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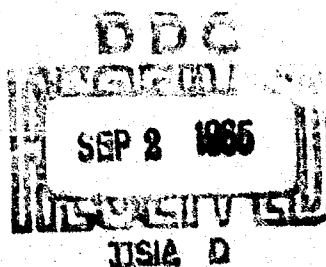
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RESEARCH MEMORANDUM SRM 66-4

AUGUST 1965

A SELECTED ANNOTATED BIBLIOGRAPHY ON COST EFFECTIVENESS AND MAN/MACHINE FUNCTION ALLOCATION

J. Scott Webb
Joe E. Willis
Ronald D. Anderson



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A SELECTED ANNOTATED BIBLIOGRAPHY ON COST-EFFECTIVENESS
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by

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August 1965

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Research Memorandum SRM 66-4

Submitted by

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BACKGROUND AND PURPOSE

It is becoming increasingly evident that advances in technology (especially microelectronics) are having significant effects on the place of men in Navy weapon systems--present and future.¹ Decisions pertaining to the allocation of system functions to man or machine are becoming increasingly difficult. Such decisions could be facilitated by the use of a cost-effectiveness ratio, this ratio to be used as a basic formula for the comparison of the cost-effectiveness of functions as allocated to human operation versus automated operation.

This bibliography was prepared as the first part of an effort in which the feasibility of developing a general cost-effectiveness formula is being examined. The major areas of interest represented in this bibliography are:

- (A) SYSTEM COSTS, including a representative sample of factors which would relate to them.
- (B) SYSTEM EFFECTIVENESS, including reports which concern the cost-effectiveness ratio.
- (C) MAN/MACHINE FUNCTION ALLOCATION.

BENEATH THE NUMBER OF EACH BIBLIOGRAPHY ENTRY IS A LETTER (A, B, OR C) WHICH INDICATES THE MAJOR AREA(S) OF SUBJECT MATTER, CORRESPONDING TO THE ABOVE THREE AREAS OF INTEREST.

An addendum includes important articles which became available during the time that the bibliography was in press.

¹See The Impact of New Technology on the Navy's Human Factor, Presentation to the Chief of Naval Material Technical Briefing, 2 December 1964 and to the Bureau of Naval Personnel, 4 December 1964, Kaplan I. E., U. S. Naval Personnel Research Activity, San Diego, California.

1. Alchian, Armen A., Reliability of Cost Estimates - Some Evidence, The Rand Corporation, RM-481, 30 October 1950, pp. 11, (Unclassified)

This report presents some data on the reliability of cost estimates obtained from several sources. It was believed that studies of cost estimates and their accuracy, no matter what the type of item being produced or operated, would shed light on the cost estimation reliability problem. The range of unreliability detected in this study is such that a confidence in being able to bracket the true costs requires bracketing values in the ratio of about 2-1 (ratio of upper limit to lower limit).

2. Annotated Bibliography of New Developments Research Branch Studies, Personnel Research Division, Bureau of Naval Personnel, January 1963, pp. 45, (Unclassified)
3. Arzigian, Simon, Methods and Problems of Computation of Enlisted Personnel Costs, U. S. Naval Personnel Research Activity, Task Assignment 301.01-01W, PRAW Report No. 64-16, February 1964, pp. 59, (Unclassified)

Provides, in some detail, "an explanation of the methodology employed in the computation of enlisted personnel costs. Sources of information have also been indicated and an analysis of problem areas which are encountered in the course of research has been made."

"Personnel costs discussed in this report are by no means the only costs incurred by the Navy in the personnel costing area. For example, additional study is required in the area of training costs, particularly for the accurate valuation of amortization of expensive training equipment and the costs of on-the-job training required after school to bring personnel in various ratings to an acceptable technical level."

4. Baldwin, LT Edwin M., USN, An Analysis of the Cost and Requirements of the Fleet Ballistic Missile Submarine Personnel Subsystem, Thesis, United States Naval Postgraduate School, 1963, pp. 37, (Unclassified)

"The Polaris Submarine Weapons System is presently employing two crews per submarine, working in shifts in order to maximize the time on station for each submarine. The cost of this personnel policy as compared to the cost of using other alternatives is of current interest. The purpose of this thesis is to present a technique for making this comparison. The actual data is not presented here, but hypothetical examples are given."

5. Barbour, A. A.; Firstman, S. I.; & Kamins, M.,
(B) Standardization of Automatic Test and Checkout Equipment:
(C) A Preliminary Discussion, The Rand Corporation, RM-2685,
25 November 1960, pp. 53, (Unclassified)

"This report is intended as a guide in the evaluation of the technical and economic feasibility of standardizing automatic test and checkout equipment. Amounting to a "think piece", it covers what the authors believe to be the topics pertinent to several levels of standardization. It is not a partisan study, since care has been taken to point out the problems and pitfalls inherent in standardization, and it includes a section devoted to arguments against standardization."

6. Barfoot, Charles B., A Preliminary Cost-Effectiveness Handbook,
(B) Technical Operations Research, Arlington, Massachusetts,
November 1963, (Unclassified)

This preliminary handbook was developed for use by United States Army Combat Developments Command Field Agencies and AD HOC Study Groups in the preparation of cost-effectiveness studies. The handbook discusses the purpose of cost-effectiveness analysis, general methods for comparing alternative systems, and the major elements of the analysis. Two examples of cost-effectiveness evaluations are presented. General references and a bibliography of published sources for cost data and of publications on systems and force structure costing are included.

7. Bell, Chauncey F., Cost-Effectiveness Analysis As A Management Tool, Rand Corporation, Santa Monica, California, October 1964,
(B) (Unclassified)

The potential value of cost-effectiveness analysis as a management tool is discussed. Such analyses can be useful because they suggest an examination of alternative ways of attaining a given objective or goal, because they focus attention on selecting appropriate objectives and relevant variables, and because they require identification and quantification of these factors. While such apparent precision may sometimes lead to unwarranted confidence in the results, any management decision is affected as much or more by such short-comings. Independent of cost-effectiveness analysis, on balance, then, the identification, quantification, and systemization of cost-effectiveness analyses adds to the likelihood that the resulting judgement decision is a good one.

8. Bell, Chauncey F.; Kamins; & Milton, Determining Economic Quantities of Maintenance Resources: A Minuteman Application, The Rand Corporation, Santa Monica, California, January 1963, (Unclassified)

This memorandum introduces a technique for computing manpower and equipment requirements that takes into account three critical and frequently overlooked factors. These are: the randomness of the failure patterns--the uncertainty of the time any particular malfunction will occur; the workshift policy--when maintenance personnel are on duty; and the cost-effectiveness trade off--the marginal increase in system capability weighed against the cost of providing a marginal increase in resources. The quantities of maintenance personnel and ground equipment estimated with the technique presented here will economically meet anticipated requirements within the accuracy limitations of the three inputs necessary to the computation. These are: failure rate or reliability, repair time or maintainability, and cost.

9. Boren, H. E., Jr., Individual Weapon System Computer Cost Model, The Rand Corporation, Santa Monica, California, RM 4165PR, AF49 638 700, July 1964, (Unclassified)

This memorandum describes the operation of one computerized weapon system cost model used by the Rand Cost Analysis Department to determine resource requirements for individual weapon systems that consist of either aircraft, aircraft and air-to-surface missiles (ASM'S), or strategic missiles (for personnel requirements only). Included is a general description of the model with particular emphasis on the personnel subroutine, which can handle eight specific types of weapon systems of the Strategic Air Command, the Air Defense Command, the Tactical Air Command, and the Military Air Transport Service, and extrapolate from these eight weapon systems 72 varying weapon system mixes and basing situations. The discussion is oriented toward describing the actual operation of the model rather than the underlying reasons for the methodology used.

10. Bovaird, R. L.; Goldman, A. S.; & Slattery, T. B.,
(B) Concepts in Operational Support Research, TEMPO, General Electric Company, RM 60TMP-70, 21 November 1960, pp. 39, (Unclassified)

This paper deals with concepts involved in the field of "Operational Support of Complex Military Systems". Operational support, as used here, refers to the process which has the objective of keeping system availability (or unavailability) at acceptable levels. An attempt is made to gather into a cohesive form those principles characterizing the new science which is evolving from integrated studies on reliability, maintainability, and logistics problems. The concepts presented here have been developed out of support studies of several current military electronic systems.

11. Brooks, Samuel H., Reliability Cost/Effectiveness A Pilot Study, Aerospace Corporation, San Bernardino, California, (B) Final Report TDR 269S4853 1, AF04 695 269, AF04 695 469, BSD TDR 64 91, (Unclassified)

A mathematical model is developed and explored to examine the overall relationship between effectiveness--in terms of reliability, availability, and maintainability--and the costs to be allocated and apportioned among the reliability efforts. This model leads to an estimate of how much should be spent on reliability during design and development of a missile system, and how much should be spent in ensuring the reliability and availability for each individual missile during its operational life. A computer program was developed and parameter studies along these lines were initiated. Requisite optimization and information methods are discussed. Preliminary indications are that cost/effectiveness modeling is feasible and leads to methods of program control. Further studies to expand these results are recommended.

12. Clary, James N.; & Arzigian; Simon; Personnel Costs for Ten Selected Ratings (AC, AE, AQ, AT, AX, ET, FT MM, RD, ST) (A) Naval Personnel Research Laboratory, Washington, D. C., WRM No. 65-2, April 1965, (Unclassified)

"Designed to meet the urgent need of the Secretary of the Navy's Task Force on Military Personnel Retention for personnel costs for ten selected ratings. Cost information in the report should prove useful to other consumers as well."

"The personnel costs presented herein are based on the latest available information and reflect all known adjustments."

13. Cole, Roy D.; Keith, Melvin H.; & Seeley, Richard B.,
(B) A Light-Attack Tactical Weapon System Study (U),
Naval Ordnance Test Station, China Lake, California,
January 1960, (CONFIDENTIAL)
14. Connors, Alonzo J.; Dye, H. ; Erler, R. L.; Joe, R. H.;
(A) & Martin, C. P., Techniques for Predicting R and D Costs
and Schedules of Automatic Flight Control Systems: Volume
1, Aerodynamic Vehicles. Planning Research Corporation,
Los Angeles, California, Report for September 1962 -
August 1963, (Unclassified)

The objective of this report was to investigate and formulate techniques for predicting the development cost and development time of automatic flight control systems in aerodynamically supported vehicles--both manned and unmanned. An empirical approach is taken, using relevant historical data on 25 automatic flight control systems. The predictive methodology is formulated using two types of statistical estimation models. The resultant predictive techniques are expressed as simple algebraic equations that can be evaluated to obtain cost and time estimates for a proposed flight control system.

15. Cooper, Joel, "An Integrated Approach to System Maintainability",
(B) in F. L. Andenbrandt (ed.), Electronic Maintainability, Volume
(C) 3, Reinhold, New York, 1960, (Unclassified)

"Since a high percentage of malfunctions are initiated by humans, a method for estimating the 'human reliability' of a system would be useful during the planning and development sequence. It is proposed that classifying maintenance operations and collecting data on time, accuracy, and variability in performing them would be useful. Such data could be applied for example, to the man-machine allocation problem: If human response variability for a set of operations is too great, then that group of tasks becomes a good candidate for mechanization or procedural revision.

16. Deprotine, P. R., Characteristics of ABM Systems Optimized
for Defense Against Small Attacks, Douglas Aircraft Company,
(A) Incorporated, Santa Monica, California, SM48055, SD247,
November 1964, (Unclassified)

This appendix presents the cost breakdown of all System-A deployments considered in detail. The costs are presented in two ways. First, the cost of individual batteries or radar sites is presented, followed by a summation of the total investment for all sites in a specific system. Second, the annual operating and maintenance costs are listed per battery and radar site, followed by a summation for total system annual and 5-year operating and maintenance costs. Each section presents the data in both the format provided in the ARPA cost guidelines and in the cost model format. Taking the RDT&E category as an example, the first sheet, starting with preliminary research and design studies lists all elements of the basic cost model. The following sheet, headed RDT&E format, rearranges these elements into the ARPA cost guideline format. This dual arrangement continues for investment and operating cost categories. The cost model presentation is retained because its greater level of detail permits the reader to make his own analysis of any major cost area of interest. The index is arranged to permit easy retrieval of any category or element of cost.

17. Deprotine, P. R., Characteristics of ABM Systems Optimized for Defense Against Small Attacks, Volume III, Technical Appendixes, Part 6, Appendix G3, System B Cost Substantiation (M), Douglas Aircraft Company, Incorporated, Santa Monica, California, SM48055, SD247, November 1964, (Unclassified)

This Appendix presents the cost breakdown of all System-B deployments considered in detail. The costs are presented in two ways. First, the cost of individual batteries or radar sites is presented, followed by a summation of the total investment for all sites in a specific system. Second, the annual operating and maintenance costs are listed per battery and radar site, followed by a summation for total system annual for 5-year operating and maintenance costs.

18. Deprotine, P. R., Characteristics of ABM Systems Optimized for Defense Against Small Attacks, Volume III, Technical Appendixes, Part 7, Appendix G4, System C Cost Substantiation, Douglas Aircraft Company, Incorporated, Santa Monica, California, November 1964, (Unclassified)

This appendix presents the cost breakdown of all System-C deployments considered in detail. The costs are presented in two ways, first the cost of individual batteries or radar sites is presented, followed by a summation of the total investment for all sites in a specific system.

Second, the annual operating and maintenance costs are listed per battery and radar site, followed by a summation for total system annual for 5-year operating and maintenance costs.

19. Enlisted Personnel Costs For Use In SEA HAWK Cost Effectiveness Comparisons (First Report). New Developments Research Branch, Personnel Research Division, Bureau of Naval Personnel, Washington, D. C., Report No. ND 64-63, May 1964, (Unclassified)

Provides "... information on personnel costs to be used in cost effectiveness comparisons being conducted for the SEA HAWK project." It "... utilizes existing BUPERS cost methodology that has been developed in earlier reports, and in some instances additional consideration".

"This SEA HAWK personnel cost report is divided into two major parts. The first part presents in detail the method of computation of personnel cost figures and discusses ways of implementing personnel costs in SEA HAWK Program evaluations. The second part presents cost data sheets for twenty-seven ratings."

20. Enthoven, Alain C., The Economics of Navy Pay, The Rand Corporation, P-1051, 2 April 1957, pp. 18, (Unclassified)

The occasion for this discussion was the appearance of the Cordiner report on the military pay structure. The author states that the recommendations made in the Cordiner report are a step in the right direction, and they represent an attempt to readjust salary scales in accordance with supply and demand and productivity considerations. However, as an economist, the author would like to see more reliance placed upon a flexible system of reenlistment bonuses. He states that such a system would be particularly desirable for the Navy.

21. Enthoven, Alain C., The Mathematics of Military Pay, Rev. ed., The Rand Corporation, P-1100, 11 November 1957, pp. 30, (B) (Unclassified)

The purpose of this paper is to explain the mathematical theory of maximization of military effectiveness within the limitations of a fixed budget and to show that the theory has an appropriate application in the pay question.

22. Firstman, Sidney I., How Much Automaticity for Checkout Equipment, The Rand Corporation, P-1867, 4 January 1960, pp. 24, (Unclassified)

The author states that the degree of automaticity with which an automatic checkout system operates is determined primarily by the method of programming (or control) employed, i.e., whether, for example, a digital computer or a paper tape control system with manual decision is employed. And since the nature of the programmer determines, to a large extent, the nature of the checkout system (and vice versa), this paper discusses some of the relevant differences between the two generic types of automatic programmers--internally and externally programmed--that should be considered when determining the degree of automaticity to build into an automatic checkout system for any particular application.

23. Firstman, Sidney I., Some Limitations of Automatic Test Equipment, The Rand Corporation, P-2319, 22 May 1961, pp. 6, (Unclassified)

This article discusses some of the limitations of automatic test equipment (ATE). The limitations are broken into the following four categories: (1) limitations surrounding automatic testing per se; (2) those most clearly associated with ATE-prime equipment interactions; (3) those associated with ATE operating in its environment; and (4) those concerned primarily with man-machine activities.

24. Firstman, S. I.; Barbour, A. A.; Brom, J. R.; Jordan, N.; Kamins, M.; Meyer, K. H.; & Voosen, B. J., An Omnibus of Briefing Papers on Analysis of Automatic Checkout Equipment and Aids to Its Design, The Rand Corporation, RM-2750, 12 June 1961, pp. 158, (Unclassified)

"This memorandum is a summary briefing, together with shorter back-up briefings, on a RAND study of automatic checkout equipment and aids to its design (Project ACE). The material, essentially unchanged, has been gathered in this format to make ACE results available quickly to persons who are concerned with automatic checkout equipment but who have not heard the presentations.

The memorandum opens with a summary of RAND's Project ACE, including a checklist of operational features. This is followed by nine briefing papers on subordinate aspects. Detailed back-up material is cited where appropriate. A bibliography of ACE publications released or in process is provided on p. vii."

25. Firstman, Sidney I.; & Jordan, Nehemiah, Operational and Human Factors in Planning Automated Man-Machine Checkout Systems, The Rand Corporation, Memorandum RM-2835, April 1962, pp. 60, (Unclassified)

"This Memorandum, aimed at improvement of planning and designing of automated checkout and test equipment (ACE) for military systems, is part of a larger RAND study of automatic checkout equipment.

It is based in large measure on an extensive survey of automated checkout and test equipment as it has been used in the field, supplemented by study of human factors relevant to both the process of automating such equipment, and the subsequent operation of the ACE, in furtherance of overall effectiveness of military systems."

26. Fisher, G. H., Weapon System Cost Analysis, The Rand Corporation, Santa Monica, California, Report No. P823, (Unclassified)

This paper is concerned with how cost is to be estimated and taken into account in an analysis of weapon systems. It is assumed that the analyst is dealing with that class of systems analysis problems where cost considerations are relevant.

27. Fitts, P. M. (ed.), Human Engineering for an Effective Air-Navigation Air Traffic-Control System, Ohio State University Research Foundation, December 1950, (Unclassified)

The following four alternative man-machine systems are described: (1) fully automatic control, (2) automatic control with human monitoring, (3) semiautomatic control supplemented by human performance of critical functions, and (4) primary control by human operators who would be assisted by effective data-analysis, data-transmission, and data-display equipment.

The abilities in which humans (machines) surpass machines (humans) are also given.

28. Fox, Peter D., A Theory of Cost-Effectiveness for Military Systems Analysis, Operations Research, Volume 13, No. 2, March-April 1965, pp. 191-200, (Unclassified)

This paper presents a theoretical basis for cost-effectiveness analysis. It is argued that, frequently, a range of effectiveness or cost levels may be acceptable to whoever must ultimately decide which military system (if any should be acquired. The function of the analyst

is to present a schedule of alternatives and not to optimize in the sense that he recommends the selection of a particular alternative. The formulation of the schedule is discussed where the cost and effectiveness associated with each alternative are viewed as random variables. The paper concludes with some general observations relating to military system selection.

29. Franks, P. E.; & Furnish, C. W., Automated Maintenance: Theory, Practice, and Implications for Training, WADD Technical Report 60-412, August 1960, pp. 23, (Unclassified)

"The automatic checkout concept may be justified insofar as it (1) reduces skilled manpower needs, or (2) serves to achieve an extremely short operational reaction time. A successful checkout system must be multipurpose, accurate, efficient (in terms of testing time), seldom fail, and have a quick change capability while keeping costs within reasonable limits.

Assuming that ACE will soon be in use and time is short to prepare for its impact, the anticipated effects of ACE on personnel skill levels, motivation, logistics, cost, system accuracy, and training are discussed."

30. Freed, Alvyn M., Human Interactions in Man-Machine Systems, Human Factors, Vol. 4, No. 6, December 1962, pp. 389-396, (Unclassified)

"Human interactions play a vital role in the reliability of man-machine systems. Techniques are necessary to insure that those which occur do so because they are so designed and planned. A tentative approach to providing lists of such interactions, and ways of defining, labelling and measuring them are suggested as basic to design input. Methods for isolating units of interactive behavior are proposed and samples of system behavior and their respective activities described in terms of actions and reactions. The need for definition and labelling of activities couched in operational terms is emphasized in the interest of design, training and measurement of human interactions in man-machine systems. Techniques for accomplishing these steps are suggested."

31. Gagliardi, U. O.; Kaplan, J.; & Vallerie, L. L., Man-Computer Systems and Allocation of Resources Problems, Dunlap and Associates, Incorporated, Contract No. Nonr-3602(00), January 1964, (Unclassified)

The work reported concerns the observation of problem-solving behavior exhibited by subjects who were given an allocation-of-resources task. The task was to deploy Polaris-like weapon systems against a given target system under stated constraints. While the task is formulable as an integer linear programming problem, the subjects solved it by resorting to heuristic procedures. These procedures, as well as the solutions produced, seem to indicate that a problem solver may encounter considerable difficulty in uncovering the ordering of decision alternatives, if this ordering is a partial one.

Following the study of unaided performance, two distinct computer-aid concepts were developed and tested.

32. Geisler, M. A., Man-Machine Simulation Progress, The Rand Corporation, P-2086, 23 August 1960, pp.10, (Unclassified)

This paper discusses a technique which has been largely developed through use in logistics research. The technique has been applied to studies of large logistics management systems in which decision-making under uncertainty is required. The procedure is to build man-machine simulations, and to use them in experimental situations. The output is a description of decision rules, information flows, and an organizational structure that improve the cost and effectiveness of the logistics system. Man is used in these simulations for his learning, adaptiveness, and flexibility.

33. Goldman, A. S., Introduction to the Economic Theory of System
(A) Development in Operational Support, TEMPO, General Electric
(B) Company, RM 62TMP-39, 1 May 1962, pp. 59, (Unclassified)

"The prime purpose of this report is to present decision making tools, derived from economic theory, to assist in the development of complex military systems. The emphasis is on the operational support aspects (reliability-maintainability-availability) of system design but the reader will also find that the philosophy applies to other areas as well (e.g., performance trade offs). A secondary, but no less important, purpose is to present a primer of production economics for reference by engineers in various phases of product development."

34. Gordon, T. J.; & Helmer, O., Report on a Long-Range
(B) Forecasting Study, The Rand Corporation, Santa Monica,
(C) California, September 1964, (Unclassified)

This report describes an experimental trend predicting exercise covering a period extending as far as fifty years into the future. The experiment used a sequence of questionnaires to elicit predictions from individual experts in six broad areas: scientific breakthroughs, population growth, automation, space progress, probability and prevention of war, and future weapon systems. Results of the experiment illuminate a number of points: The contents of the predictions themselves, the bases on which respondents claimed their predictions were made, the spread of expert views, the convergence of views following data feedback, the expert's critiques of each other's views, and not least of all, the weaknesses of the method and the possible means for improving it.

35. Grodsky, M. A.; Levy, G. W.; & Sorkin, R. D., A Model of Human
(B) Maintenance Behavior-I: Development of the Problem and Evidence
(C) for a Model, The Martin Company Engineering Report 11133, 1960,
(Unclassified)

Four criteria are suggested for studying the advantages of automatic or manned modes for space flight: payload weight, economy (overall operational costs), utility of man, and mission effectiveness.

Previous studies indicated that application of these criteria justified a manned vehicle. "It is apparent that there is a definite per cent weight advantage in using a manned mode of maintenance as opposed to an automatic mode of maintenance. It should be noted that the increased weight in the manned mode of maintenance also includes the weight required to support men within the system." These savings may be attenuated in the actual case because equivalent or greater cost expenditures would be necessitated by the selection and training of personnel to perform maintenance.

36. Haythorn, W. W., Human Factors in Systems Research, The Rand
(C) Corporation, P-2337, 7 June 1961, pp. 32, (Unclassified)

In the research described in this paper, the primary methodological device is simulation combining symbolic representations of some aspects of systems, realized on a digital computer, with individual decision makers drawn

from the population from which the ultimate users of the system are drawn. The organization of the paper is based on the sequence of personnel subsystem considerations in the system development process including: (1) the allocation of tasks to men and machines, (2) the estimation of manpower requirements by skill types and levels, (3) systems training, (4) decision analysis, (5) the use of simulation in systems design, and (6) more basic human factors research.

37. Haythorn, W. W., Maintenance Scheduling Decisions and the Importance of Information, The Rand Corporation, P-2302, 9 May 1961, pp. 23, (Unclassified)

A procedure for estimating maintenance personnel requirements by Air Force specialty code, using information regarding the reliability of the hardware under a variety of conditions and the possible operational and maintenance policies to be adopted, was developed. These two aspects of the study and their impact on overall system cost and effectiveness were discussed.

The application of the information system and the utilization of the maintenance personnel requirements estimation technique were instrumental in increasing missile alert status by approximately 15 per cent and reducing total system cost by like amount.

38. Heinemann, Robert W., An Objective Approach to Program Planning, Ammunition Engineering Directorate, Picatinny Arsenal, Dover, New Jersey, TM1345, December 1964 (Unclassified)

Research and development funds expended on systems which never reach the field waste huge sums of money every year. This fact is accepted as inevitable on the basis that only a limited number of the completed studies will meet with sufficient success to permit field use. The reasons for dropping the other studies involve factors such as complexity of design, manufacture or operation, cost, marginal--or no improvement, unreliability, safety problems, lack of requirements, lack of funds, unfeasibility or aborted studies. This report outlines a program which, if properly developed, would yield the required information to objectively analyze proposed major programs. Further work is required to formulate the program into a workable and useful management tool.

39. Hoisman, A. J.; & Daitch, A. M., Techniques for Relating Personnel Performance to System Effectiveness Criteria: A Critical Review of the Literature, Dunlap and Associates, Incorporated (Western Operations), Contract No. Nonr-4314(00), September 1964, pp. 45, (Unclassified)
40. Howard W. J.; & Goldman, A. S., Application of Some Economic Concepts to System Operational Availability, TEMPO, General Electric Company, RM 62TMP-7, 1 June 1962, pp. 41, (Unclassified)

Subject to performance requirements, systems designers and management are concerned with either (1) allocating a fixed budget between reliability and maintainability in order to maximize availability, or (2) attaining a required availability at minimum cost. By means of discussion and example, the problem of choosing among alternatives is investigated relative to achieving desired levels of system availability.

41. Howell, Richard P., Method for Estimating Manufacturing Facility Requirements, Stanford Research Institute, Menlo Park, California, (Unclassified)

The objective of this research was to derive a means of making or evaluating an early estimate of facility requirements for contemplated weapon systems. Given the maximum level of annual expenditure anticipated for the procurement of the hardware of the system. The method described in this report was developed on the basis of data obtained from authoritative published sources. Because of the limits of time and money available, efforts were not made to refine the individual companies, however, since the results are accompanied by an expression of the probable range of values that might be expected, the user has at his disposal a means for determining whether the results are accurate enough for his requirements.

42. Human Factors in Automatic Checkout Equipment: An Annotated Bibliography, The Rand Corporation, Memorandum RM-2756-PR, March 1962, pp. 88, (Unclassified)
43. Investigation of the Relationships of Operational Reliability, Development Cost, and Development Time of Selected Guided Missiles (U), Planning Research Corporation, Los Angeles, California, Final Report, March 1963, (CONFIDENTIAL)

44. Jannsen, T. J.; Glazer, H.; & Des Roches, J. C., User's Manual for the Computerized Electronic System Cost Model, MITRE Corporation, Bedford, Massachusetts, October, 1964, (Unclassified)

The economic factors department of MITRE has developed a computerized electronic system cost model as part of its work in system cost methodology. This document described the initial version of the model and gives instructions for the electronic data processing procedures, including presentation of the key punch input forms, computer output formats, and a description of the computer program logic. The model, currently operational, has been programmed for the IBM 7090 computer requires a 32,768 register core memory. The objectives of this manual are to provide a primer for the cost analyst, and a reference manual for the detailed operations on the use of the model.

45. Jordan, Nehemiah, Allocation of Functions Between Man and Machines in Automated Systems, Journal of Applied Psychology, Volume 47, No. 3, June 1963, pp. 161-165, (Unclassified)

"Fitts (in an article in 1951) recommended that man be compared to machines and be chosen for those functions which he does better than machines and vice versa. To do so is wrong; when we can compare a man to a machine, we find that we can also build a machine for the function involved. Hence the lack of progress. Men and machines are complementary, rather than comparable. Once the problem is so reformulated, new ways of thinking, which appear to be promising, open up."

46. Jordan, Nehemiah, Human Factors Aspects in Maintainability, (B) The Rand Corporation, P-2459, October 1961, pp. 11, (C) (Unclassified)

This article takes a look at the broad area of maintainability as discussed by human factors scientists and engineers. This area is further subdivided into the three major interdependent sub-areas of: design for maintainability; training the maintenance man to be able to assume the responsibility for maintaining the equipment; and the tools, equipment and/or aids that are necessary to enable the maintenance man to meet his responsibilities. Each of these areas is considered in turn as they are related to human factors problems.

47. Jordan, Nehemiah, The Allocation of Functions Between Man and Machines in Automated Systems, The Rand Corporation, P-2310, 16 May 1961, pp. 11, (Unclassified)

This article briefly reviews the history and problems associated with the study of allocation of functions. The author also discusses the allocation problem within the framework of automated systems.

48. Kidd, Jerry S., A New Look At System Research And Analysis, (B) Human Factors, Vol. 4, No. 4, August 1962, pp. 209-216, (Unclassified)

This report is an attempt to integrate some conceptual and methodological divergencies in man-machine system research. A conceptual format and a procedure for input analysis are proposed which are derived from a cybernetics model. The format is suggested as a means to organize theoretical propositions. Some problems related to real-time simulation as a research method for system research are considered and an approach to methods improvement is discussed.

49. Lambert, C. G., Index of Published Papers, System Development Corporation, SP-0/000/01, 1 June 1962, pp. 60, (Unclassified)

50. Mann, L. O.; Primas, W. H.; & Jackson, R. J., Enlisted Personnel Costs for Use in ASW Surface Ship Systems Cost-Effectiveness Comparisons, Personnel Research Division, Bureau of Naval Personnel, Washington, D. C., Report No. ND 65-40, December 1964, (Unclassified)

". . . Presents personnel costs for the twenty-seven ratings envisioned as being utilized in ASW surface ship systems and related subsystems.

The personnel cost data provided are presented in Section II in two tabular listings; (1) cumulative cost per pay grade for each rating reported and (2) cumulative cost per year per pay grade for each rating. These listings differ considerably from the first and second enlistment type costs employed in the previous SEA HAWK personnel cost reports. The latter cost listings did not allow the conciseness and flexibility required for cost-effectiveness comparisons. The method employed in this memorandum has made an attempt to include all known cost elements paid by the government in support of enlisted personnel."

51. Marshall, A. W.; & Meckling, W. H., Predictability of the Costs, Time and Success of Development, Rev. ed., The Rand Corporation, P-1821, 11 December 1959, pp. 24, (Unclassified)

In its role as advisor to the Air Force on research and development policies RAND is continually forced to make use of predictions about particular development projects. Inevitably there has been concern over the confidence which can be attached to such predictions. This paper presents the results of some recent research into the extent and nature of the uncertainty in new developments.

52. McGrath, Joseph E.; & Nordie, Peter G., Synthesis and Comparison of System Research Methods, Human Sciences Research, Incorporated, Contract No. 2525(00), Report No. 9, February 1960, pp. 143, (Unclassified)

In 1958, Human Sciences Research, Incorporated initiated a research program aimed at synthesis of system research methodology under sponsorship of Personnel and Training Branch, Psychological Sciences Division, Office of Naval Research.

The central objective of Phase I was to review methodologies of system research studies to attempt to construct a useful set of concepts for organizing and comparing research methods, and to evaluate the potential fruitfulness of such an approach for providing a synthesis of system research methods. Phase II was basically an extension of the procedures used in the Phase I feasibility study, in order to modify and elaborate the concepts which had been developed.

53. McGrath, J. E.; & Nordie, P. G., "Theory of Allocation of Functions to Man and Machines", Synthesis and Comparison of System Research Methods, Human Sciences Research Incorporated, Report HSR-RR-60/1-SM, February, 1960, (Unclassified)

" . . . a two-part approach is seen as being required for a solution to the allocation problem. First, a common, descriptive, quantitative language must be developed which can be applied to man and machine capabilities. Second, a logic of allocation decisions must be formulated. The two are clearly interdependent. The problem will receive major emphasis in Phase III of this research program."

54. McGrath, Joseph E.; Nordlie, Peter G.; & Vaughan, W. S., Jr.,
(B) A Systematic Framework for Comparison of System Research
(C) Methods, Human Sciences Research, Incorporated, Report No. 1,
November 1959, pp. 62, (Unclassified)

The central aims of the program are to systematically review and integrate the methods which have been employed in studies of complex man-machine systems; to compare alternative methods and procedures which have been used to carry out various steps of such system studies; and to determine the major methodological weaknesses requiring concentrated research effort. Subsidiary aims are to develop a frame of reference and a common language within the system research domain to aid communication among scientists from diverse disciplines, and to suggest means of applying existing methods to new problem areas.

55. McKendry, James M.; & Harrison, Paul C., Assessing Human
(B) Factors Requirements in the Test and Evaluation Stage of
(C) Systems Development (Technical Report), HRB-Singer, Incorporated, Volume 1, Contract Nonr 4203(00), Report No. ND 64-68, June 1964, pp. 46, (Unclassified)

This report outlines an initial attack upon the problem of determining when, where, and how human factors inputs should be provided during the planning and development cycle of Naval Systems, with particular emphasis being given to measuring the consequences of such inputs in terms of systems effectiveness. All work was directed toward the Test and Evaluation (T and E) phase of system development in order to develop measures of effectiveness capable of being applied to a specific system undergoing T and E by the Operational Test and Evaluation Force (OPTEVFOR).

56. Moores, B. L., User's Manual for the Computerized Electronic
(A) System Cost Model: 7030 Modifications, MITRE Corporation, Bedford, Massachusetts, October 1964, (Unclassified)

A computerized electronic system cost model was developed by the systems analysis department and documented in ESD-TDR-63-446. The present document describes the changes which resulted from converting the computer program for the model from FORTRAN II for the IBM 7090 to FORTRAN IV for the IBM 7030, and from implementing several operational improvements.

57. Novick, David, Concepts of Cost for Use in Studies of Effectiveness, Rev. ed., The Rand Corporation, P-1182,
(A) 4 October 1957, pp. 14, (Unclassified)
(B)

The two principal ways of conducting a study in terms of system effectiveness and cost are described: (1) the "fixed effectiveness" case where, for a specified level of weapon effectiveness (e.g., target destruction), the alternative equipment possibilities are compared on the basis of economic resource cost, usually expressed in terms of dollars as a common denominator (2) the "fixed budget" case where, for a specified military budget for a particular mission, the alternative weapon proposals are compared on the basis of weapon system effectiveness, measured, for example, in terms of targets destroyed.

58. Novick, David, System and Total Force Cost Analysis, The Rand Corporation, Memorandum RM-2695-PR, April 1961, pp. 141, (Unclassified)

This memorandum described the aims, concepts, and methods of military cost analysis as developed by the Cost Analysis Department of the Rand Corporation. Like the 1956 report on Weapon-System Cost Methodology, which it replaces, the present memorandum is concerned basically with the estimation of costs for proposed military activities so that informed choices can be made among them. It extends the earlier report by considering in more detail the underlying principles of cost analysis, and by describing methods for analyzing the costs of total force structures as well as individual systems.

59. Odom, Charles T.; & Sebastiani, Lambert J., A Method of Considering Attrition Rate in Cost-Effectiveness Studies, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, September 1964, (Unclassified)

This report presents a method of considering attrition rate in cost-effectiveness studies. The method is developed and illustrated by its application to a typical situation in order to show the effect of attrition rate on missile and launcher requirements. The total number of launchers required to defeat a threat is expressed as a function of length of battle and attrition rate. The total number of missiles required to defeat a threat is expressed as a function of attrition rate. Total costs then can be determined for each weapon system reflecting the added cost of attrition.

60. Quade, E. S., Analysis for Military Decisions, The Rand Corporation, Santa Monica, California, November 1964, (Unclassified)

Contents: Analysis for Air Force decisions, the selection and use of strategic air bases, the why and how of model building, the relevance of costs, analysis and design of conflict systems, assumptions about enemy behavior, gaming methods and applications, strategies for development, mathematics and systems analysis, the use of computers, costing methods.

61. Report on Bureau of Naval Personnel Symposium, "U. S. Navy Manpower Management Prospectus for the 1970's", U. S. Naval Station Washington Navy Yard Annex, 16-17 April 1963, pp. 106, (Unclassified)

A two-day symposium, sponsored by the Bureau of Naval Personnel, arose out of a need for representatives of all Navy commands, activities, and agencies to anticipate and to explore Navy manpower requirements in the 1970's. Manpower requirements were examined as well as major problem areas to be encountered in fulfilling these requirements. Possible solutions to manpower problems were advanced, in the form of recommendations, by the seminar group

62. Rigney, Joseph W.; & Hoffman, Lyle S., Human Factors Research in Electronics Maintenance: An Analysis of Recent Trends, With Some Suggestions for the Future, Department of Psychology, University of Southern California, Technical Report No. 35, July 1962, pp. 168, (Unclassified)

The following six broad areas are identified, and representative studies in each, along with their implications, are discussed:

1. The measurement of maintainability of equipment now in the field.
2. Military standards and specifications, and human factors handbooks to guide design of equipment for maintainability.
3. The automation of maintenance tasks, by means of automated test equipment.
4. Studies of maintenance variables using the classical experimental methods.

5. Investigations in traditional personnel areas conducted in the maintenance field.

6. Mathematical modeling techniques used to simulate human problem solving and other complex behavioral processes.

63. Schaeffer, K. H.; Fink, John B.; Rappaport, Maurice;
(B) Wainstein, Leonard; & Erickson, Charles J., The Knowledgeable
(C) Analyst: An Approach to Structuring Man-Machine Systems,
Stanford Research Institute, Project No. IMU-3546 (AIR FORCE
TECHNICAL REPORT AFOSR 4490), February 1963, pp. 132,
(Unclassified)

In an attempt to evolve a general method for system analysis, this paper presents the matrix--network approach for the analysis of complex man-machine systems. This approach consists of seven steps which show how a system can be structured and how mathematical models of systems aspects can be incorporated into the overall analysis. However, some of these steps involve, besides formal rules, the judgement of knowledgeable analysts. To delve deeper into this judgement function, various logical, methodological, and psychological aspects concerning this function are discussed by different authors. On the basis of these discussions the principal author develops requirements which must be met by successful approaches to the structuring of complex systems.

64. SEA HAWK SHIP CONTROL GROUP, SEA HAWK Preliminary Cost-
(B) Effectiveness Study on Ship Control Subsystems, MEL Research
and Development Report 53/64, 22 May 1964, (Unclassified)

"Conducted to evaluate the broad range of ship control systems available with the state-of-the-art to determine the area for final system development to be employed on the SEA HAWK ship. System objectives were defined. The selected systems were divided into three subsystems (Heading Control, Speed Control, and Environment Information), and ideal subsystems were defined for each objective. Subsystem configurations were devised, and their ability to meet the objectives were rated (Effectiveness). Each subsystem cost was estimated, and the subsystems were combined into six ship control systems. The subsystem costs were summed, and the effectiveness of the system was derived. The cost-effectiveness of each system was compared to an ideal system."

65. Sebring, H. C., Cost Effectiveness Logic for Missile Weapon Systems Selection, General Electric Company, Philadelphia, Pennsylvania, July 1962, (Unclassified)

The logic for an effectiveness comparison of missile weapon systems is presented. The measure is defined as the number of a selected target set that can be neutralized with a fixed probability by each weapon system, of which the gross force is determined from a selected fixed budget. An important part of the logic is target destruction assessment, and mathematical methods are presented to determine the numbers of hard and soft targets that can be neutralized by the net forces of each weapon system. A basis is provided for weapon system selection since each can be evaluated in terms of numbers of potentially destroyed targets. A separate investigation of the warhead requirements for area targets is presented as an appendix.

66. Sebring, H. C., Missile Weapons Systems Effectiveness Logic (U), Presented at the 19th National Meeting, Operations Research Society of America, 25-26 May 1961, (Unclassified)

The logic for an effectiveness comparison of missile weapons systems is presented. The effectiveness measure is defined as the gross force cost to destroy selected numbers and categories of targets. Each with a fixed probability. Mathematical methods are presented to determine the net and gross force requirements to attack hard point targets and soft area targets. With appropriate modifications, the logic and methodology are applicable to other weapons systems types. A basis is also provided for optimum target assignments among weapons systems since each theoretical attack can be evaluated in terms of cost.

67. Sharkey, E. H., The Advantages of Functional Packaging of Electronic Equipment, The Rand Corporation, P-1629, 5 March 1959, pp. 8, (Unclassified)

The discussion here is concerned primarily with how packaging methods can materially affect the out-of-commission time of the aircraft, and the cost and difficulties of line maintenance.

The methods that the line maintenance people must use are largely dictated by the decisions made by the packaging engineer in the original equipment design.

68. Siegel, Arthur I.; & Wolf J. Jay, A Technique for Evaluating
(B) Man-Machine System Designs, Human Factors, Volume 3, March 1961.
(C) pp. 18-28, (Unclassified)

"A computer based method for digitally simulating the performance, in one-operator systems, of operators who possess various characteristics is described. The method is believed applicable for evaluating various system designs while the system is in the early design stage. Two operational tasks, landing an F4D aircraft on a carrier and firing an air-to-air missile, were simulated using the method. The predictions from the model were compared with outside criterion data for the same tasks. The predictions are held to conform generally with reality and to be reasonable. The results of the two applications of the model were in general agreement. It is held that the model may be considered sound and may now be tentatively employed for comparative evaluation of alternative system designs or for predicting system performance."

69. Siegel, Arthur I.; & Wolf, J. Jay, Techniques for Evaluating Operator Loading in Man-Machine Systems, Applied Psychological Services, Contract Nonr-2492(00), July 1963, pp. 59,
(C) (Unclassified)

A digital computer simulation model was previously derived and employed for simulating the performance of the operator(s) in a man-machine system. The technique is based on an analysis of the performance of each operator, arranged into ordered, discrete actions called "subtasks", and the compilation for each of certain source data.

Since the development of the original model, a number of possible modifications have become apparent. Moreover, although logical expectancy indicated the model to be usable for either one or two operator systems, the model had never been exercised on a uni-operator system. Accordingly, the present study focused on investigating: (1) the applicability of the model to uni-operator situations, and (2) the effects of the modifications on the agreement of the results from application of the model with criterion data.

70. Siegel, Arthur I.; Wolf, J. Jay, & Sorenson, R. Trent,
(C) Techniques for Evaluating Operator Loading in Man-Machine Systems (Evaluation of One or a Two-Operator System Evaluative Model Through a Controlled Laboratory Test), Applied Psychological Services, Wayne, Pennsylvania, July 1962, pp. 87, (Unclassified)

A stochastic, digital computer simulation model was previously derived for and applied to the problem of simulating one or two operator man-machine systems. Further test of the validity of the model through comparisons of the model's predictions of team performance with the actual performance of trained teams on a man-machine task is described. A complex two operator man-machine equipment test involving team and individual branching, operator stress build-up, looping, cooperative work, communication, waiting, etc., was developed.

71. Siegel, B., Parametric Study--Continuously Manned Space Offense Systems (U), Aerospace Corporation, Los Angeles, California, January 1964, (SECRET)

72. Story, A. W., Man-Machine System Performance Criteria,
(B) Electronic Systems Division, Air Force Systems Command,
(C) USAF, Bedford, Massachusetts, ESD-TR-61-2, May 1961, pp. 61, (Unclassified)

In this report, four categories of criteria are developed for the evaluation of man-machine system performance. The applicability of these criteria during system design, building, and testing is discussed. Some illustrative evaluations of man-machine systems are surveyed. Problems that accrue through the use of simulative features in the assessment of system performance are considered.

73. Swain, A. D.; & Whol, J. G., Factors Affecting Degree of Automation in Test and Checkout Equipment, Dunlap and Associates, Incorporated, Stanford, Connecticut, (D&A-TR-60-36F), March 1961, (Unclassified)

74. Sweetland, Anders, Assessing the Impact of Weapon System Modifications by Field Study: A Feasibility Demonstration, The Rand Corporation, Santa Monica, California, Memorandum Report, November 1964, (Unclassified)

Studies have been made on ways to increase the productivity of the Air Force maintenance management system. These studies have suggested adding clock hours

and status data to the current data system (AFM 66-1, Maintenance Management), and have proposed the use of computers in maintenance management and analysis. These additions have made practicable analyses of maintenance data that were heretofore deemed impossible. The memorandum continues the previous line of inquiry. It demonstrates how these adjuncts to the present system may be used to assess the cost and effectiveness of engineering modifications. The procedures are described using two examples: An engine modification of T-38A aircraft, and a fire-control system modification of F-101B aircraft. The two procedures are then contrasted to show how the combination of methods can provide the most meaningful set of data. It is shown how the method of recording and analyzing may also be used to provide a history of the installation-check-out process during this vital period.

75. Systems Analysis and Cost Effectiveness, Parts I-VI (M),
(B) Adjutant General Department of the Army, Washington, D. C.,
April 1964, (Unclassified)

Systems analysis is a systematic, quantitative approach to the complex military-economic problems encountered in the Defense Program. The systems analysis cost effectiveness technique is not a cure-all. Nor is it an automatic decision-maker. It is limited by the quality and subjectiveness of the measurable factors put into each alternative. An increased army systems analysis effort can assist in attaining the best possible solution to Army problems and improving the justification of related Army programs. Even if one disagrees in principle with some aspects of analysis or cost effectiveness comparisons, still an understanding is necessary of these widely-used principles and techniques.

76. Systems Effectiveness, Office of Naval Material (Systems Effectiveness Branch), January 1965, pp. 205, (Unclassified)

The main purpose of this pamphlet is to provide personnel of the Naval Material Support Establishment (NMSE) a collection of papers in a single volume which reflect the attitude and philosophy of the Chief of Naval Material towards various aspects of systems effectiveness. It also provides a discussion of the planning, design, and cost considerations in system development as well as some techniques now being utilized in the NMSE in order to realize the development of effective systems.

77. Tallmadge, G. K.; Hoffman, Lyle S.; & Cooper, Joel I.,
(B) Recommendations for a Navy-Sponsored Research Program in
(C) Electronics Maintenance, Thiokol Chemical Corporation,
Humetrics Division, Contract No. NOP-1352, Technical Report
H-TR-63-5, October 1963, pp. 138, (Unclassified)

"A planning study was carried out to develop a master program of Navy-sponsored research in the field of electronics maintenance. Based on an analysis of current and anticipated problems and trends in maintenance, a statement of research needs is presented in the following four general program areas: (1) the human component, (2) the hardware component, (3) the integrated system and its support environment, and (4) the handling of maintenance information. Then, within each major program area a five-year sequence of research projects is outlined, roughly costed, and discussed."

78. Thomas, R. E., et al., The Effect of Various Levels of
(C) Automation on Human Operator's Performance in Man-Machine
Systems, Battelle Memorial Institute, June 1960,
(Unclassified)

"If a system is under-automated, the operators probably will be numerous, overloaded, and 'connected' inefficiently. If a system is over-automated, the equipment will be complex and expensive and man will be relegated to a monitoring role. In either case, system performance will be degraded. Conceptually, at least, an optimum level of automation exists. The project described here attempts to develop an 'automation model' for the function allocation problem."

79. Weapons Requirements: Integrated Maintenance Management for
(B) Aeronautical Weapons, Weapon Systems, Related Equipment,
Bureau of Naval Weapons, Code Identification 1001 WR-30,
1 May 1963, pp. 124, (Unclassified)

"This document establishes the policy, terms and conditions governing the implementation and execution of an integrated maintainability and support program for weapons, weapon systems and related equipments to be procured under the contract in which this document is cited. It is the specific intent of this document to charter the Integrated Maintenance Management Team to manage the total Logistic Support Program. Accordingly, this document is designed to develop, early in a program, a maintenance plan which is tailored to specific commodities and contracts."

80. Westerman, Dean P.; & Mathias, Ronald F., A Cost Model for Use in Cost-Effectiveness Analyses of Dissimilar Weapon Systems, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, MR1602, IMO23201A098, September 1964, (Unclassified)

A model is presented for the determination of system costs in cost-effectiveness studies of dissimilar weapon systems. The assumptions employed are listed so that an adaptation of the model may be made to fulfill individual study requirements.

81. Whittenburg, John A., Methodology for Evaluation of a Man-Machine Surveillance System, Human Sciences Research, Incorporated, Contract Nonr 2525(00), Report No. 6, December 1959, pp. 19, (Unclassified)

The purpose of this paper was to focus attention on the methodological requirements of a particular research study and the steps that were taken to meet these requirements. A statement of the general methodological problem in this research study may be phrased as follows: to determine the performance capabilities and limitations of the human as a component of a weapon system not-in-being.

The specific problem of the study was to determine the capabilities and limitations of the human, as an aerial observer, to acquire combat intelligence information under conditions of ground combat projected for the decade 1960-1970, so as to guide the development of criterion measures of aerial observer proficiency and pinpoint areas requiring training emphasis.

82. WSEIAC, Cost-Effectiveness Optimization (Summary, Conclusions & Recommendations), Final Report of Task Group IV, Headquarters, Air Force Systems Command, Andrews Air Force Base, Maryland, AFSC-TR-65-4, Volume 1, January 1965, (Unclassified)

"The underlying principles associated with cost-effectiveness analysis are discussed. The rationale, purpose, methodology required, and nature of the results that can be obtained by means of the analysis are presented in summary form. Illustrations of the type of input data required and the logic associated with its application are provided. The summary constitutes an overview of the more detailed task analysis and supplementary technical material presented in Volumes II and III. Included are the conclusions and recommendations as set forth in Volume II."

83. WSEIAC, Cost-Effectiveness Optimization (Technical Supplement),
(B) Final Report of Task Group IV, Headquarters, Air Force Systems
Command, Andrews Air Force Base, Maryland, AFSC-TR-65-4,
Volume III, January 1965 (Unclassified)

"A discussion of optimization which amplifies the material in Volume II, Section IV is presented. Optimization principles, criteria and checklists, as well as a summary of various applicable techniques is included. A series of six examples are described covering a number of critical aspects of cost-effectiveness analysis in considerable detail. Treated in the examples are: (1) Optimization of effectiveness based on reliability, maintainability, performance, and cost; (2) Allocation of reliability requirements among subsystems; (3) Payload allocation among three subsystems based on a fixed weight constraint; (4) Determination of best checkout routine for a limited prelaunch test; (5) Optimization of availability for a complex system; and (6) Trade-off study between site hardening and dispersal for a missile system."

84. WSEIAC, Management Systems (Elements of Effectiveness Assurance Management), Final Report of Task Group V, Headquarters, Air Force Systems Command, Andrews Air Force Base, Maryland, AFSCR-TR-65, Volume II, January 1965, (Unclassified)

". . . presents summaries of many of the studies carried on by the task group during the six months of WSEIAC formal meetings and investigations. From these studies the concept and philosophy of a System Effectiveness Assurance Management System (SEAMS), the major policy issues, and recommendations presented in Volume I were developed. Air Force management of system effectiveness activities is assessed through surveys of some of the principal offices and commands. Industry capability for response to these new requirements is measured. A review of activities and discipline requirements essential to effectiveness assurance management in the context of the AF 375 series documents is provided. Finally, a series of studies and discussions of pertinent elements of system effectiveness is furnished, including a data central proposal, the effect of incentives, and appendixes on specification management, parts research and program management elements of the concept and definition phases of system development."

85. WSEIAC, Requirements Methodology, Final Report of Task Group
(B) I, Headquarters, Air Force Systems Command, Andrews Air Force
Base, Maryland, AFSC-TR-65-1, January 1965, (Unclassified)

"The objective of Task Group I was 'To review present procedures being used to establish system effectiveness requirements and recommend a method for arriving at requirements that are mission responsive'. Applicable documents were examined, including Department of Defense Directives and Instructions, Air Force Regulations, Manuals, Specifications, Office Instructions, etc., that might be used to establish effectiveness requirements. Detailed examination of the Specific Operation Requirement (SOR) and the companion Directorate Office Instruction (DOI) 11-7 resulted in the preparation of a proposed Air Force Manual (Appendix I). This document provides checklists, guidelines, and procedures for SOR preparation that include the significant elements of system effectiveness. A proposed Air Force Regulation (Appendix II) was developed to formalize a program of effectiveness evaluation and prediction for the system life cycle. Policy, concepts, and major command responsibilities are developed. Additional conclusions and recommendations are submitted relative to the effectiveness requirements that constitute necessary steps to development of an Air Force wide system effectiveness management program."

ADDENDUM

1. "ADM Lee Tells How Weapons Systems Are Analyzed", Data,
(B) Volume 10, No. 5, May 1965, pp. 35-40, (Unclassified)
(C)

The methodologies used and the problems encountered in weapon system analyses are discussed in this interview. ADM Lee also discusses the "man function" in the man-machine relationship.

2. "Aid in Determining Profit on Fee Objective for a Contract",
(A) The Navy Management Review, NAVEXOS P910, Volume IX, No. 7
and 8, July-August 1964, pp. 15-19, (Unclassified)

"Weight Guidelines" is a method of assigning weights or percentage points to the many factors which must be taken into account in determining the profit or fee objective for a contract. It is a means for contracting officers to better evaluate cost proposals and decide upon a profit or fee objective which properly reflects the contractor's justifiable return. "Weighted Guidelines" is meant to be used only in the negotiation of profits where cost analysis is performed.

3. Amber, G. H.; & Amber, P. S., A Yardstick for Automation,
(C) Instruments and Automation, Volume 30, 1957, pp. 677,
(Unclassified)

Various techniques have been used to classify automation devices into basic sub-units. James Bright used the graphic "Automation Profile", Leaver and Brown wrote a "Functional Morphology of Mechanisms" and Amber and Amber here propose a mathematical notation based on the information and energy.

4. Arzigian S.; & Clary, J., "Report on Enlisted Personnel
(A) Replacement Costs (BM, ET, FT, MT, RM)", PRAW Report (64-4),
February 1964, (Unclassified)

This research report was designed to meet the urgent need of the Chief of Naval Personnel for enlisted personnel replacement costs for the BM, ET, FT, MT, and RM ratings. The replacement costs presented were based on the latest available information and reflected all known adjustments, including the increases in pay and allowances authorized by Congress in 1963.

5. Arzigian S.; Coulombis, T., "Report on Enlisted Personnel
(A) Replacement Costs", PRAW Report (63-8), May 1963,
(Unclassified)

This research effort was conducted in response to the urgent need for a comprehensive study of "Enlisted Personnel Replacement Cost" for use by the Chief of Naval Personnel in satisfying requests from higher authorities. The report is limited to a discussion of the costs associated with replacement of ETs, FTs, and ATs in pay grades E-1 through E-6.

6. Arzigian, S.; Couloubis, T., "Report on Enlisted Personnel Replacement Costs", PRAW Report (63-22), August 1963, (Unclassified)

This report presents research findings of the second portion of Phase I of a study dealing with enlisted personnel replacement costs. "Report on Enlisted Personnel Replacement Costs," PRAW Report Number 63-8 of May 1963 discussed the replacement costs of ETs, FTs, and ATs. This report is a supplement to it and provides replacement costs for the following seventeen additional ratings: RD, SO, MT, RM, TM, MR, CE, MM, MV, EM, HM, BM, VT, YN, SK, JO, CS.

7. Chapanis, A., Human Engineering, in Operations Research and Systems Engineering (Ed. by C. D. Flagle; W. H. Huggins & R. H. Roy), The John Hopkins Press, Baltimore, Maryland, 1960, Chapter 19, pp. 534-582, (Unclassified)

This chapter covered some of the human factors involved in the design of automatic and semiautomatic machine systems. It demonstrated that there are still quite a few human problems in most such systems, and that a successful automatic system requires the engineer to consider carefully the role of the human operator and how he is designed into the system. Finally, it suggested why the human factors specialist is often considered a member of the systems design team, and in what ways he can contribute to the important and challenging task of designing new systems for our automatic world of tomorrow.

8. Chapanis, A., On Some Relations Between Human Engineering, Operations Research and Systems Engineering, A report of research r contract with Office of Naval Research, John Hopkins :sity, Report No. 8, 13 May 1960, (Unclassified)

This is an elaboration of some remarks made at the First Systems Symposium at the Case Institute of Technology, Cleveland, Ohio, April 26-28, 1960. Chapanis discusses some of the activities and the relations between human engineering, operations research and systems engineering.

9. Chapanis, A., On the Allocation of Functions Between Man and Machines, Occupational Psychology, Volume 39, No. 1, 1965, pp. 1-11, (Unclassified)

Describes the nature of the allocation problem, discusses approaches taken to the problem in the past, and gives some of the authors views on the contemporary status of the problem, along with suggestions of a strategy for dealing with it.

10. Enlisted Personnel Procurement and Processing Cost Report, (A) (DD Form 804, Report Control Symbol DD-MP & R (SA) 390), SECNAV Instruction 1130.2A, Fiscal Year 1963 (second half), (Unclassified)

11. Fitts, P. M., Functions of Man in Complex Systems, Aerospace Engineering, Volume 21, No. 1, pp. 34-39, (Unclassified)

(B) Fitts states that "the central issue in allocating functions to men in systems is the overall performance of the system, relative to cost, not what man does 'better' than a machine, or vice versa". After discussion of the appropriate way to approach the question of man's role in complex systems, some of his major limitations and special capacities are considered.

11. Grodsky, M. A., Risk and Reliability, Aerospace Engineering, (C) Volume 21, No. 1, 1962, pp. 28-33, (Unclassified)

(B) This paper was primarily concerned with presenting data demonstrating the contributions of a spacecraft crew to higher reliability and lower risk.

The performance of the crew in terms of efficiency and reliability was discussed under two experimental conditions. The ability of the human within these situations appeared adequate. A brief discussion of stress was also given which indicated that sensory deprivation effects can be reduced by selection, training, and spacecraft arrangement.

12. "How We Buy and What We Buy", The Navy Management Review, (A) NAVEXOS P910, Volume IX, No. 7 and 8, July-August 1964, pp. 4-6, (Unclassified)

This article takes a look at the procurement functions and the various procurement programs undertaken by the Office of Naval Material.

13. Jackson, R.; Mann, L.; & Primas, W., Officer Personnel Costs For Use in ASW Surface Ship Systems Cost Effectiveness Comparisons, PRAW Report (65-63), June 1965, (Unclassified)

This memorandum presents costs for officers estimated to man an ASW surface ship (DE type). However, costs are considered appropriate for other surface type, (1100), officers. Officer cost data presented are designed for use in cost effectiveness studies for projects in the RDT&E cycle.

14. Morton, A. S., et al., Annex B - A Survey Study of Reenlistment Incentives, INS Study II - Manning the Future Navy (U), NOnr - 3732(00), October 1964, (Unclassified)

The primary aim of this study of reenlistment and incentives was to obtain information about the helpfulness of possible new incentives in raising the first term enlisted reenlistment rates for personnel categories where these rates are undesirably low.

15. Navy Department, Cost Estimates of Weapons Systems Ships, Aircraft and Task Forces - Fiscal Year 1962 (U), NAVEXOS P1986, Office of the Comptroller, 31 March 1961, (CONFIDENTIAL)

This publication sets forth statistical cost estimates developed for overall planning purposes by the Performance Analysis Branch of the Progress Reports and Statistics Division. These direct costs for ships, aircraft and guided missiles are presented to serve as a general reference for Navy use. It is the fourth edition of "COST" prepared by the Comptroller of the Navy and data are based on 1962 budget factors.

16. Per Captia Cost of Training in Navy Schools (BUPERS Management), (A) BUPERS Notice 1500, Fiscal Year 1963, (Unclassified)
17. Stroud, J.; & Irwin, W., "Protect the Military Victims of Automated Command Systems", Armed Forces Management, Volume 11, (C) No. 10, July, 1965, pp. 87-89, (Unclassified)

Using the Naval Tactical Data System (NTDS) as an example, the authors contend that, as the automated command "tree" becomes more efficient, it will begin to displace people in the traditional command structure. And as this happens, the authors say, our attitude toward personnel retraining will have to change. Rather than a sought for privilege, retraining will have to become a well paid duty.

18. "Systems Effectiveness: ONMs Approach", Data, Volume 10,
(B) No. 5, May 1965, pp. 35-40, (Unclassified)

This article contains an interview with Commander Keith N. Sargent, USN, concerning "Systems Effectiveness" and related topics.

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