summary Report - Additional Part; Derivation of Revised Promotion Rate for LTC and MAJ Segments (concluded)

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column in Table D-2) must be added to those officers who had already been promoted to the next higher grade from T_0 up to the year being considered. Since the promotions commence at T_0 in this example, the values in the column "0-5 Promoted Before T-0" in Table D-3 are necessarily zero because the system considers that T_0 is the beginning of all activity. However, the population values which will appear in this column for subsequent years will reflect promotees from earlier years. The total promotees at T_0 ("Total Prom" column) are therefore comprised of only the "New-Promotees" in each YOS represented. The total number promoted, by YOS, is then multiplied by the user-supplied input attrition rate ("Attr. Rate for Grade-5" Column) for officers of that grade and YOS, to compute the number attrited in that grade and YOS ("Attrition" column).

(b) The values in the "Total Prom" and "Attrition" columns are each summed across all YOS represented. The "Attrition" total (49.40 in Table D-3) is divided by the "Total Prom" sum (1918.36 in Table D-3) to compute an attrition rate for those officers promoted.

(3) In the third step of calculating attrition and promotion rates, the starting population at T_0 must be "aged" to reflect the attrition and promotion that occurred in the T_0 - T_1 interval, to arrive at the starting population at T_1.

(a) This procedure consists of subtracting the promotions and the attrition in grade from the T_0 starting population, by YOS, to arrive at the amount of that YOS group remaining at T_1. Table D-4 illustrates the "aging" of the populations presented in Tables D-1 through D-3. In Table D-4, the "Starting Population" of 331.7 MAJs in their 11th YOS at T_1, represent the 343.0 "Starting Population" in their 10th YOS at T_0 (in Table D-2), less "Promotions" of 1.37 at T_0 (in Table D-2) and "Attrition in Grade" of 9.91 (in Table D-2). Similarly the "Starting Population" with 13 YOS at T_1 (Table D-4), 2007.5, represents the "Starting Population" with 12 YOS at T_0 (Table D-2), 2156.0, less "Promotions" of 99.18 and "Attrition in Grade" of 49.36.

(b) An exception to the "aging" procedure is employed for the last YOS represented in a grade (i.e., the 20-21 YOS line in Table D-4). The values on this line include that YOS and later YOS, for computation purposes (which, in Table D-4, are both zero and are therefore not readily apparent). When the values on this line are non-zero, in computing the starting population with 20 YOS and over, at T_1, that population is the sum of the starting populations at T_0 with 19-20 YOS plus those with 20-21 YOS and over, less promotions and attrition in grade for both groups. For example, if the "starting population" of the 19-20 and 20-21 (and

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over) YOS groups at T_0, in Table D-2, were 13.0 and 3.0, respectively; "Promotions," 0.12 and 0.00; and "Attrition in Grade" 8.63 and 2.06, then the "Starting Population" for the 20-21 YOS group line in Figure D-4 (representing the population with 20 YOS and over) would be 5.31. This value would have been computed by adding together the "Starting Population" of the 19-20 and the 20-21 (and over) YOS groups at T_0 from Table D-2 (i.e., 13.0 + 3.0 = 16), subtracting the combined "Promotions" (0.12 + 0.00 = 0.12), and the combined "Attrition in Grade" (8.63 + 2.06 = 0.69); or (16.0 - 0.12 - 0.69 = 5.31). The value 5.31, the "Starting Population" for the 20-21 YOS line, when rounded to the nearest one-tenth, would be 5.3.

c. Calculation for Subsequent Years. - Upon completion of the three-step procedure in b above, the attrition and promotion rates for each subsequent year in the projection period are computed, applying the same three-step procedure to the attrition rates supplied by the user and the starting populations derived in b.

d. Modification to Promotion Rates. - Since the promotion rates for LTC and MAJ computed in the initialization phase are only estimates based upon past years, the rates are revised in the matrix generator activity of the processing phase. The revised rates are based upon results produced in previous segments of the processing phase--specifically, the unfilled requirements derived from the COL or LTC solutions. Computation of the revised rate(s) consists of dividing the total unfilled requirements that can be filled by promotees in a given year by the total possible population available for promotion.* The revised (recomputed) promotion rate(s) is then used in the matrix generator activity, since the new rate is a closer approximation to the concept of promoting to fill vacancies.

6. Derivation of Attrition and Promotion Rates for Colonels. - The three-step procedure described in paragraph 5 for producing annual attrition and promotion rates for LTCs and MAJs is modified to a two-step procedure for COLs. Weighted average promotion rates and attrition rates for COLs promoted to general officer are not needed for the COL segment, because general officer grades are not included in ODSAS. Consequently, the annual attrition rates for COL are computed in a manner similar to the attrition rate for LTCs or MAJs remaining in grade, except that the COL attrition rate

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*The printed output of the matrix generator activity for LTC and MAJ segments displays the derivation of the revised promotion rate for each year played in the model (see paragraph III-3b(1)(b)).

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for each YOS represented includes promotion as a form of attrition. Attrition rates for LTCs/MAJs remaining in grade do not include promotion as a form of attrition (paragraph 5b(1) (b) above).

a. The first step is to multiply each YOS population by the corresponding rate with promotion. Computations are illustrated at Table D-5. The values in the "Population" and "Rate w/Prom" columns, which are extended as input by the user, are multiplied to produce the attrition by YOS shown in the "Population * Rate w/Prom" column. The population values and the attrition values are summed across all YOS represented, to produce the column totals shown. Then the total "Attrition" is divided by the "Population Sum" to produce the "Attrition Rate" in grade 6 for that year.

b. The second step is the same as the third step in the process described in paragraph 5. That is, the COL population with n years of service, less the attrition of those with n years of service, becomes the COL population 1 year later, with n+1 YOS. Table D-6 illustrates the "aging" of the COL population at T_0 to a point 1 year later (T_1). (Note: The last YOS group (i.e., 29-30)

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